Markets for Energy Efficiency - Exploring the new horizons of tradable certificate schemes

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Markets for Energy Efficiency

Exploring the new horizons of tradable certificate schemes

Doctoral Dissertation, September 2008

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The painting on the front cover was painted in 1990 by Christine Wamsler. For the author, this painting symbolises many aspects of the research presented in this thesis. First, it represents the challenges and complexities related to policy evaluation. Second, it symbolises the dynamics of tradable certificate schemes as applied to energy efficiency and their interaction with other policy instruments.

Acknowledgements

From the outset, this research journey has reminded me of my good old climbing days in the Andes/Patagonia. In any climbing enterprise in which I participated, there was a lot of enthusiasm but also frustration at certain points. On any trip, there were moments of calm but also a lot of hustle and bustle. During a climb, there was a great deal of energy, but also many moments of fatigue. Mountaineering has also taught me that although we may do certain things on our own, no climbing endeavour is a solo event. A permanent constellation of people is always there to support each step a climber makes, in one way or another.

My supervisors facilitated in many ways the accomplishment of this thesis. Thomas B. Johansson gave me the opportunity to carry out this PhD project. His experience and groundbreaking work on energy for sustainable development helped me understand and develop numerous aspects of the research. Lena Neij played a vital role during the writing of this thesis. Her continuous support, direction, and involvement were essential to accomplishing many, if not all, of the research objectives. Her knowledge and experience on energy policy evaluation greatly assisted the research. She helped me to overcome numerous hurdles and her dedication to this research often extended beyond the call of duty. Tack så mycket, Lena!

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Luis Alberto Mundaca Toro

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Executive summary

Background and research objective

Energy is critical to human development and acts as a fundamental link between the challenges encompassing sustainable development. However, scientific evidence is emerging on an almost daily basis regarding the negative impact of energy production and consumption on the health of both human beings and ecosystems. The topical issue of human-induced climate change can be taken as a remarkable example. While energy plays a pivotal role for mankind, it is argued that the present structure of market incentives and policy conditions is not sufficient to effectively address the challenges posed by energy for sustainable development.

Lately, the importance of increased energy efficiency in the context of sustainable development has regained policy momentum. Due to the fact that increased energy efficiency can benefit both society and the environment (e.g. reduce greenhouse gas [GHG] emissions, boost industrial competitiveness, generate employment and business opportunities, and improve the housing stock and comfort level of occupants), ever-increasing attention has been given to the role of public policy in providing the market incentives necessary to increase energy efficiency and encourage a sustainable energy future.

Within this context, recent developments in European energy (efficiency) policy reveal a growing interest in creating markets for energy efficiency to realise energy savings at the lowest possible cost. France, Italy and Great Britain have begun to implement tradable certificate schemes to improve energy efficiency, so-called *Tradable White Certificate (TWC) schemes*. Other EU member states are analysing potential design options and/or implementing their own TWC schemes (e.g. the Netherlands, Denmark and Poland). Furthermore, policy efforts undertaken at the European level could trigger the implementation of more national TWC schemes, or even form the basis of a future EU-wide TWC scheme. The creation of a TWC scheme entails a mandatory energy savings target that certain market actors (e.g. energy suppliers) are required to meet during a given time period. As in any tradable certificate scheme, flexibility is crucial because it is up to obliged parties to decide how to meet their energy savings targets cost-effectively. The energy savings realised are credited with certificates. With the purpose of equalising marginal compliance costs, subject parties have the option of trading certificates to meet their individual targets.

Pursuant to such developments, the growing political interest in TWC schemes inspired the author of this thesis to consider more closely their evaluation and performance. Theory-based expectations used to legitimatise TWC schemes are consistent with many aspects of policy on energy for sustainable development. However, while political efforts and attention have been devoted to encouraging TWC schemes, the public policy process related to TWC schemes has lacked an evaluative component. In fact, much interest and implementation has relied on the expected benefits resulting from increased energy efficiency, and the theoretical economic rationale of cost-effectiveness embedded in tradable permits schemes in general. The situation is consistent with the fact that while there are a growing number of energy efficiency policy instruments being implemented, only scattered policy evaluation efforts can be identified in the literature. In addition, interest in energy (efficiency) policy evaluation seems to be limited. All in all, it is argued that more (systematic) policy evaluation studies are needed.

In accordance with these concerns, the research objective is to enhance our knowledge about the implications and complexities of creating markets for energy efficiency (i.e. TWC schemes). To achieve the objective, several ex-ante and ex-post evaluation studies were conducted to ascertain the (potential or actual) impacts and outcomes of TWC schemes. By achieving the research objective, the thesis attempts to develop an understanding of what to evaluate regarding TWC schemes and how. In turn, the research aims to support related policy development processes. As a whole, the research is driven by the multiple benefits resulting from policy evaluation, and the need to respond to the lack of policy evaluation studies in the field of energy efficiency. To address the objective, the following research questions were chosen:

- How do TWC schemes perform from a broad evaluation perspective? What are the critical aspects/conditions that affect their performance?

- What are the limitations/obstacles and strengths/advantages of the evaluation methods used to assess the performance of TWC schemes?

Table A: *Main design characteristics of current national TWC schemes*

	Great Britain	Italy	France
Saving target	468 PJ (130 TWh)	243 PJ (67 TWh)	194 PJ (54 TWh)
Time frame	2005–2008	2005–2009	2006–2008
Obliged parties	Suppliers of gas and electricity with ≥15,000 customers	Distributors of gas and electricity with ≥100,000 customers served	Suppliers of gas, electricity, cooling, and/or heating with annual sales ≥ 0.4 TWh. Suppliers of LPG with annual sales ≥ 0.1 TWh
Eligible actors	Only obliged parties, but sub-contracting is allowed	Obliged parties, non-obliged distributors and ESCOs	Obliged parties, ESCOs and any actor able to achieve ≥1GWh in savings
Market size	Eight suppliers covering 99% of energy supply markets	Approx. 24 distributors of natural gas; 10 distributors of electricity; 570 non-obliged distributors, and ≥ 550 ESCOs	Approx. 2,400 energy suppliers, 23 obliged parties capture ≥ 90% obligation
Eligible sectors	Household sector only	All energy end-use sectors, incl. distribution networks. ≥ 50% target to be achieved in elect. and gas savings	All energy end-use sectors including transportation but excluding installations covered by EU-ETS
Eligible technologies	E.g. cavity wall insulation, loft insulation, condensing boilers, A-rated appliances.	Approx. 14 categories, e.g. micro CHP, solar heaters, small PV applications, double glazing, A-rated appliances.	Approx. 100 measures for the household and commercial sectors; approx. 20 for the industrial and 5 for the transport sector.
Type of trading allowed	Bilateral	Bilateral and spot	Bilateral and spot
Penalty for non-compliance	A fine of up to 10% of the obliged party's turnover	Fee that is proportional and greater than investments needed to compensate for non-compliance	2 Euro cents per kWh

Research methodology

The research methodology was driven and framed by both policy-oriented research and policy evaluation. Whereas the former focuses on the solution of public problems through improved policies, the latter deals with multiple methods of investigation to support policy design and instrument choice. The research also took its point of departure in the fact that public policy, and policy instruments in particular, are the object of policy evaluation.

Several case studies were used to conduct ex-ante and ex-post studies and approach an empirical and normative understanding of TWC schemes. From an ex-ante perspective, the research explored potential impacts of hypothetical TWC schemes. From an ex-post standpoint, impacts and outcomes of current TWC schemes were investigated (i.e. Great Britain, Italy and France). During the progression of work on this thesis, the following specific studies were carried out: (i) the modelling of the impacts and effectiveness of an EU-wide TWC scheme, (ii) the identification and analysis of transaction costs (Great Britain), (iii) the analysis of flexibilities for achieving cost-effectiveness, including trading behaviour and non-trading patterns (Great Britain, Italy and France), and (iv) the use of a multi-criteria evaluation framework, including economic efficiency analysis (Great Britain and Italy). As one can observe, the research attempted to conduct a wide evaluation of TWC schemes, beyond the narrow area of cost-effectiveness and energy savings. In fact, new and innovative energy efficiency policy instruments with a large set of attributes, such as TWC schemes, require an extended evaluation. Guided by a number of claims, anticipated effects and/or theory–based expectations associated with or related to TWC schemes, several evaluation criteria were used, namely energy-saving/environmental effectiveness, economic efficiency, cost-effectiveness, transaction costs, administrative burden, technical change, political feasibility and distributional equity.

With the aim of providing a comprehensive and balanced picture of TWC schemes, different methods for data collection and analysis were used to conduct the research. In terms of methods for data collection, the research collected data across various sources to approximate objectivity and reduce inevitable uncertainty. The research included literature review, interviews, questionnaires and focus group discussions. In terms of methods for data analysis, qualitative and quantitative approaches were used. Concerning the former, policy analysis, discourse and text analysis, a systems approach, and transaction cost analysis were applied. Regarding the latter, a mathematical

simulation model, cost-benefit analysis, descriptive statistics and transaction cost analysis were also used.

As a whole, the methodological position of the research was supported by the use of triangulation. That is, several independent routes were used to address the analysis of TWC schemes. Based on multiple disciplines, the combination of different methods for data collection and analysis was designed to systematically integrate value-critical aspects with empirical issues related to TWC schemes.

Main cross-case findings

In terms of *energy-saving/environmental effectiveness*, findings showed that for a TWC scheme to be relevant in terms of energy and the environment (as well as in the context of sustainable development), ambitious energy savings targets must be set. Ex-ante studies show that, under several policy assumptions, a TWC scheme can achieve ambitious energy saving targets (e.g. above 25% compared to the baseline by 2020). In addition, the estimated contribution of a modelled EU-wide TWC scheme at any target level according to the first Kyoto commitment period (2008–2012) reached approximately 60% of the EU 'bubble' Kyoto target. Conversely, ex-post analyses indicated a poor level of ambition among energy savings targets (<1% of annual energy consumption of end-use sectors under coverage). Although a high level of effectiveness was observed, findings suggested that this might be an effect of soft target levels, reflecting low policy ambition levels and/or pitfalls in the regulatory framework. From the environmental standpoint, the British TWC scheme is the only one with explicit environmental targets. For this case, it was estimated that GHG emission reductions due to efficiency improvements during the first phase (2002-2005) represented 1% of total household GHG emissions. Ex-post results also showed that the integrity of energy-saving (and environmental) effectiveness also relied on non-compliance rules (in particular financial penalties), effective enforcement and policy measures to prevent the free-riding effect. In all, a TWC scheme can achieve a high degree of effectiveness if it works with and is supported by an effective portfolio of policy instruments.

When it came to *economic efficiency*, the results seemed to confirm the socio-economic and environmental benefits of increased energy efficiency. First, findings showed that energy cost savings represent the majority of the economic benefits when a TWC scheme is implemented. When adding together the social and environmental benefits of increased energy

efficiency, the justification for energy efficiency improvements was strengthened. Results from an ex-post cost-benefit analysis carried out for the British TWC scheme showed net economic benefits for society as a whole. Considering the official discount rate of 6%, net present values were estimated to be in the range of approximately € 1,660 M to € 1,830 M in the British case. These results were obtained even if a high burden of transaction costs for obliged parties, and a low level of and socio-economic environmental benefits were assumed. In all events, additional research is needed to gain a wider and better quantification of all socio-economic benefits related to increased energy efficiency as such; which poses a remarkable challenge for a thorough evaluation.

In relation to *cost-effectiveness*, a variety of key results were generated. Ex-ante results suggested that a TWC scheme could achieve a given energy saving target at the lowest possible cost. These results also included highly ambitious targets. Furthermore, and from a societal perspective, a cost-effective techno-economic potential of increased energy efficiency of more than 30% was estimated compared to the baseline. In all of the cases analysed, ex-ante results were subject to several crucial assumptions (e.g. zero transaction costs and the existence of adequate capital to support investments). Ex-post findings showed several indications of cost-effectiveness. For the British TWC scheme, energy savings costs were estimated to be lower than an alternative policy instrument. It was also found that energy savings costs were lower (by 20%) than the costs predicted by ex-ante studies. In addition, whereas market liquidity was limited, and a real TWC scheme did not emerge during the first phase, obliged parties indicated that trading was not necessary because compliance costs were already equated in the competitive bidding process for subcontracting insulation measures. In Italy, pre-conditions for cost-effectiveness were identified, namely (i) the emergence of a TWC market (both spot and bilateral) and (ii) a common (spot) market price. However, indications of free-riding and market power exercised by certain obliged parties added uncertainties to indications of cost-effectiveness under the Italian scheme. In all cases, and due to the relative concept of cost-effectiveness, there is a great need for analyses comparing TWC schemes and alternative policy instruments.

For the specific *trading activity under TWC schemes*, the 'to-trade-or-not-to-trade' dilemma was identified. On the one hand, market behaviour under the Italian TWC scheme showed a clearer preference towards to-trade. In the first compliance year 145,796 TWCs were traded—17% on the spot market

and 83% through bilateral contracts (i.e. company-to-company). In Italy, one TWC is equivalent to one tonne of oil equivalent (toe). On the other hand, market behaviour under the British TWC scheme showed a clearer tendency towards not-to-trade. Trading did occur, but to a much lesser extent that in Italy. For the trading of obligations, two trades were identified. In terms of trading of energy savings, six obliged parties purchased energy savings retroactively. The lack of trading activity was affected by a number of considerations, including (i) large cost-effective potentials and an excess of energy savings, (ii) penalties for non-compliance that also encouraged over compliance, (iii) extensive use of the banking option, as obliged parties saw the scheme as a rolling programme, (iv) a strategic learning approach to energy efficiency, (v) low market liquidity and financial gains, (vi) the need for approval from the authority to trade, and (vii) increased competitiveness attributable to the commercial benefits of energy efficiency improvements. In the case of the latter of these, while observers were mainly concerned with the cost savings that can be accomplished through trading, obliged parties seemed more interested in the commercial benefits arising from increased energy efficiency (e.g. increased branding and customer loyalty). In the short term at least, findings suggested autarky compliance strategies under both the British and French TWC schemes.

Regarding *transaction costs*, ex-post results showed that not only trading can be hampered, but also the planning and implementation of eligible measures under TWC schemes. Findings strongly suggested that the search for information and the persuasion of customers were relevant sources of transaction costs for obliged parties upstream in the lifecycle of certificates. For the British case, findings revealed a low level of trading activity, although this was affected slightly by perceived transaction costs (e.g. liability risks in case of non-compliance). While numerous sources of transaction costs were borne by obliged parties under the British scheme—conceivably entailing high costs, approximately 10% to 30% of investment costs for insulation measures—results suggested that the scheme was nonetheless cost-effective and economically efficient (as noted above). No estimates of transaction costs were drawn for the Italian and French cases, and further research is needed here. However, it was found that the nature and scale of transaction costs are likely to be different for each scheme due to endogenous elements (e.g. design, coverage, programme requirements, data reliability) and exogenous determinants (e.g. market conditions, geographic context and the portfolio of policy instruments). Consequently, no general assertions can be made.

In terms of the *administrative burden* on public authorities, only partial ex-post evidence was generated. Research findings suggested that the limited coverage of the British scheme (i.e. with only one eligible sector) combined with an ex-ante measurement and verification (M&V) approach to energy savings, is a workable design through which public authorities can keep administrative costs at a low level. With a team of approximately six full-time professionals dedicated to the TWC scheme, administration and enforcement costs represented less than 1% of the regulator's annual budget. The largest share of costs was related to the external auditor and the management of the database keeping track of the progress of each obliged party. In contrast, the more extensive coverage of the Italian and French schemes, which also include ex-post M&V of energy savings, could entail a sizeable burden for public authorities. In all cases, results are likely to be case-specific, so this criterion underscored, once again, the importance of endogeneity (i.e. design and resulting coverage). Furthermore, results also showed that the simplicity and cost-effectiveness of M&V approaches must be balanced with robustness and reliability.

Regarding *technical change*, ex-ante results showed that, subject to highly ambitious targets, a TWC scheme can encourage innovative technologies (e.g. micro-renewable energy technologies). Conversely, ex-post findings showed that current TWC schemes have basically encouraged the dissemination and implementation of mature technologies, which are already commercially available. For instance in Great Britain, the dominance of insulation measures was clear during the first phase of the scheme. Measures of this type contributed to 56% of the total savings achieved, or nearly 38% of the savings redeemed. Due to extensive potential for cost-efficiency in the insulation segment, it is unlikely that micro-generation (e.g. solar photovoltaic [PV] panels or micro-wind), which is relatively speaking less cost-effective, will make a contribution in the short/medium term under the British TWC scheme. In Italy, a similar situation was found, in which most of the savings generated in the first compliance year were realised through commercially available technologies (e.g. insulation, A-rated appliances, improvements in district heating systems). In addition, and due to the option granted to Italian obliged parties to claim savings retroactively, a substantial share of measures (approx. 60%) were implemented prior to the actual implementation of the scheme. This suggested a free-riding effect, which may also bring into question the additional component of eligible technologies. Again, this evaluation criterion underscored the importance of endogeneity, as the degree of technical change is driven by design elements,

in particular ambitious energy saving targets and/or criteria for additionality and the resulting set of eligible technologies.

With regard to *political feasibility*, ex-post results showed that the legitimacy of TWC schemes can follow different tracks. On the one hand, the Italian experience showed that several obstacles exist even if there is strong political consensus on policy objectives. The scheme was supposed to commence in 2002, but it was finally implemented in 2005. This three-year delay was heavily influenced by lengthy discussions and time consuming negotiations on four main issues: (i) the level of ambition of the energy savings targets, (ii) the development of M&V approaches, (iii) the allocation of savings obligations, and (iv) the existence of investment cost-recovery mechanisms. During the period in which the research was being carried out, political uncertainties arose regarding the future the Italian scheme following the first compliance period (i.e. after 2009). On the other hand, results from Great Britain suggested that the legitimacy of the scheme has not been jeopardised. This could be explained by a number of factors, including (i) a high degree of political commitment towards climate change and energy efficiency policies, (ii) the ex-ante evaluation of the scheme's impacts (on a measure-by-measure basis and also at the aggregate level), (iii) an extensive and statutory consultation process prior to the implementation of the scheme, (iv) key stakeholders already being familiarised with the operation of the TWC scheme, (v) the limited coverage of the scheme (i.e. the household sector), meaning it is considered a workable policy instrument for the authorities, and (vi) the TWC scheme's explicit support of the Fuel Poverty Strategy, which aims to reduce the number of households spending more than 10% of their income to satisfy energy needs.

As far as *distributional equity* is concerned, a number of key aspects can be highlighted. First, and due to increased energy efficiency, several potential ancillary benefits were identified (e.g. increased competitiveness and employment generation, reduced fuel poverty, reduced GHG emissions, improved housing stock and increased security of energy supply). These aspects are consistent with the discourse on energy for sustainable development. The findings clearly suggested that if co-benefits were taken into account, the economic attractiveness of increased energy efficiency, triggered by a TWC scheme, would increase. However, given international trading of TWCs, one could easily infer that countries realising energy savings at the lowest marginal costs (i.e. those with a cost-effective supply of TWCs) could derive ancillary benefits. In the presence of an EU-wide TWC scheme, this may imply a disadvantage for countries that have been

historically committed to increased energy efficiency. In all cases, ex-post results suggested that households could derive net financial benefits. However, fair and transparent investment cost-recovery mechanisms play a critical role. Otherwise cross subsidies can occur and (low-income) households that have *not* implemented measures could shoulder an unfair financial burden. Prima facie, one can argue that investment costs are likely to be distributed equally by obliged parties across all end-users. In Italy, indications were observed of rent-seeking behaviour on behalf of obliged parties. This raised distributional concerns, as obliged parties may be obtaining windfall profits at the expense of taxpayers.

Concluding remarks

The results of this thesis showed that the performance of TWC schemes is rather unique and context-specific. It is therefore difficult to make generalisations. It is concluded that several endogenous and exogenous aspects/conditions affect the performance of TWC schemes. First, the design and resulting coverage (i.e. endogeneity) can heavily affect several elements of implementation and performance. For instance, the level of ambition of the energy savings targets, the size of the market, the provision of readily available information to market agents, minimum regulatory barriers to trade, the extent of technical change and the strength and effectiveness of M&V approaches and enforcement. These elements can, in particular, determine the order of magnitude of the effects, the sources of transaction costs, the dynamics of trading activity, and the level of compliance. Second, several market conditions also affect the performance of TWC schemes, in particular those that inhibit the adoption of energy efficiency technologies (e.g. information problems). In addition, energy prices, the right of consumers to choose their energy supplier and the involvement of different market actors in the scheme (e.g. contractors, retailers, ESCOs) were found to be significant elements shaping the market dynamics of TWC schemes. Third, certain policy conditions were also identified that influence the performance of TWC schemes. On the one hand, informative policy instruments are required to reduce uncertainties and transaction costs, and support related technological learning processes. On the other hand, economic policy instruments that provide adequate capital are critical in supporting the necessary investments in eligible energy efficient technologies. In addition, TWC trading markets can function when policy design and implementation encourage this. Finally, the interdependence of energy efficiency policy instruments posed a significant challenge to determining the added value of TWC schemes. However,

neglecting connections and synergies between policy instruments can lead to biased assertions.

If TWC schemes are to play a relevant policy role in the context of energy for sustainable development, endogeneity is crucial. In particular, highly ambitious energy saving targets, fair and transparent investment cost-recovery mechanisms, non-compliance rules and effective enforcement can play a fundamental role. Ex-post results suggest that TWC schemes can be a valuable policy instrument, albeit not a panacea for increasing energy efficiency and encouraging energy systems towards a path of sustainable development. A TWC scheme is a complex policy instrument and some designs can work better than others. Findings strongly suggest that continuous ex-post evaluations are needed for each individual TWC scheme to improve its regulatory framework and performance. In all events, comparative evaluation studies between TWC schemes and other policy instruments are highly recommended to improve policy assessments.

From the methodological point of view, the appropriateness of triangulation was confirmed throughout the thesis. That is to say, a variety of methods for data collection and analysis were needed to address the empirical and normative understanding of TWC schemes. The application of each individual method showed advantages and disadvantages. Therefore, the research showed that no single best method or dataset was relevant in providing a comprehensive analysis of TWC schemes. By using different but complementary evaluation approaches, the thesis offers a template for the evaluation of current or future TWC schemes, showing what to evaluate and suggesting how this should be achieved. For energy (efficiency) policy instruments with a large set of attributes, conducting an inclusive policy evaluation requires a mixture of research methods for data collection and analysis. On the whole, the research shows that multi-criteria policy evaluation allows a better understanding of the broad effects, attributes and complexities of TWC schemes.

Finally, lessons drawn by this thesis strongly suggest that evaluation needs to be brought into the mainstream of energy (efficiency) policy. Although a comprehensive policy evaluation is a complex and resource-intensive process, it is a doable exercise that provides, among many other benefits, continuous policy learning opportunities for both policy makers and stakeholders. Policy experimentation must work closely together with policy evaluation to improve policy design and support the choice of instrument.

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List of Appended Papers

Paper I: Farinelli, U., Johansson, T. B., McCormick, K., Mundaca, L., Oikonomou, V, Örtenvik, M., Patel, M., & Santi, F. (2005). 'White and Green': Comparison of market-based instruments to promote energy efficiency. *Journal of Cleaner Production* 13 (10-11):1015-1026.

Paper II: Mundaca, L. (2008). Markets for energy efficiency: Exploring the implications of an EU-wide 'Tradable White Certificate' scheme. *Energy Economics* (forthcoming).*

(*) Best Nordic PhD Paper 2008 in social science. Prize awarded by the Energy Forum and the Nordic Energy Research Council.

Paper III: Mundaca, L. (2007). Transaction costs of Tradable White Certificate schemes: The Energy Efficiency Commitment as case study. *Energy Policy* 35 (8):4340-4354.

Paper IV: Mundaca, L., Neij, L., Labanca, N., Duplessis, B., & Pagliano, L. (2008). Market behaviour and the to-trade-or-not-to-trade dilemma in 'Tradable White Certificate' schemes. *Energy Efficiency* (forthcoming).

Paper V: Mundaca, L., & Neij, L. (2008). A multi-criteria evaluation framework for 'Tradable White Certificate' schemes (submitted to *Energy Policy*).

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Abbreviations

AEEG	Autorità per l'Energia Elettrica e il Gas (Electricity and Natural Gas Regulator)
BAU	Business-As-Usual
CBA	Cost-Benefit Analysis
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CO_{2-eq}	Carbon Dioxide Equivalent
CRA	Cost-Revenue Analysis
DOE	US Department of Energy
E^3	Energy-Economic-Environment
EDF	Électricité de France
EEC	Energy Efficiency Commitment
EEE&ES	Energy End-use Efficiency and Energy Services
EESoP	Energy Efficiency Standards of Performance Programme
EIA	Energy Information Administration
EJ	Exajoule
ESCOs	Energy Service Companies
ETSAP	Energy Technology Systems Analysis Programme
EU	European Union
EU-ETS	EU Emission Trading Scheme
FCEA	Free-of-Charge Energy Audit
GHG	Greenhouse gas
GWh	Gigawatt Hour
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt Hour
M&V	Measurement and Verification
MARKAL	Market Allocation Model
MtC	Million Tonnes of Carbon
Mtoe	Million Tonnes of Oil equivalent
MWh	Megawatt Hour
OFGEM	Office of Gas and Electricity Markets
PJ	Petajoule

PV	Photovoltaic
R&D	Research and Development
RES	Reference Energy System
RQ	Research Question
SAGE	System for Analysis of Global Energy
SHPs	Social Housing Programmes
SO_2	Sulphur Dioxide
TCs	Transaction Costs
Toe	Tonne of Oil Equivalent
TWC	Tradable White Certificate
TWCs	Tradable White Certificates
TWh	Terawatt Hour
UNCED	United Nations Conference on Environment and Development
WSSD	World Summit for Sustainable Development

ONE

1. Introduction

This Chapter aims to lay the foundations for this PhD dissertation by defining the research framework and delineating the context within which the research was carried out. The content introduces the research problem, objectives and research questions, presents the scope and limitations of the investigation and describes the target audience. At the end of this Chapter, the structure of the thesis is outlined.

1.1 Background to the research

Ever since the publication of the Limits to Growth—work commissioned by the Club of Rome—and the Brundtland report, entitled Our Common Future, the challenge of how to work towards and realise sustainable development has been on the international political agenda. Sustainable development encompasses a broad and complex challenge involving the relationship between present and future generations; the inter-connection and accomplishment of social, environmental and economic goals; and contributions by many different actors in exploring new paths of economic development (WCED, 1987).

Energy is critical to human development and acts as fundamental link to the challenges that sustainable development encompasses (see e.g. Goldemberg *et al.,* 1988; Hollander, 1992; IAC, 2007; IEA, 2004; Johansson and Goldemberg, 2002; Kaya and Yokobori, 1997; UNDP *et al.,* 2000). While the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 provided a major framework for fostering sustainable development, it was not until the World Summit for Sustainable Development (WSSD) in 2002 that the critical role of energy in the context of sustainable development was explicitly addressed (Bradbrook *et al.,* 2005; Goldemberg and Johansson, 2004). Considering how vital the production and use of energy is for the fulfilment of human needs, critical connections were made between energy and water (e.g. the environmental impact of hydropower), energy and biodiversity (e.g. the impact of climate change from energy-

related greenhouse gas [GHG] emissions), energy and human health (e.g. the impact of indoor pollution due to inefficient energy technologies), and energy and agriculture (e.g. bio energy as replacement for fossil fuels).[1] As a result, several aspects of the Plan of Implementation of the WSSD stated energy as an essential instrument in supporting sustainable development beyond the energy policy arena (Goldemberg and Johansson, 2004). With a focus on implementation, the plan resulting from the WSSD argues that energy is critical for the support of economic, social and technological systems (see UNDP *et al.,* 2002).

Although energy plays such a pivotal role for mankind, patterns of energy production and consumption remain unsustainable (Bradbrook *et al.,* 2005; Goldemberg, 1996; IEA, 2004; Johansson and Goldemberg, 2002; Kaya and Yokobori, 1997; Smil, 2005, UNDP *et al.,* 2000). For instance, new scientific evidence is emerging on an almost daily basis about the negative effects of energy-related environmental problems. Human-induced climate change can be taken as a remarkable example (cf. Metz *et al.,* 2007). In fact, atmospheric pollution generated by conventional energy systems based on fossil fuels threatens the health both of humans and ecosystems, as well as the well being of present and future generations (e.g. Goldemberg and Johansson, 2004; Johansson and Goldemberg, 2002; UNDP *et al.,* 2000; 2002). From the social point of view, approximately 2 billion people do not have access to modern forms of energy carriers such electricity and liquid fuels (IEA, 2002b; Goldemberg and Johansson, 2004). Moreover, dependence on imported fuels makes many countries vulnerable to economic and social disturbance (e.g. IEA, 2002b; UNDP *et al.,* 2000). People lacking energy access are unable to take advantage of modern forms of energy that provide various energy services (e.g. lighting, heating, cooling), resulting in negative implications for poverty alleviation, human development and economic growth (e.g. IEA, 2002b, 2004; IAC, 2007; Goldemberg *et al.,* 1988; Sachs, 2005).[2] Alternatives to today's dominant energy technology systems do exist, but there is uncertainty about the political commitment necessary to drive their deployment, scale, and timeframe to redress the world's current unsustainable energy patterns (IAC, 2007; Metz *et al.,* 2007; UNDP *et al.,* 2000).

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[1] For details see UNDP *et al.* (2002:9).

[2] The term *energy service* refers to the delivered benefits of useful energy consumption, such as heating, refrigeration, lighting, cooking, transportation, etc., as opposed to the simple provision of units of energy as such (see Blok, 2006; Johansson and Goldemberg, 2002).

Due to the fact that energy systems are increasingly being de-regulated, much attention has been given to the role of public policy to provide the right market incentives and foster a sustainable energy future (e.g. Barton, 2005; IEA, 2002b; Johansson and Goldemberg, 2002; Sathaye *et al.,* 2007). In supporting sustainable development, energy systems cannot be left to markets alone (see e.g. Bradbrook *et al.,* 2005; Goldemberg and Johansson, 2004; IAC, 2007; UNDP *et al.,* 2000). For instance, social and economic development is heavily linked with access to modern energy services, so public intervention is needed to broaden access in developing countries. In addition, negative social and environmental impacts of energy production and consumption are not reflected in price mechanisms, which have recently been subject to critical policy focus (cf. Goldemberg and Johansson, 2004; IAC, 2007; Levine *et al.,* 2007). Sound policies remain at the core of the challenge to make energy markets compatible with sustainable development goals, (see e.g. IAC, 2007; Goldemberg *et al.,* 1988; Johansson and Goldemberg, 2002; Gupta *et al.,* 2007). As energy markets become more liberalised, it is argued that *public sector oversight is needed now more than ever to greatly reinforce markets' benefit to society and the environment* (Barton, 2005; Goldemberg and Johansson, 2004; IAC, 2007; Jaccard and Mao, 2002; Lyster, 2005). In fact, the Plan of Implementation of the WSSD underscores the role of the public sector in making sound policy interventions (Goldemberg and Johansson, 2004). The fundamental challenge of making energy policies contribute to sustainable development goals is how to expand energy services in such a way that this enlargement is "environmentally sound, as well as safe, affordable, convenient, reliable, and equitable" (Johansson and Goldemberg, 2002:1).

On the whole, it is argued that the *present structure of market incentives and policy conditions is insufficient to effectively address the challenges of energy for sustainable development* (Goldemberg and Johansson, 2004; IAC, 2007; IEA, 2002b; Jaccard and Mao, 2002). To redress these counterproductive trends, it is argued that the implementation of sound policy instruments targeting *renewable energy* and *energy efficiency*[3] are becoming increasingly vital to our society (see e.g. Goldemberg and Johansson, 2004; Jochem *et al.,* 2000; Laponche *et al.,* 1997; Levine *et al.,* 2007; Metz *et al.,* 2007). The implementation of sound policy instruments is urgently needed to provide the right market incentives to change or optimise current patterns of energy

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[3] The term *energy efficiency* is herein simply used to refer to the ratio of the energy output (i.e. energy services) to the energy input. It includes all modifications (e.g. technical, managerial) that result in a reduction in the energy used for meeting a given energy service demand (e.g. lighting, heating).

production and consumption that are compatible with economic, environmental and social goals (IEA, 2002b; IAC, 2007; Metz *et al.,* 2007).

Lately, *the importance of increased energy efficiency in the context of sustainable development has re-gained political momentum* (see e.g. Goldemberg and Johansson, 2004; Metz *et al.,* 2007). Recent years have witnessed a continuous escalation in oil prices, increased awareness of the need for energy security, and growing energy-related environmental problems— including the threat of human-induced climate change—which are all contributing to the re-assessment of society's energy use (cf. Goldemberg and Johansson, 2004; Jochem *et al.,* 2000; Metz *et al.,* 2007). In fact, a growing body of evidence shows that increased energy efficiency can benefit both society and the environment. Efficiency improvements can reduce atmospheric pollution; lessen negative externalities[4] resulting from energy production; boost industrial competitiveness; generate employment and business opportunities; improve the housing stock and the comfort level of occupants; enhance productivity; increase security of supply; and contribute to poverty alleviation, among other aspects (see e.g. European Commission, 2005; IAC, 2007; Jakob, 2006; Jochem *et al.,* 2000; Laponche *et al.,* 1997; Leaman and Bordass, 1999; Levine *et al.,* 2007; Rosenfeld and Ward, 1992). Based on the above arguments, research on energy efficiency policy is paramount because of the role it can play in fostering a more sustainable energy future (see e.g. IEA, 1997a; IAC, 2007; Jochem *et al.,* 2000; Goldemberg and Johansson, 2004; Levine *et al.,* 2007). Throughout the writing of this thesis, the environmental importance of increased energy efficiency was high on the political agenda, particularly in Europe.

However, despite multiple social and environmental benefits embedded in increased energy efficiency, a number of market failures and barriers have traditionally prevented efficiency improvements (see e.g. Jaffe and Stavins, 1994a; 1994b; Sanstad and Howarth, 1994). On the one hand, major potentials for increased energy efficiency have been identified (see e.g. IEA, 1997a; 1997b; Jochem *et al.,* 2002). Nevertheless, globally, the current level of energy efficiency, in converting primary energy to useful energy, is

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[4] *Externalities* are understood as the costs or benefits, arising from any activity, that are not taken into account (i.e. not reflected in market prices) by the person/organisation carrying out that activity (e.g. the consumption or production of a good). In the case of *negative* externalities, the level of welfare of one individual is adversely affected by another and no compensation takes place (e.g. pollution).

estimated at no more than about 35% (Jochem *et al.,* 2002).[5] On the other hand, the so-called energy efficiency gap is generally used to describe the slow diffusion of profitable efficient technologies that fail to achieve market success (Jaffe and Stavins, 1994a; 1994b). There is compelling evidence that efficiency improvements have been under-realised due to information issues, high (implicit) discount rates, bounded rationality, principal agent problems, negative externalities not reflected in energy prices, high transactions costs, uncertainties about technical performance, lack of sufficient capital, investment risks, etc. (see e.g. Gates, 1993; Howarth and Sanstad, 1995; Jaffe and Stavins, 1994a; 1994b; Lutzenhiser, 1992; Metcalf, 1994; Ruderman *et al.,* 1987; Suttherland, 1991; Train, 1985). However, specific policy instruments have the potential to correct/reduce many of these market conditions. With the ability to create or stimulate markets through several policy instruments, public policy targeting energy efficiency has a critical role to play.

1.2 Problem definition

Within the context described previously, it has been argued that the creation of markets for energy efficiency—so-called *Tradable White Certificate (TWC) schemes*—represents a policy instrument that should be considered as a means of realising energy savings at the least-possible cost and address various energy challenges related to sustainable development (see e.g. Bertoldi and Rezessy, 2006; Capozza *et al.,* 2006; European Commission, 2006a; Rader and Norgaard, 1996).[6] Developments in European energy (efficiency) policy reveal a *growing interest in creating markets to boost energy*

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[5] A common classification of energy efficiency potentials include: (i) theoretical potential, (ii) technical potential, (iii) techno-economic potential and, (iv) market potential. The *theoretical potential* refers to the minimum energy input required to keep a given energy service demand satisfied with due consideration to the laws of thermodynamics. *Technical potential* usually refers to what can be achieved by using the best available technologies at a certain point in time. Consequently, it represents energy savings that can be realised from the most efficient energy technologies regardless of cost considerations. The *techno-economic potential* refers to the technical potential but with due consideration to costs. Whereas energy efficient technologies usually entail higher investment costs compared to standard technologies, they have lower operational (fuel) costs. The *market potential* refers to the level of efficiency improvements that is achieved in practice. Thus, it reflects all the obstacles and market barriers that hamper energy efficiency potentials from being completely realised. For a detailed description of energy efficiency potentials see e.g. Jaffe and Stavins (1994b), Jochem *et al.* (2000), and IEA (1997a).

[6] Note that the terms *Markets for Energy Efficiency* and *TWC schemes* are used interchangeably throughout the text.

efficiency cost-effectively. In the past few years, France, Italy and Great Britain have embarked on implementing tradable certificate schemes to improve energy efficiency and other EU member states are analysing potential design options and/or implementing a TWC scheme (e.g. The Netherlands, Denmark, and Poland). The creation of TWC schemes entails a mandatory energy saving target that certain market actors are required to meet during a given time period. As in any tradable permit scheme, flexibility is crucial because it is up to subject participants to decide how to meet their target cost-effectively. Realised energy savings are credited with certificates.[7] With the purpose of equalising marginal compliance costs, subject parties have the option of trading these certificates to meet their individual targets. A detailed description of TWC schemes is given in Section 3.2.

In addition to the above-mentioned national trends, policy efforts are being undertaken at the European level that could trigger the implementation of more national European TWC schemes; or even form the basis for a future EU-wide TWC scheme. First, the adopted Energy End-use Efficiency and Energy Services (EEE&ES) Directive, which sets an indicative cumulative energy saving target of 9% for the ninth year of application of the Directive, aims to enhance cost-effective improvements in all end-use sectors (European Commission, 2006b:69). Encouraging several policy instruments for energy efficiency improvements and increased provision of energy services, the Directive further mentions that EU member states are allowed to implement TWC schemes.[8] In addition, and following a revision of how national TWC schemes are executed, the European Commission will assess the suitability of proposing a Directive to develop TWC schemes. Second, addressing the European Action Plan for Energy Efficiency—which indicates policies and measures for realising a 20% estimated savings potential in the EU by 2020—the European Commission highlights that the EEE&ES Directive allows the evaluation of an EU-wide TWC scheme in 2008 (European Commission, 2006a). Third, the adopted Green Paper Doing More with Less identifies numerous barriers to, and options for, increased energy efficiency. Calling for concrete policy measures, it poses the question of whether an EU-wide TWC scheme could be implemented with the least bureaucratic burden (European Commission, 2005). Furthermore,

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[7] Note that the words *permit* and *certificate* are used interchangeably throughout the text.

[8] The Directive on EEE&ES defines *white certificates* as "certificates issued by independent certifying bodies confirming the energy savings claims of market actors as a consequence of energy efficiency improvement measures" (European Commission, 2006b:68).

the adopted Green Paper also states that the European Commission is already preparing itself for a possible EU-wide TWC scheme to allow trading of energy saving among member states (European Commission, 2005).

Pursuant to such development, *the growing policy interest in TWC schemes raised the attention of the author of this thesis regarding their evaluation and performance.* This was because the implementation of TWC schemes has displayed a public policy dichotomy. On the one hand, theory-based expectations used to legitimatise TWC schemes are extensive and consistent with many aspects of the policy discourse on energy for sustainable development. That is, increased energy efficiency can benefit both society and the environment. In turn, multiple policy agendas and objectives have been used to support the implementation of TWC schemes.[9] On the other hand, while considerable policy efforts and attention have been devoted to encouraging TWC schemes, the public policy process related to TWC schemes has lacked evaluation.[10] Indeed, much of the interest and implementation has relied on the expected benefits resulting from increased energy efficiency and the theoretical economic rationale of cost-effectiveness embedded in tradable permits schemes in general.[11]

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[9] Expected benefits include reduced atmospheric pollution, increased security of energy supply, enhanced competitiveness and employment generation, etc. They have often been mentioned and used to justify the creation and implementation of TWC schemes (see e.g. Bertoldi and Rezessy, 2006; Capozza *et al.,* 2006). Furthermore, public discourse justifying the implementation of TWC schemes has also included poverty alleviation aspects (see DEFRA, 2004).

[10] For instance, the implementation of the Italian and French TWC schemes was mostly supported by the general policy discourse of increased energy efficiency rather than specific and/or independent assessments (cf. Capozza *et al.,* 2006; Mundaca and Neij, 2006). Concerning Great Britain, the scheme was subject to an ex-ante evaluation focused on energy savings, costs and emission reductions (see DEFRA, 2004). However, one can argue that this evaluation was mostly the outcome of the ex-ante approach developed by the authority for measuring and verifying energy savings. This is because the methodology to grant energy savings without ex-post measurement and verification, and the resulting energy and economic outcomes, had to be in place before the actual implementation of the scheme.

[11] Similar concerns about the lack of evaluation have been pointed out for the environmental policy field as such, in particular for the case of policy instruments addressing the energy and environmental interplay (see e.g. Bemelmans-Videc *et al.,* 1998; Harrington *et al.,* 2004; Mickwitz, 2003; and OECD, 1997; 2002). Some authors argue that policy evaluation entered the environmental field much later that many other public policy fields (see Knapp and Kim, 1998; Mickwitz, 2006).

The situation described above is consistent with the fact that *there are a limited number of systematic energy (efficiency) policy evaluation studies* and that *practices in the field of energy (efficiency) are not harmonised* (see e.g. Blok, 2006; Taylor and Jollands, 2007; Vreuls *et al.,* 2005). Whereas the discourse on energy for sustainable development has greatly underscored the need for the implementation of sound policy instruments to increase energy efficiency, much less attention has been paid to the evaluation of policy instruments as such. Consequently, while there are a growing number of energy efficiency policy instruments being implemented, only scattered policy evaluation efforts can be identified in the literature (see e.g. Boonekamp, 2005; Dowd, 2008; Harmelink *et al.,* 2007; Vreuls *et al.,* 2005). It is argued that there seems to be limited interest in energy efficiency policy evaluation, and that the few studies that have been conducted have traditionally targeted the narrow—albeit challenging to quantify—area of impacts, in terms of energy savings, emission reductions and energy savings costs (see e.g. Boonekamp, 2005; Harmelink *et al.,* 2007; SCR *et al.,* 2001; Swisher *et al.,* 1997). Lately, the International Energy Agency (IEA) has underscored several gaps concerning the evaluation of energy efficiency policy instruments, including the lack of studies at the national level and the need to provide minimum methodological guidelines (see Taylor and Jollands, 2007).[12]

Pursuant to these concerns, *there is a need to evaluate the effects (impacts and outcomes) of TWC schemes and not only to rely on theory-based expectations (and enthusiasm) to implement this policy instrument.* [13] Recognising the fact that policy instruments are needed to stimulate markets to more strongly promote increased energy efficiency, evaluation is needed to better support the public policy development process. In other words, policy experimentation must

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[12] In relation to new and existing environmental policies as such, note that the 6th Environmental Action Programme for the European Union (Article 10) explicitly calls for improvements in the policy decision-making through ex-ante and ex-post evaluations. This also addressed energy (efficiency) policies tackling climate change (Article 5). As a result of this initiative, the Commission launched a system of *Integrated Impact Assessment* to address significant environmental, economic and social impacts arising from major EU policy (proposals) in 2002. However, it has been argued that the quality of the evaluation studies is low and that the actual effects of the studies on the policy decision-making are unknown, even in cases in which comprehensive analyses have been performed (see Pallemaerts *et al.,* 2006).

[13] In the reviewed literature, an *outcome* is understood as the response to the policy instrument by subject participants (e.g. adoption of new technologies, development of new business plans, etc.). An *impact* is understood to be the resulting changes generated by outcomes on society and the environment (e.g. energy consumption, health problems, etc.) (see e.g. Dye, 1976; EEA, 2001; Fischer, 1995; Hildén *et al.,* 2002; Vreuls *et al.,* 2005).

work closely beside policy evaluation. In the case of TWC schemes, it has not been clear why and how a given TWC scheme was finally chosen and designed (e.g. France and Italy). On the one hand, a lack of ex-ante evaluation may result in the implementation of TWC schemes that may contribute very little, if anything, to overcome the problems that justify their implementations. On the other hand, a lack of ex-post policy evaluation can result in the continuation of ineffective and inefficient TWC schemes, long after they should have been improved or removed. Therefore, there is a need to evaluate the effects of TWC schemes and to thoroughly assess the merit of this new (innovative) policy instrument. Based on the above-described arguments, the research problem can be summarised as follows:

Despite growing interest among policy makers in the creation of TWC schemes, less attention has been paid to evaluating the impacts and outcomes permitting the assessment of the merit of a policy instrument of this kind and its ongoing improvement. Therefore, research is needed to understand the critical aspects/conditions that affect the performance of this instrument. Moreover, there is an insufficient understanding of the (potential) evaluation methods that can be used to evaluate TWC schemes.[14]

On the whole, this doctoral thesis shows that the *performance of TWC schemes is very case and context-specific, so extrapolations are difficult to draw*. In all events, three crucial aspects affecting the performance of TWC schemes were found: (i) their design, and thereby coverage; (ii) the market conditions in which they operate and (iii) an effective portfolio of policy instruments also addressing energy efficiency. Ex-post results suggest that *TWC schemes can be a valuable policy instrument, albeit not a panacea for increasing energy efficiency and encouraging energy systems towards a path of sustainable development*. If TWC schemes are to play a relevant policy role in the context of energy for sustainable development, endogeneity (i.e. design) is crucial. In particular, highly ambitious energy saving targets, fair and transparent investment cost-recovery mechanisms, non-compliance rules and effective enforcement can play a fundamental role. As a result of increased energy efficiency, TWC schemes can reduce negative externalities resulting from energy production; generate employment and business opportunities; improve the housing

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[14] To support the contemporary relevance of the research problem, note that, at the time of writing, the IEA dedicated a workshop (in February 2008) to compliance, monitoring and *evaluation* of energy efficiency policies. Under this initiative, the importance of energy efficiency policy evaluation, but lack of studies, was once again fully recognised by several participants and organisations. For further details, visit
http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=349

stock and the comfort level of householders; increase security of energy supply; and contribute to fuel poverty alleviation.

Based on lessons drawn from the evaluation of TWC schemes, I essentially argue that *evaluation needs to be mainstreamed in energy efficiency policy. It can no longer be neglected.* Whereas a comprehensive policy evaluation is a complex and resource-intensive process, it is a doable exercise that provides continuous policy learning opportunities both to policy makers and stakeholders, among many benefits. This research shows that numerous methods, criteria and approaches exist that can be used to support the public policy process related to the design, evaluation and implementation of TWC schemes. The resources involved and the dynamics and interactions with policy instruments largely frame the challenges encompassed by energy efficiency policy evaluations.

1.3 Objective and research questions

The research is driven by the need to contribute to knowledge on energy efficiency policy evaluation. In fact, the research responds to the lack of evaluation studies in the field of energy efficiency (see e.g. Dowd, 2008; Gillingham *et al.,* 2006; Taylor and Jollands, 2007; Vreuls *et al.,* 2005).[15] Framed in the context of policy-oriented research, the purpose of the research is thus to generate 'knowledge for action' concerning energy efficiency policy evaluation.

The objective of the research is to enhance our knowledge about the implications and complexities of creating markets for energy efficiency (i.e. TWC schemes). By achieving this objective, the research aims to support the public policy development process related to TWC schemes and draw methodological lessons for energy efficiency policy evaluation.

On the whole, the research seeks to provide a comprehensive, detailed and insightful portrait of TWC schemes with the aim to support current and future related public policy processes. To achieve the research objective, a wide evaluation is conducted. With several policy efforts underway at the EU level that could trigger more (national) TWC schemes, this research is thus timely in supporting and providing broad and valuable insights into

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[15] The research also responds to requests made by scholars and international organisations calling for more policy evaluation studies addressing tradable permit schemes in particular (see e.g. OECD, 2002; Tietenberg, 2006).

current and/or future public policy processes related to this policy instrument. In particular, research findings are expected to provide key lessons for countries that are about to embark on the implementation of TWC schemes, by identifying key design elements, defining what to evaluate in TWC schemes and suggesting how to do this.

To achieve the objective*, several ex-ante and ex-post evaluation studies were conducted* to ascertain the potential or actual impacts and outcomes of TWC schemes. By performing ex-ante evaluation studies, the research identified and analysed several impacts of hypothetical TWC schemes (see papers I and II). The research also investigated the outcomes triggered by the implementation of current TWC schemes (see papers III and IV). The research focused on the strategies undertaken by obliged parties to comply cost-effectively with their energy saving targets. The research was mostly carried out by analysing transaction costs and the set of flexibilities given to parties to comply cost-effectively. The implementation of TWC schemes was also investigated from different angles, including connections between political commitment and the operation of TWC schemes, and changes in the regulatory framework. Finally, the research included various ex-post evaluation studies covering different geographical areas (e.g. Great Britain and Italy) in specific case studies (see papers IV and V). Impacts and outcomes resulting from TWC schemes were analysed in the light of the original policy formulation or stated policy targets. On the whole, a number of policy implications were drawn as a result of the research. Interactions between TWC schemes and other energy efficiency policy instruments were also addressed. A variety of quantitative and qualitative methods and evaluation criteria (see Chapters 2 and 3 for details) were used to provide tangible evaluation results.

To address the objective, the following research questions were chosen to investigate specific aspects of the research:

- RQ 1: How do TWC schemes perform from the perspective of a broad evaluation? What are the critical aspects/conditions that affect their performance?

- RQ 2: What are the limitations/obstacles and strengths/advantages of the evaluation methods used to assess the performance of TWC schemes?

Section 5.2 proposes answers to these research questions and elaborates on the conclusions of the research in relation to each question. Findings regarding RQ 1 and RQ 2 are also presented through Chapter 4 on a paper-by-paper basis. Furthermore, note that specific research objectives (in each paper) and hypotheses (see next section) were established to investigate RQ 1.

The *significance of the research objective and research questions* can be judged by the multiple benefits embedded in policy evaluation. In general, evaluation supports the most suitable design of public policy (see EEA, 2001; Fischer, 1995; Rossi *et al.,* 2004). Evaluation is needed in order to gain a better understanding of the effects of policy instruments and to assess whether they are capable of achieving the impacts and outcomes that would justify their introduction (cf. Bardach, 2005; Bemelmans-Videc *et al.,* 1998; Chen, 1990; Harrington *et al.,* 2004; Mickwitz, 2003). Likewise, policy evaluation can improve the design and choice of policy instruments by showing how they perform under different policy and market conditions (cf. Baumol and Oates, 1998; OECD, 1997; 2002; Vedung, 1997). Policy evaluation is also crucial in verifying results, withdrawing inefficient policies or providing the corrections necessary to improve the performance of policy instruments in order to resolve the problem(s) and secure the policy objective(s) (cf. Fischer, 1995; Mickwitz, 2003; Vedung, 1997). Policy evaluation also advances the administration of policy instruments, provides public accountability, and indicates how to ensure that the public policy process translates into policy instruments that are as effective as possible (cf. EEA, 2001; OECD, 2002). Furthermore, evaluation is critical for the generation of knowledge and policy learning that reshapes public policies (e.g. Bemelmans-Videc *et al.,* 1998; EEA, 2001; Mickwitz, 2003; Rossi *et al.,* 2004). Based on the arguments presented, the research problem is justified through the usefulness of the potential applications of the research findings.

The fact that this research was supported by several agencies, research programmes and research organisations can also be taken as an indication of the relevance of the enquiry (i.e. the European Union Energy SAVE Programme, the International Institute for Applied Systems Analysis [IIASA], the European Commission Intelligent Energy Europe Programme, the Swedish Energy Agency [STEM], the Swedish Electrical Utilities R&D Company [ELFORSK], and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning [FORMAS]).

1.4 Research hypotheses

To address RQ 1, several hypotheses were used as a starting point for further investigation. The *hypotheses emerged from the claims, attributes and/or theory-based expectations related or attached to TWC schemes*. That is, the introduction of this policy instrument is based on the claims or assumptions that a TWC scheme is economically efficient, (cost) effective and involves a lower administrative burden for public authorities (see e.g. Bertoldi and Rezessy, 2006, Langniss and Praetorius, 2006; Monjon, 2006; Oikonomou and Patel, 2004; Pavan, 2002; Voogt *et al.,* 2006). Meanwhile, the research also focused on the assertions that TWC schemes seek to support technological change and that transaction costs can hamper trading activity (cf. Bertoldi and Rezessy, 2006, Langniss and Praetorius, 2006; NERA, 2006). Finally, due to the fact that the process of implementing these schemes has also been framed in terms of high legitimacy and the reduction of fuel poverty, the research focuses on political feasibility and distributional equity as evaluation criteria (cf. Bertoldi and Rezessy, 2006; Monjon, 2006; NERA, 2006; Pavan, 2002) (see more details in Section 3.2).

Based on these claims or attributes, related or attached to TWC schemes, several hypotheses were elaborated. These are stated below, along with a brief description of evaluative aspects that were addressed when conducting the research:

Hypothesis 1: Given non-compliance rules and effective enforcement, TWC schemes can achieve an energy-saving and/or environmental target(s) with a high degree of certainty. The research attempted to assess obliged parties' compliance level regarding energy saving targets and the resulting reductions in emissions (if explicitly acknowledged as a target). The hypothesis was mostly analysed in terms of target achievement, ambition level of the target, implemented eligible technologies, and non-compliance rules.

Hypothesis 2: Due to increased energy efficiency, society obtains net economic benefits under a TWC scheme. To address this hypothesis, the research attempted to ascertain whether TWC schemes maximise the difference between total social benefits (i.e. energy cost savings and social and environmental benefits) and total costs (i.e. investment costs, administrative costs and transaction costs). The hypothesis was addressed through a cost-benefit analysis, which is considered the suitable operational and pragmatic formulation by which to approach economic efficiency (i.e. to identify potential Pareto improvements) (see e.g. Stavins, 2004; Tietenberg, 2006).

Hypothesis 3: TWC schemes can deliver energy savings at low(est) possible costs. The research focused on whether an energy saving target can be achieved at the lowest possible cost. Furthermore, it was analysed in terms of the equalisation of marginal costs across obliged parties or, alternatively, by considering whether (estimated) costs were higher or lower than the most probable alternative policy instrument. The analysis also identified pre-conditions for cost-effectiveness, such as a common market price and trading between parties facing different costs.

Hypothesis 4: Transaction costs hamper the trading of certificates under TWC schemes. The research attempted to examine all of the costs—other than investment and administrative costs—faced by obliged parties in initiating and completing transactions under TWC schemes (cf. Matthews, 1986). The hypothesis was analysed in terms of sources (e.g. due diligence, the finding and assessment of information, negotiations with trading partners, acquisition of legal services, measurement and verification) and the scale of transaction costs during the entire lifecycle of TWCs.

Hypothesis 5: TWC schemes can involve a low administrative burden for public authorities. To investigate the hypothesis, the research addressed the workload and financial resources that public authorities face when a TWC scheme is implemented and enforced (cf. Nordhaus and Danish, 2003; Rist, 1998). It also focused on the administrative outcomes that the implementation of TWC schemes can generate for the public authority, looking at their internal response resulting from the implementation of a TWC scheme.

Hypothesis 6: Technical change is encouraged by TWC schemes so that new technologies are introduced. This research looked at the development and dissemination of new energy efficient technologies induced by TWC schemes (cf. OECD, 2002; Tietenberg, 2006). The research focused on the types of measures implemented under TWC schemes. Furthermore, technical change was also investigated by considering changes in the so-called selection environment (see Nelson and Winter, 1977; Kemp, 1997) and changes related to the role of obliged parties and their commitment, behaviour and organisational development to cope with a TWC scheme.

Hypothesis 7: TWC schemes enjoy a high degree of political legitimacy. The research addressed the obstacles that hamper or enhance the political acceptability of implementing a TWC scheme (cf. Nordhaus and Danish, 2003). From the public authority's perspective, the extent to which a TWC scheme avoids

conflict or interferes with the beliefs, interests and ambitions of subject participants was investigated (cf. Bemelmans-Videc *et al.,* 1998). In particular, the research attempted to identify critical design elements that affect (or fail to affect) the political feasibility of TWC schemes, including trading aspects.

Hypothesis 8: Due to increased energy efficiency, (low-income) households derive financial benefits as a result of the implementation of TWC schemes. The research investigated whether the implementation of energy efficiency technologies yielded financial benefits for households. In addition, the research looked at how compliance costs are (potentially) distributed. Potential benefits or losses resulting from different compliance strategies were also explored.

The above-mentioned hypotheses led to the selection of specific evaluation criteria for the research. Explanations and conceptual details related to the selected evaluation criteria are given in Section 3.1.2. It must be stressed that the extent of the analysis under each hypothesis differs. This was driven mostly by the availability, accessibility and quality of data (see research limitations below).

1.5 Scope and limitations

This research deals with a broad set of issues regarding the evaluation and implementation of TWC schemes. However, as a result of the research iterative process, several aspects need to be mentioned concerning the defined research boundary. Furthermore, limitations—those factors beyond the control of the researcher—are also elaborated below as they affected the scope of the research.

Taking several TWC schemes that have been hypothesised or that are currently being implemented, *the main research focus of this thesis was on the evaluation of TWC schemes.* The research aims to support policy evaluation targeting tradable certificate schemes in the field of energy efficiency by identifying and analysing their (potential) effects (i.e. impacts and outcomes). The research was not intended to evaluate energy efficiency gains resulting from technologies/projects and/or improvements in individual facilities.[16] While the research focus was on the energy demand side, the supply was

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[16] For guidelines in this regard, extensive and detailed information can be found in the International Performance Measurement and Verification Protocol (see DOE, 2001).

also touched upon, but only when necessary (e.g. when exploring emissions and negative externalities generated from power production). Data availability heavily framed the extension of the analysis of the implementation phase of TWC schemes.

This thesis is based on five studies that are appended as separate papers. Bearing in mind the aim and specific objectives of this research, the thesis analysed several aspects related to the design and implementation of TWC schemes. The *availability and reliability of data* largely determined the results and the extent of the analysis covered under each stage of the public policy process. The scope was narrowed to the following aspects:

- In terms of evaluation criteria: cost-effectiveness (papers I, II, IV and V), economic efficiency (paper V), transaction costs (paper III and V), energy-saving effectiveness (papers I, II, IV and V), environmental effectiveness (papers II and V), distributional equity (paper II), administrative burden (paper V), technical change (see papers IV and V) and political feasibility (papers I and V);

- In terms of evaluation methods and tools: mathematical energy-economic-environment (E^3) simulation tool (papers I and II), transaction costs analysis (papers III and V); triangulation (papers II, III, IV and V), cost-benefit/revenue analysis (paper V), and;

- In terms of temporal approach, both ex-ante (papers I and II) and ex-post (papers III, IV and V) evaluations of TWC schemes were carried out.

The *geographical scope of the ex-ante evaluation studies* included the Europe Union (15+) (see papers I and II), and Germany and Italy in particular (see paper I). For the case of European Union (15+), data were aggregated, so results represent average estimates for this geographic area. Here, it has to be acknowledged that heterogeneity plays a significant role because consumer behaviour and regional differences are relevant in public policy. Although greater geographic details were desirable when performing the modelling exercise, it must be noted that a multi-regional E^3 model for Europe was not available when the research was being conducted.[17]

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[17] For instance, a pan-European MARKAL–TIMES model will be available sometime in 2008. Models for 29 European countries are being developed under the project New Energy

The *geographical scope of the ex-post evaluation studies* mainly involved Great Britain (i.e. England, Wales, and Scotland) and Italy (see papers III, IV and V). In fact, much of the information came from this group of countries due to the fact that schemes were introduced there in 2002. Thus, the richness of the findings and the resulting analysis were heavily focused on Great Britain. Early experience from Italy was also analysed from an ex-post standpoint, although this was performed in less detail than the British case. France also implemented a TWC scheme, although, for the most part, only descriptive data related to the design of the scheme were available when the research was being carried out. Consequently, the French TWC scheme was only touched upon where the limited information available so permitted. Overall, a *lack of a counterfactual situation or baseline was identified*, in particular for Italy and France. This aspect, crucial for policy evaluation, made it difficult to investigate relevant ex-post aspects (e.g. cost savings resulting from trading and additional energy savings).

In terms of *access and sources of data*, most of the information came from official documents, academic literature and other research initiatives (private and public). Despite the fact that market actors affected by the implementation of TWC schemes (i.e. energy companies) were constantly approached throughout the entire research, a rather limited number of actors were willing to participate. This is relevant because information disclosure is crucial for an ex-post evaluation. However, for strategic and commercial reasons, some market actors were reluctant to report data, including financial information about investments, the internal resources devoted to the management of the programme, etc. In addition, even when market players were willing to contribute to this research, lacked internal accounting, preventing such contributions. Thus, they could not provide all of the required information (e.g. disaggregate estimates of transaction costs and investment costs). Consequently, it was necessary to make estimates and, in such cases, the assumptions made are outlined explicitly. In addition, assumptions and limitations embedded in estimates originating from other studies were taken into account, but subject to critical analysis. Only conservative estimates were produced and sensitivity analyses were performed. To reduce the level of uncertainty and subjectivity, several steps

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Externalities Development for Sustainability. For further information, visit http://www.needs-project.org. However, it is yet unknown whether the development of this pan-European model will allow the (partial) modelling of an EU-wide TWC scheme. In addition, it is unlikely that other researchers will have open access to the model and its related databases.

were undertaken (e.g. triangulation) to address the validity and reliability of the research findings (see Section 2.5 for details).

Finally, policy evaluation also has a comparative element (see e.g. Fischer, 1995; Mickwitz, 2003; Scriven, 1991). However, *a comparative evaluation between TWC schemes and other energy efficiency policy instruments was not undertaken by this research*. This was largely driven by the availability of comprehensive datasets (or evaluation studies) for other energy efficiency policy instruments. Furthermore, the orientation and scope of the research initiatives in which the author of this thesis was involved also framed the exclusive focus on TWC schemes. Nevertheless, interactions between TWC schemes and other energy efficiency policy instruments were identified and analysed to some extend. In fact, the analysis of TWC schemes in the context of the portfolio of energy efficiency policy instruments was a permanent focus for the author of this thesis. Therefore, several findings were made and policy implications were discussed at a basic level in all the papers.

1.6 Target audience

A key strength of a thesis based on peer-reviewed papers, as this one, is that a wider audience can be reached. When arguing about the justification of this research, one can notice that the target audience of this thesis is mixed and broad. These target groups are addressed separately below.

For *policy and decision makers*, this research aims to support the public policy development process related to TWC schemes. On the one hand, the findings and policy recommendations generated by this research can support the design and evaluation of TWC schemes in countries about to embark on the implementation of this policy instrument. On the other hand, the work presented herein can feed back into the operation and implementation of current TWC schemes. In addition, as TWC schemes address the interplay of energy and climate change issues, it is also expected that the research may provide valuable insights for policy makers working with both energy and climate policy.

Scholars and evaluation practitioners interested in energy policy also represent a relevant target group for this research. As mentioned before, this research is a response to the lack of evaluation studies in energy and environmental policy identified by the research community. This research supports

knowledge generation by addressing several theoretical, empirical and normative aspects of energy policy evaluation applied to TWC schemes.

Energy companies already or potentially affected by the implementation of TWC schemes are also part of the target audience. The thesis is expected to provide them broad insights into the complexities and dynamics of these created markets. It shows how the regulatory framework can affect market activity. Furthermore, it aims to support a learning process among these actors by revealing several aspects about the market behaviour under TWC schemes. Market insights cannot only be valuable for energy companies subject to current TWC schemes, but also for companies that may be affected and/or interested in the implementation of future TWC schemes.

Finally, there is a growing interest in creating TWC schemes in the Americas.[18] Therefore, experiences from Europe regarding the operation, implementation and performance of TWC schemes can be of relevance to that region. In fact, lessons learnt from Europe can allow stakeholders to better support the public policy process regarding the design, evaluation, and choice of TWC schemes.

1.7 Thesis outline

The thesis consists of a research summary presented in five Chapters as well as five appended research papers. Some of these papers have been developed solely by the author of this thesis. Others have been co-authored with researchers at the IIIEE or from other research organisations. Thus, the contribution of the author differs in every case (see Table 1-1).

Chapter 1 laid the foundations for this thesis. It described the framework of the research by detailing its context, research problem, questions, research objectives, hypotheses, scope, limitations and target audience. It also outlined the main contents of the thesis.

Chapter 2 elaborates on the research methodology adopted and applied in the thesis. This includes a description of scientific research positioning, key choices of research design, and the research methods for data collection and analysis. Qualitative and quantitative methods for data analysis are described,

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[18] Personal communication with Neil Kolwey (June 2007, E-Source US) and Juris Agüero (September 2007, ENDESA International). See also Hamrin *et al.* (2007).

including specific analytical frameworks that were developed to support the research process. Furthermore, it also describes the steps undertaken to ensure the validity and reliability of the findings and conclusions.

Chapter 3 briefly presents aspects of the conceptual framework used in the research. The Chapter is divided into two parts. The first part focuses on key conceptual considerations regarding energy (efficiency) policy, policy instruments, policy evaluation and evaluation criteria. The second part provides a detailed description of TWC schemes. It elaborates on the key conceptual aspects that frame the theoretical constructs and analysis of this policy instrument. Subsequently, it describes key design considerations and provides an overview of existing European TWC schemes.

Chapter 4 presents the main findings and key observations presented in the papers. It summarises and discusses the results in the light of the research objective and research questions. Findings are presented on a paper-by-paper basis. Therefore, the Chapter also elaborates on how the different papers are related to, and built on, each other.

Chapter 5 offers concluding observations. It starts with key conclusions as far as the research questions are concerned and it continues with implications for energy efficiency policy evaluation in general. The Chapter also presents policy recommendations regarding the design and implementation of TWC schemes. At the close of the Chapter, the main contribution to existing body of knowledge is presented and further research is suggested.

Table 1-1: Research papers and contributions by the author of this thesis

Publication	Title	Contribution
Paper I	Farinelli, U., Johansson, T. B., McCormick, K., Mundaca, L., Oikonomou, V, Örtenvik, M., Patel, M., Santi, F. (2005). 'White and Green': Comparison of market-based instruments to promote energy efficiency. *Journal of Cleaner Production* 13 (10-11):1015-1026.	The researcher (fourth author) conducted parts of the modelling work addressing the EU15+, collected data of current TWC schemes, elaborated on the limitations of the overall modelling exercise, and designed and supported the modelling work for Germany.
Paper II	Mundaca, L. (2008). Markets for energy efficiency: Exploring the implications of an EU-wide 'Tradable White Certificate' scheme. *Energy Economics* (forthcoming).	The researcher (single author) conducted all of the research and analysis, and wrote the entire article.
Paper III	Mundaca, L. (2007). Transaction costs of Tradable White Certificate schemes: The Energy Efficiency Commitment as case study. *Energy Policy* 35 (8):4340-4354.	The researcher (single author) conducted all of the research and analysis, and wrote the entire article.
Paper IV	Mundaca, L., Neij, L., Labanca, N., Duplessis, B., Pagliano, L. (2008). Market behaviour and the to-trade-or-not-to-trade dilemma in 'Tradable White Certificate' schemes. *Energy Efficiency* (forthcoming).	The researcher (first author) designed the research framework, conducted data collection and carried out the majority of the analysis. The researcher wrote most of the article.
Paper V	Mundaca, L., Neij, L. (2008). A multi-criteria evaluation framework for 'Tradable White Certificate' schemes. Submitted to *Energy Policy*	The researcher (first author) designed the research framework, conducted data collection and carried out the majority of the analysis. The researcher wrote most of the article.

TWO

2. Research methodology

This Chapter describes the methodology used during the research. On the whole, the research methodology was driven and framed by both *policy-oriented research* and *policy evaluation*. Policy-oriented research aims to solve societal problems through improved public policies (cf. Hakim, 2000; Fischer, 1995). Based on multiple disciplines and research methods, the focus of policy-oriented research is on actionable factors or variables, either complementing theoretical constructs or taking preference over them (Hakim, 2000; Majchrzak, 1984). Equally important is the fact that the research methodology was framed by policy evaluation. Policy evaluation is herein understood as the activity of applied social science dealing with multiple methods of investigation that support policy-making in solving public problems (Dunn, 1981). This research takes it point of departure in the fact that public policy, and policy instruments in particular, are the object of policy evaluation (Fischer, 1995).[19]

On the whole, Chapter 2 presents the design of the research methodology, which is understood as the logical and strategic plan determining how to get from 'here' (i.e. research objectives and questions) to 'there' (i.e. research answers and conclusions) (Yin, 2003). The Chapter begins by explaining the position of the research in relation to scientific research paradigms. It then elaborates on the methodological choices influencing the overall research methodology. It continues with the methods used for data collection and analysis. Finally, the Chapter concludes by discussing aspects related to the validity and reliability of the results.

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[19] More conceptual considerations related to both policy-oriented research and policy evaluation are elaborated throughout Chapters 2 and 3.

2.1 Scientific research positioning

The scientific position of any research activity is framed by research paradigms. According to Kuhn (1970), a paradigm comprises the general views and assumptions that the members of a particular scientific community adopt or share to address a particular subject.[20] Four major philosophical research paradigms are distinguished in the literature: positivism, post-positivism, critical theory, and constructivism. It is argued that scientific research paradigms can be described in the following terms: (i) ontology (i.e. philosophy of reality; nature of being), (ii) epistemology (i.e. theory of knowledge, especially with regard to its limits and the distinction between justified belief and opinion) and (iii) methodological position (i.e. set of methods, postulates and procedures used in a particular area of study) (Guba and Lincoln, 1998). Based on this terminology and classification, the scientific research positioning that frames this doctoral thesis is elaborated in this section.

From the *ontological* point of view, the researcher's position is that there is an external reality, which exists independently of the researcher's own view of reality. That is, a physical world exists but our knowledge and comprehension is insufficient for us to have a full understanding of it. Furthermore, a social world also exists and is permanently built upon, framed, and affected by our values, knowledge and experiences. This research rejects the radical positivist position that advocates the existence of only one truth. Thus, from the post-positivist point of view, every observation is fallible and theories are revisable. Then, one can only influence and come within reach of reality (Popper, 1963). On the whole, reality can be understood, albeit to a limited extent, and generalisations can be made but with an inherent degree of uncertainty.

The ontological position described above is consistent with the type of research that drove this doctoral thesis: policy-oriented research and not theoretical research. Policy-oriented research is concerned with 'knowledge for action'; which underscores the importance to change the world through improved public policies (cf. Hakim, 2000). Policy-oriented research usually distances itself from purely theoretical research; which aims to produce 'knowledge for understanding' and focuses on explaining causal loop processes—usually framed by a single social discipline (Hakim, 2000;

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[20] It is argued that the existence of a paradigm capable of supporting a normal science tradition is the characteristic that distinguishes science from non-science (Kuhn, 1970).

Majchrzak, 1984).[21] In this doctoral thesis, although 'knowledge for understanding' provides the conceptual foundations of the research, 'knowledge for action' has greater significance. This is not to say that explaining reality is less important. The research simply takes its point of departure in the fact that to advance energy efficiency policy evaluation, the main ontological focus is more on actionable factors rather than theoretical constructs. Consequently, the context of the research application drives the form of the content of the knowledge sought.

The ontological position also embraces the author's personal belief that the current knowledge about unsustainable patterns of energy production and consumption is already sufficient to justify urgent but sound public policy. Current knowledge on human-induced climate change can be taken as a remarkable aspect supporting the ontological position of the research. The researcher departs from the fact that increased energy efficiency continues to be an untapped source of sustainable prosperity that our society can no longer afford to overlook. Thus, the ontological appropriateness of the research can be judged by the need for public policies to address the complex social phenomena that energy, environment and human development encompass.

From the *epistemological* point of view, this research is positioned between positivism and post-positivism, including aspects of critical theory. While several conceptual aspects are taken into account, the research methodology in the thesis also supports criticism on the positivist view of evaluation, in particular that addressing the fact-value dichotomy.

To begin with, it has to be acknowledged that the contemporary approach to policy evaluation is based on positivism (Fischer, 1995). This means that policy evaluation commits itself to the development of factual knowledge. Under this philosophical scientific position, the researcher's ability to produce empirical data that can be generalised to other social contexts is of prime importance. In the field of policy evaluation, the positivist component is manifested in a set of empirical analysis techniques, such as mathematical simulation models, cost-benefit analysis, survey research and systems analysis (Fischer, 1995; Putt and Springer, 1989). However, it is argued that by focusing on empirically based methodologies (e.g. calculation of

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[21] Note that there is no firm dividing line between theoretical research and policy research. A number of overlaps and similarities are indeed found. See Hakim (2000) for an in-depth review of these aspects.

efficiency and effectiveness of policy), the positivist tradition has reduced evaluation to serving a technocratic form of policy decision-making process with little attention to social phenomena (Fischer, 1995). In other words, the technocratic approach of policy evaluation seeks the translation of political and social aspects into technically defined goals, which focuses on facts and sets aside social values (Dye, 1998; Fischer; 1995).

Central to the technocratic view of evaluation is the principle of separating facts and values. This aspect stresses the view that empirical research must be conducted without reference to normative aspects (Fischer, 1980; Proctor, 1991). This principle offers a clear-cut separation between scientific and political functions in policy analysis (Fischer, 1995). Some authors have argued that the orientation towards value aspects (e.g. what ought to be the case) falls beyond the dominion of policy evaluation because it is the search for empirically based causal knowledge (e.g. what is the case) that qualifies policy evaluation as a social science (Falco, 1973; Fay, 1976). According to this, social scientists should take a value neutral orientation, in which values and value judgements without truth content should be downgraded to personal preferences and kept outside empirical research (Weldon, 1953).

However, the fact-value dichotomy has been criticised by a number of social scientists (see e.g. Fischer, 1980; Strauss, 1959). This criticism leans towards the post-positivism philosophical positioning. A key departure point for arguing against the positivist approach of policy evaluation is the inherently normative, value-laden nature of social and political phenomena and evaluation itself (see e.g. Bardach, 2005; Chen, 1990; Fischer, 1995). Detractors of the positivist view of policy evaluation argue, for instance, that the very process of establishing the concepts and tools to be employed in evaluations rests upon implicit value judgements (Cook and Shadish, 1996; Fischer, 1980; Strauss, 1959). Furthermore, the post-positivist view argues that the concept of value neutrality is in itself a value orientation approach that has clear implications and consequences for evaluation (Fischer, 1980; Proctor, 1991; Strauss, 1959). That is, the attempt to separate facts and values reflects a profound misunderstanding and alteration of the nature of the social world itself, as it is "an organised universe of meanings that normatively construct the social world" and not a "mere set of physical objects to be measured" (Fischer, 1995:13). Moreover, as every policy instrument is purposeful and based on a point of view, it is argued that policy evaluation is inevitably based on value orientation (Chen, 1990; Fischer, 1980; Strauss, 1959).

According to Emery (1993) and Bardach (2005), policy makers and the research community bring with them their own identity, values, ideals, preferences, and attitudes that influence their input into the public policy process. To explain and/or approach social phenomena in policy analysis, social scientists must get inside the circumstances and understand the significance of the social events from the stakeholder's own goals, values and point of view (Emery, 1993; Fischer, 1995). From the critical theory[22] standpoint, this means that findings in policy evaluation are inherently value-mediated because the values of the researcher inevitably influence the examination (see e.g. Chen, 1990; Fischer, 1995). To better explain the social phenomena, critics of the fact-value dichotomy call for the design of adequate methodological frameworks that can amalgamate the mix of facts and values.

When it comes to this doctoral thesis, it has to be acknowledged that the positivist component of policy evaluation is captured by the research (i.e. use of empirically based methodologies for data analysis). However, the research attempts to bridge the fact-value dichotomy and distances itself from the radical technocratic or authoritarianism label related to the positivist component of policy evaluation. This radical technocratic view is sometimes characterised as the superiority of scientific policy methods over political decision-making processes (see Fischer 1995; Heineman *et al.,* 1990). Taking into account the criticism mentioned above, the research merges empirical aspects (e.g. use of a simulation model—see Section 2.4) with reference to normative issues (e.g. use of normative evaluation criteria—see Section 3.1.2). In addition, the research is also a response to the debate of fact-value dichotomy, which calls for more qualitative approaches to investigate the social-value dimension of public policy (see Chen, 1990; Fischer, 1995). As elaborated below, the multidisciplinary orientation of this research, in combination with *triangulation* as a research approach, attempts to provide a comprehensive portrait of both facts and values regarding the policy instruments under enquiry: Tradable certificate schemes applied to energy efficiency.

From the *methodological* point of view, the research's position is driven by both policy-oriented research and policy evaluation. Policy-oriented research focuses on 'knowledge for action' (Majchrzak, 1984) and stresses the need

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[22] Broadly understood as the philosophical approach that provides descriptive and normative bases for social inquiry (Morrow and Brown, 1994).

for multidisciplinary research (Gibbons *et al.,* 1994). Whereas theoretical research is characterised by a single oriented discipline (i.e. Mode I—discipline-based), policy-oriented research deals with knowledge production based on different disciplines (i.e. Mode II—policy-oriented) (Gibbons *et al.,* 1994). It is argued that the multidisciplinary element of policy-oriented research arises from the fact that current societal problems are too dynamic and complex to be tackled from a single-discipline perspective (Hakim, 2000). In line with the aspects described above, the multidisciplinary component of this research, built upon several elements of different social sciences, namely evaluation theory, public policy, environmental economics and new institutional economics. In fact, it is often argued that policy research studies are of greater disciplinary interest than theoretical research (see Hakim, 2000).

Policy-oriented research is then characterised by the use of multiple research methods to attain a more inclusive and balanced picture of the subject studied (see e.g. Majchrzak, 1984; Mickwitz, 2006; Rossi *et al.,* 2004). Likewise, policy evaluation is characterised as applied social science dealing with multiple methods of enquiry to support policy analysis (Dunn, 1981). As a merging point concerning the methodological orientation of this doctoral thesis, there is the fact that research on evaluation is a growing area in policy-oriented research (see Hakim, 2000).

Consistent with the ontological and epistemological positions of the research, the research's methodological position is supported by the use of *triangulation.* The term is defined as "the attempt to get a fix on a phenomenon or measurement (and, derivatively, an interpretation) by approaching it via several independent routes" (Scriven, 1991:364-365). According to Denzin (1978), triangulation refers to the research approach that employs different sources of data, methodologies and theoretical perspectives to address the analysis. Consequently, one of the initial hypotheses of the research is that there is no single-best method for evaluating policy instruments—including TWC schemes. As a result, different methods were used to collect data and evaluate them (see Sections 2.3 and 2.4). The combination of different methods for data collection and (quantitative and qualitative) analyses was designed to systematically integrate value-critical aspects with empirical concerns regarding TWC schemes. The overall methodological approach also highlights the importance of uncertainty and promotes multiple perspectives for conducting policy evaluation (cf. Frechtling and Sharp, 1997; Hakim, 2000).

2.2 Key initial methodological choices

Several conceptual choices framed the research methodology as a whole. These aspects include the methods of reasoning, the degree of involvement of the researcher, and the unit of analysis. A description of each aspect is given below.

Methods of reasoning. When it comes to the method of reasoning, the research design encompassed a combination, or mixture, of both *deductive* and *inductive* approaches. On the one hand, deductive reasoning is characterised as a top-down approach (Bryman, 2004). This means that the research starts with a theory related to the subject under study, then narrows this down to a specific hypothesis that is tested, permitting observations to be made and the confirmation or disproval of the hypothesis (Bryman, 2004; Flick, 2006). The deductive method was useful for the research due to the fact that the disciplines or branches of knowledge supporting this research (e.g. evaluation[23], policy analysis, environmental economics, and new institutional economics) are now well established. They provided a key conceptual foundation (see Chapter 3) that served to frame and guide the research. Throughout the research, several hypotheses were elaborated. To collect observations and confirm or disprove these hypotheses, various case studies were used (e.g. on the nature and scale of transaction costs under the TWC scheme implemented in Great Britain).

On the other hand, inductive reasoning was also used in the research. This method of reasoning is characterised as a bottom-up approach (Bryman, 2004). It starts with observations, followed by the identification of patterns, the formulation of tentative hypotheses and the development of certain general conclusions or theories (Bryman, 2004; Flick, 2006). This method of reasoning was useful due to the fact that the discourse on energy for sustainable development—the topic setting the key point of departure justifying this research—is a relatively new field and as yet has no theory

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[23] For Scriven (1991:141) evaluation is "the name of an autonomous discipline… it refers to the study and application of procedures for conducting objective and systematic evaluation". More recently, Scriven (2004) noted that the fact-value dichotomy has delayed the development of evaluation into a discipline. The bottom line argument was that evaluation should not be considered scientific because of its lack of objectivity (i.e. social scientist should assume a value-neutral orientation) (as elaborated in Section 2.1). Scriven (2004) argues that whereas evaluation has been practiced for many years, it is only recently that it has been accepted as, or evolved into, a discipline. See also Fischer (1995) for a discussion on evaluation as scientific discipline.

attached to it. Furthermore, several observations resulting from the research did not fall under the disciplines used for the conceptual framework. For instance, patterns related to innovation, management and organisational theories were identified (e.g. papers III and IV). The inductive approach thus led to a more open-ended and explanatory focus in the findings.

Degree of involvement of the researcher. Regarding the degree of involvement of the researcher, basically two stances were adopted at certain points in the research process. These positions were also driven by the scientific research positioning described before. First, the applied character of the research led to the researcher adopting an *independent position.* This characterised various stages of the research, in which a passive role or one of non-involvement with the object under study was assumed. For instance, methods for data collection were based on literature review and random personal communications with stakeholders. Methods of analysis were subsequently based on a mathematical simulation model and cost-benefit/revenue analysis (see papers I, II and V). Findings were presented and discussed mostly in closed research circles. This independent position was characterised by the development of theoretical constructs and an understanding of the subject of investigation that was rather evident from the outset.

Second, the researcher became actively involved with the subject of investigation at different stages of the research. This led to a *participatory action research* position.[24] The researcher became involved in various research initiatives that allowed him to move from an understanding of the subject to seeking and exploring actionable aspects related to the enquiry (see papers III and IV). This stage was characterised by an iterative and active interaction between the researcher and policy and decision makers directly working on energy (efficiency) policy in general, and TWC schemes in particular. For instance, this approach allowed a more in-depth view on the justification and evaluation (or not) of TWC schemes. In addition, the researcher also interacted with energy companies that are (potentially) required to comply with mandatory energy savings as a result of TWC schemes. In addition to the investigation and discussion of empirical aspects with stakeholders, normative aspects and policy recommendations were drawn up on the basis of this stance of action research. Active collaboration with other scholars allowed the researcher to tackle other analytical issues and thus expand the scope of the research. Findings were presented and

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[24] See Whyte (1991) for an in-depth description of *participatory action research*.

discussed in a variety of professional communities—not only academic. On the whole, action research played a critical role in judging the validity and reliability of the research (see Section 2.5 for further details).

Unit of analysis. The unit of analysis of the research is the *case study* and its justification arises from various angles. According to Patton (1990) and Merriam (1988), case studies have become a basis of evaluation research and evaluation theory. Although a case study does not generate definitive answers, "it is a means by which a particular policy objective and the specific circumstances of its implementations can be examined and documented in fine detail" (Fischer, 1995:78). In combination with triangulation, a case study can present a rounded and more complete account of public policy (Frechtling and Sharp, 1997; Hakim, 2000). This unit of analysis is the most flexible component of research design and allows descriptive and exploratory efforts to be combined and makes it possible to test research ideas and hypotheses (Hakim, 2000). It is argued that no evaluation methodology has greater strength and application than the case study (Starling, 1989). Case studies can generate knowledge and foster a broad understanding of how public policies influence society and the environment, helping research stakeholders to gain insight in the subject of study (Fischer, 1995). Today, case studies are recognised as a valuable unit of analysis for evaluation research (Hakim, 2000; Yin, 2003). They have largely contributed to the understanding about the processes of policy formulation and evaluation (Yin, 1984).

The policy instrument of tradable certificate scheme(s) applied to energy efficiency (i.e. TWC scheme) was taken as a case study and is described in detail in Section 3.2. As argued in Chapter 1, the creation of TWC schemes is considered an innovative policy approach (see e.g. Bertoldi and Huld, 2006; Capozza *et al.,* 2006; Langniss and Praetorius, 2006). However, the growing policy interest in implementing TWC schemes has not been matched by a similar interest in evaluating their effects and assessing their merit. Consequently, there was a need to enhance our knowledge about TWC schemes and unveil the expected and/or actual policy effects (impacts and outcomes) of such schemes. On the whole, the selection of TWC schemes offered an important research opportunity to inform and support the development of related public policy processes.

In addition to the lack of evaluation, alongside growing European policy interest in implementing (or experimenting with) this type of policy instrument in Europe, the researcher's choice was also heavily affected by

the policy discourse on energy for sustainable development. For instance, the discourse advocates policy initiatives, such as "making markets work better for society and the environment", "the increasing importance of energy efficiency in our society", and "the role of markets in successfully fostering a more sustainable energy future" (see e.g. Goldemberg *et al.,* 1988; Johansson and Goldemberg, 2002). As noted throughout the research period, the policy instrument under enquiry captures multiple policy aspects advocated by the energy for sustainable development policy agenda.

The main components of the unit of analysis to be investigated, and thus the focus of this enquiry, were:

a) Research into, and thus a better understanding of, the selected policy instrument (i.e. TWC schemes) as the "evaluand" (i.e. subject under evaluation). See all papers.

b) Compliance strategies set up by obliged and non-obliged parties subject to the policy instrument. See papers III, IV and V.

c) Geographical focus areas. In terms of ex-ante evaluation, EU-15, Germany and Italy were considered (see papers I and II). In terms of ex-post evaluations, Great Britain (England, Scotland and Wales), Italy, and France were addressed (see papers III, IV and V).[25] Ex-post evaluations allowed the quantification of the effects and a better understanding of their unique performance, usually shaped by different market and policy conditions.[26] Specific design considerations and applications implemented in TWC schemes are described in detail in Section 3.2.3.

2.3 Methods for data collection

The ontological and epistemological position of the research argues for *data triangulation* (see Bryman, 2004; Denzin, 1978). The research called for data to be collected from a variety of sources to approximate objectivity and reduce inevitable uncertainty (cf. Denzin, 1978; Fischer, 1995; Mickwitz,

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[25] Note that, due to the lack of data, the French TWC scheme was analysed to a much lesser extent than other country-specific TWC schemes.

[26] It is argued that the need for a comprehensive portrait in policy research leads the researcher to be inclined towards nationally representative studies (Hakim, 2000; Yin, 2003).

2006). As a matter of fact, one of the strengths of the research being designed around a case study is that it stresses the need for a mixture of different data collection techniques, including different methods for data analysis (see next section). The data collection methods included literature review, interviews, questionnaires, and focus group discussions.

Literature review. An extensive review of peer-reviewed material, books and grey literature (i.e. project reports, workshop/seminar presentations, institutional publications, policy statements, etc.) was conducted. This data collection method was used throughout the entire research. First, information about the research background and the context of the topic of investigation was gathered (see Chapter 1). Second, the literature review aimed to build the conceptual foundations concerning energy (efficiency) policy and policy evaluation (see Section 3.1. Third, an extensive literature review of TWC schemes was conducted on an ongoing basis throughout the research process (see Section 3.2). In this regard, (peer-reviewed) material about TWC schemes was basically inexistent when the research commenced in 2003. The focus was on scattered programme documentation and some descriptive workshop presentations about TWC schemes. At the time of writing the appended papers, this type of material was mostly confined to discussion papers and project reports resulting from different research initiatives. Material regarding the application of tradable permit schemes in other areas (e.g. atmospheric pollutants, renewable energy) greatly supported the literature review. Lately, the literature on TWC schemes has grown rapidly. Third, official information from the authorities in charge of the design, administration and/or enforcement of TWC schemes was used extensively throughout the research. Finally, once the research outcomes were obtained, literature review was important for their theoretical validation (see Section 2.5).

Interviews. According to Tellis (1997), interviews are typically the most relevant sources of case study information. This method for data collection is a useful tool for understanding complex phenomena, attitudes and beliefs in less investigated research subjects (Hastings and Perry, 2000). Interviews played an important role during the research due to the fact that limited or inexistent literature on certain evaluation aspects was found (e.g. transaction costs, political feasibility) (see Appendix B – List of interviewees).[27] Basically, two types of interviews were conducted during the research: *semi-*

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[27] Note that some interviewees were also contacted to provide specific information.

structured and *focused* interviews (see papers III, IV and V).[28] The former is usually suggested for case study research (Yin, 2003). Semi-structured interviews were based on interview protocols and addressed topics related to the country-specific public policy process of the TWC scheme under investigation. To a limited extent, focused interviews were used to investigate aspects of the administrative burden. When it came to focused interviews, these were also based on interview protocols. As details about the functioning and operation of TWC schemes did not surface into the public domain during the early stages of the research, focused interviews with policy makers and authorities working on TWC schemes were conducted to fill the gaps. The interviews addressed specific topics related to: (i) policy formulation and implementation, and (ii) aspects concerning transaction costs. The objective of the focused interviews was to obtain key insights and background information and to discuss specific topics in detail. The focused interviews were also open-ended and conducted in a conversational matter (see Appendix C – Interview protocols).

Questionnaires. This type of method involves several questions that have structured response categories; with some open-ended questions also included (Marshall and Rossman, 2006). When using a questionnaire, it is worth noticing that the research relied heavily on the truthfulness and accuracy of the participants' answers. During the research, two questionnaires were used to address the nature and scale of transaction costs under (i) the British TWC scheme (see Appendix D – Questionnaire) and (ii) the Free-of-Charge Energy Audit Programme (FCEA). Both were used to complement the information gathered through interviews. From the statistical point of view, the results of both questionnaires had limited significance, so outcomes must be taken with due caution

Focus group discussions. This method was based on the fact that "individuals' attitudes and beliefs do not form in a vacuum: people often need to listen to others' opinions and understandings to form their own" (Marshall and Rossman, 2006:114).[29] This method was used extensively, as the researcher

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[28] Semi-structured interviews are usually called structured open-ended interviews (i.e. 'emic' perspective). Focused interviews are also called key informant interviews (i.e. 'etic' perspective) (see Bryman, 2004; Marshall and Rossman, 2006).

[29] This method for data collection—largely used in marketing research—is usually defined as a group interview with several people on a specific topic (Bryman, 2004). Thus, it is usually categorised as another type of interview (see Marshall and Rossman, 2006).

had the opportunity to moderate or participate in several research initiatives that involved a number of group discussions:

a) IEA–DSM Task on Market Mechanisms for White Certificates Trading.[30] The objective of this research project was to gain experience regarding the implementation and operation of TWC schemes. Under this initiative, six dedicated and closed international focus group discussions were carried out. They involved the following participants: (i) policy makers interested in, or working directly on, TWC schemes, (ii) energy companies interested in participating in or (potentially) required to participate in TWC schemes, c) scholars and consultants working on a variety of aspects related to TWC schemes.

b) Swedish Chapter of the IEA–DSM Task on TWC schemes. The main objective of this research initiative was to increase the knowledge and understanding of TWC schemes, with the aim of exploring them from a Swedish perspective. Under this initiative, seven dedicated discussions were held. They involved the following Swedish participants: (i) policy makers interested in TWC schemes or directly working on energy and environmental policy, (ii) energy companies interested in knowing more about TWC schemes, (iii) consultants and energy-related businesses also interested in TWC schemes.

c) Intelligent Energy Europe EuroWhiteCert Project.[31] The objective of this research project was to support the conceptual and technical development of TWC schemes. Under this initiative, a steering committee (or advisory group) was formed with the aim of guiding research efforts and providing feedback.. Four closed international focus group discussions were held. The group comprised (i) international experts in the field of energy efficiency policy, (ii) policy decision-makers interested in, or working directly on, TWC schemes, (iii) and research scholars working on TWC schemes in particular or energy efficiency policy in general.

Overall, and consistent with the claims given by Frechtling and Sharp (1997), focus group discussions generated additional data and insights that would not have been likely to emerge when conducting a single interview or

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[30] For further details visit http://62.121.14.21/ViewTask.aspx?ID=17&Task=14&Sort=1

[31] For further details visit http://www.ewc.polimi.it/

doing desktop research—as used in papers II, III and IV. Furthermore, once the research outcomes were obtained, focus group discussions were crucial to test their validity, reliability and relevance (see Section 2.5). For further details about discussion groups see Appendix E – Focus group discussions.

Research workshops. Research workshops are usually an element of participatory research methods (Whyte, 1991). As a direct result of the multiple research initiatives, the researcher had the opportunity to participate in multiple research workshops. For details see Appendix F – Research workshops. Consistent with policy-oriented research, which aims to produce research outcomes that are directly useful or applicable at the policy level (Gibbons *et al.,* 1994), research workshops were relevant for both data gathering and analysis. In addition, research workshops were also critical in testing research outcomes against reality, refining them when needed, and exploring their potential generalisation and transferability to other disciplines/areas. This method for data collection was used throughout the research.

2.4 Methods for data analysis

The ontological and epistemological position of the research underscores the need of *triangulation across different methods for data analysis* (cf. Bryman, 2004; Denzin, 1978; Hakim, 2000; Frechtling and Sharp, 1997). Qualitative and quantitative methods guided the analysis and/or were used to analyse the information and data gathered. On the whole, these methods were applied to address different phases of the public policy development process built for TWC schemes—with uncertainties remaining inherent to the research process.

2.4.1 Qualitative approaches

Qualitative analytic approaches used in the research included policy analysis, discourse analysis, systems analysis, and transaction cost analysis. For the cases of policy and transaction cost analyses, note that specific analytical frameworks were developed. Qualitative approaches are briefly described below.

Policy analysis. In the research, the object of the policy analysis was the overall public policy development process that one can potentially relate to (or

expect from) the case of TWC schemes. In general terms, a public policy development process can be characterised by the following phases: (i) problem definition, (ii) policy formulation, (iii) ex-ante evaluation, (iv) policy implementation and (v) ex-post evaluation (see e.g. Bardach, 2005; Dye, 1998; Teisman, 2000). This public policy development process was used to guide the overall analysis. In this thesis, this ideal public policy development process is *not* to be taken as a rational or linear process for the development of TWC schemes.[32] This public policy process was used for analytical purposes only. In fact, the researcher does acknowledge that in the real world this process may seldom occur in an orderly, phase-by-phase progression (cf. Dye, 1998; Rist, 1998). Therefore, it must be stressed that the idealised public policy development process was used by the researcher to better structure the policy analysis and conduct the research on TWC schemes. In addition, the idealised process was also used to investigate how the different aspects investigated were (potentially) related.

Having said this, the research focused on the identification of the problem(s) or opportunity(ies) related to the choice/implementation of TWC schemes. It also studied the elements upon which TWC schemes were designed to achieve their policy objectives. Undoubtedly, the majority of the research work was devoted to the development of ex-ante and ex-post evaluation studies as such. These studies were also carried out with the aim of ascertaining potential and actual impacts of TWC schemes. They also included the analysis of relevant aspects of the design and operation of TWC schemes. When it came to the implementation of TWC schemes, the research focused on outcome evaluation, in particular the compliance strategies implemented by obliged parties (i.e. use of flexibilities). Views and insights from energy companies not yet subject to such obligations were also considered. On the whole, several evaluation methods and criteria were used to perform the evaluation studies. Note that all of the evaluation studies carried out under this research involved a quantitative research method, to a greater or lesser extent.

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[32] For instance, a *rational model of policy decision-making* is typically characterised by five methodological steps: a) the empirical identification of the problem, b) the formulation of objectives and goals that lead to optimal solution, c) the determination of the relevant consequences and probabilities of alternatives options, d) the estimation of a value (cost and or benefit) to each alternative and e) the selection of the most effective and efficient policy option (Fischer, 1995:10-11). This phase approach model of policy decision-making has been criticised by excluding normative and non-rational aspects (see e.g. Fischer, 1995; Parsons, 1995). See also Hill (1997) for a discussion on the rational model of policy decision-making.

Discourse and text analysis.[33] The analysis carried out in the research addressed "the content of talk, its subject matter and its social rather than linguistic organisation" (Edwards and Potter, 1992:28) related to TWC schemes. Likewise, discourse and text analysis allowed the researcher to look for the investigation of (private or social) concerns raised in the various arguments constructed and related to energy (efficiency) policy. To perform the analysis, the material was read carefully and data from different sources were compared systematically and consistently. Furthermore, the analysis focused on the variability and constructions in the text, but also on pattern matching. Empirical material ranged from institutional publications, programme documentation, policy statements and media articles, among others. Transcripts from interviews with key informants were also used. Bearing in mind the importance of normative and empirical claims related to TWC schemes, emphasis was given to political and policy ideas, decisions and actions. Guiding research questions were, for instance, what features of the text generate this reading? What are the claims in terms of instrumental or contributive value of TWC schemes in relation to the society and the environment?

Systems approach. The overall research framework and design described in previous sections undoubtedly implies a systems approach, which attempts to gain a better understanding of how the subject being studied interacts with other parts of the (closed or open) system (Churchman, 1979).[34] A systems approach is a holistic problem-solving process that involves both quantitative and qualitative methods (cf. Miser and Quade, 1985). In the research, the systems approach aimed to provide a comprehensive and insightful analysis of TWC schemes. To achieve this purpose, different

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[33] This type of analysis attempts to study rhetoric as processes that unfold in a regular way (see Flick, 2006).

[34] In its commonly accepted use, the term *systems approach* denotes the field of science that comprehensively explores the organisation and integration of elements with due consideration to inputs, outputs and feedbacks in its environment (cf. Churchman, 1979; Olsson and Sjöstedt, 2004). In line with systems thinking, systems theory and systems analysis, the systems approach investigates complex issues that entail a variety of causal relationships (see Miser and Quade, 1985; von Bertalanffy, 1968). It is argued that the systems approach is especially useful for research on sustainable development because it offers tools for conceptualising and constructing causal connections among complex issues (Haraldsson, 2004; Olsson and Sjöstedt, 2004). The systems approach embeds system dynamics; which focuses on the re-creation of systems and an understanding of its causal factors and feedbacks (Forrester, 1993). To the author of this doctoral thesis, the tangle of concepts may be attributed to the fact that the whole idea of the systems approach is so rich that it involves many connotations, positions, dynamism and criticism.

evaluation methods and research frameworks from different disciplines were used. The approach attempted to cover the complex relationships between multiple actors (e.g. energy companies, end-users, enforcement agency, policy makers, manufacturers and dealers of energy efficient equipments). The relationships were found to be influenced by social, financial, commercial, political, legal and environmental aspects. Guided by the systems approach, a variety of models were constructed, used or analysed during the research process. This included (i) the lifecycle of TWCs, (ii) the mathematical energy-environment-economy (E^3) modelling tool, (iii) the set of flexibilities under TWC schemes to achieve cost-effective savings and (iv) a multi-criteria evaluation framework. These models (either conceptual or mathematical) helped to structure the complex relationships and feedback resulting from the implementation of TWC schemes. It is worth noticing that in the specific field of public policy, Easton (1953, 1965) advocates a systems approach to tackle the complexities of policy analysis.[35]

Transaction cost analysis.[36] This analytical approach is based on the observation (or assumption) that decisions made by market agents are rationally bounded and based on imperfect information (see e.g. Douglass, 1990; Selten, 1990; Williamson, 1993). Transaction costs were understood as "the costs of arranging a contract ex-ante and monitoring and enforcing it ex-post, as opposed to production costs" (Matthews, 1986:906). Regarding the specific case of increased energy efficiency under TWC schemes, the research looked at transaction costs related to, for example, searching and assessing equipment; negotiating agreements to carry out and enforce a contract; and measurement and verification (M&V) of the actual level of improvement.[37]

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[35] According to Hill (1997), the systems approach advocated by Easton has acquired a significant reputation in the field of public policy. Moreover, De Greene (1993) argues that the systems approach can greatly support policy-making as it seeks to improve the environment and/or organisational culture in which a policy can be developed (see also Dye, 1976; 1998).

[36] The concept of transaction costs has been largely developed by the New Institutional Economics, of which transaction cost analysis is a fundamental component. The NIE focuses on how decisions and transactions made by market agents are frequently based on imperfect information, and also on how institutional frameworks influence the behaviour of these agents (Ménard, 2004).

[37] For instance, the problems regarding imperfect information may prohibit the purchase of equipment that aims to increase end-use efficiency. It is argued that end-users face high transaction costs in obtaining reliable, cheap, and opportune information when buying more efficient technologies (Sioshansi, 1991). In turn, the presence of transaction costs can decrease the financial gains of increasing energy efficiency (Sanstad and Howarth, 1994).

As elaborated in paper III, transaction costs are a critical factor influencing not only many aspects of energy efficiency improvements (see also Hein and Blok, 1995; Ostertag, 1999; Sanstad and Howarth, 1994), but also the creation of TWCs and the performance of the TWC schemes (see also Langniss and Praetorious, 2006; Mundaca and Neij, 2006). The analysis involved the identification of the nature (or sources) of transactions costs. To support the analysis, a conceptual model addressing the lifecycle of TWCs was constructed and included the following phases: planning, implementation, M&V, issuance, trading, and redemption (see Figure 2-1).
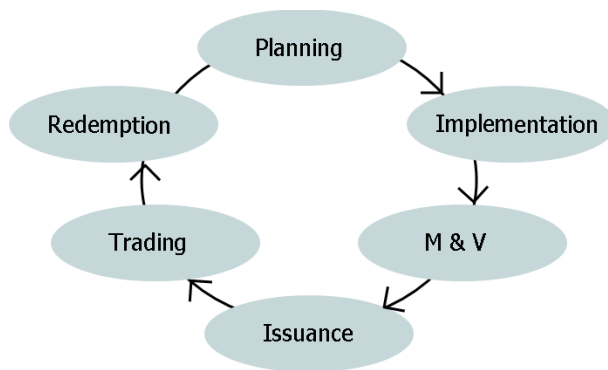
Figure 2-1: Lifecycle of Tradable White Certificates

As one can observe, the first three phases the lifecycle of TWCs are rather similar to the development of any energy efficiency project in general. That is, to create or generate a certificate, an eligible actor must plan, implement, and (depending on the regulatory framework) measure and verify (M&V) realised energy savings. The issuance phase means that the authority issues TWCs once energy savings have been certified (e.g. by an independent party). Obliged parties can then trade TWCs to fulfil individual targets, banking them for future periods and/or directly redeeming certificates to prove compliance with their commitments. Once certificates are redeemed, they are no longer available on the market. Note that this analysis also involved a quantitative component (see next section).

2.4.2 Quantitative approaches

Quantitative data analysis approaches were used during the research, including a mathematical simulation tool, cost-benefit analysis, simple statistical analysis and transaction costs analysis. These approaches are described below.

Mathematical energy-environment-economy (E³) simulation model. Policy research is commonly, but not exclusively, concerned with the simulation, forecasting, and modelling of trends (Fischer, 1995; Hakim, 2000). Within this context, the MARket ALlocation model (MARKAL) was used to develop an E³ analysis (see Seebregts *et al.,* 2001, for an overview of MARKAL models).[38] MARKAL is a bottom-up dynamic (mostly) linear programming model generator. The objective function of MARKAL is to find the combination of fuels and technologies that minimises total energy system costs while keeping exogenously determined energy demands satisfied over a given time period. The cost-optimisation process is subject to different constraints (e.g. related to atmospheric emissions, fuel supply, and capacity utilisation). For each time period (t), the model *minimises* the sum of all technologies (k), all pollutants (p), and all input fuels (f) of the various *costs* incurred. In mathematical terms, the *cost minimisation objective function* of the model is formulated as a linear programming problem:

$$min\,(TESC) = min \sum_{t,k,p,f,c} (TechCost_{tk} + OpCost_{tkf} + Imp_{tc} - Exp_{tc} - SalV_{tk} + EmisT_{tp}) \qquad (1)$$

where *TESC* represents total energy system costs, which are equal to the sum of technology investment costs *TechCost*, operating costs *OpCost* (including fixed and variable technology costs, fuel delivery costs, costs of extracting, etc.), import costs *Imp*, revenues from exported energy carriers *Exp*, the salvage value of technology *SalV,* and taxes on emissions *EmiT*. Index *c* refers to the number of energy carriers (imported and/or exported).

The use of MARKAL arose from the systems approach standpoint and the specific questions posed by the research. Within the modelling work, a major research effort was devoted to analysing the impacts of a hypothetical

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[38] MARKAL was developed by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA). In MARKAL, a user-defined Reference Energy System (RES) depicts a network of energy sources, conversion and process technologies, energy carriers, demand technologies and demand sectors (including transmission). Overall, the allocation of energy supplies to energy demands is based on minimum costs and determined by an optimisation approach.

EU-wide TWC scheme, including Italy and Germany (see papers I and II).[39] Concerning the former, MARKAL was applied to a database that depicts the Reference Energy System (RES) for Western Europe—hereafter EU15+ (see Figure 2-2). The Energy Information Administration (EIA) of the US Department of Energy (DOE) developed the EU15+ database.[40] This database is fully described in EIA-DOE (2003).[41]

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[39] Note that the work described in paper I and, in particular, paper II mostly address the results obtained for the EU15+. This refers to the 15 EU member states plus Norway, Switzerland, Malta, Iceland, Gibraltar and Greenland, hereafter EU15+. Furthermore, also note that working together with other research teams, MARKAL was applied to Reference Energy Systems depicting Germany and Italy. These results are briefly presented in paper I.

[40] The EIA-DOE developed the System for Analysis of Global Energy markets (SAGE) to examine a wide range of global energy issues; it integrates a set of regional models for the development of the International Energy Outlook 2003. In SAGE, 15 regions are identified based upon political, geographical and environmental factors: Africa, Australia–New Zealand, Canada, Central and South America, China, Eastern Europe and the Former Soviet Union, India, Japan, Mexico, the Middle-East, rest of Asia, South Korea, the US, and Western Europe. For each region, input information regarding energy service demands are developed using economic and demographic projections.

[41] Note that the entire documentation of the model and a detailed data implementation guide are publicly available and can be found at
http://tonto.eia.doe.gov/ftproot/modeldoc/m072(2003)1.pdf and
http://tonto.eia.doe.gov/ftproot/modeldoc/m072(2003)2.pdf
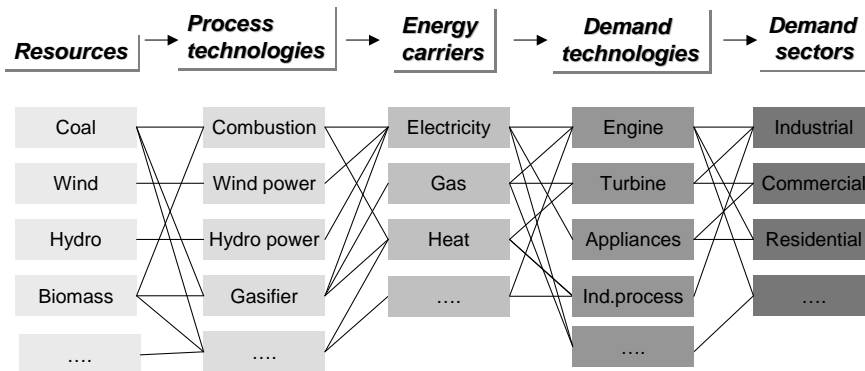
Figure 2-2: Simplified schematic representation of the Reference Energy System of MARKAL EU15+ model

Cost-benefit analysis. As noted in Section 2.1, the positivist component of policy analysis is usually manifested in the use of empirical analysis techniques, such as cost-benefit analysis (Putt and Springer, 1989).[42] For the purposes of the research, note that when addressing social costs and benefits, the term cost-*benefit* analysis (CBA) was used. The term cost-*revenue* analysis (CRA) was used when addressing private costs and benefits (i.e. no externalities included). In the research, the CBA was applied to the British TWC scheme (see paper V). The CBA began by estimating or identifying and comparing all of the incurred programme costs (i.e. administration, investment and transaction costs) and benefits. The latter includes estimates of social benefits resulting from increased energy efficiency (i.e. reduced negative externalities). Furthermore, a CRA was applied to ascertain the costs and private benefits of increased energy efficiency from the end-user

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[42] According to a number of authors, CBA is the approach normally applied in economic efficiency assessments (see e.g. Rossi *et al.,* 2004; Stavins, 2004; Tietenberg, 2006). It is argued that a cost-benefit analysis (CBA) is one of the most ambitious quantitative approaches to be used in policy analysis (see e.g. Freeman, 2003; Tietenberg, 1996; Turner *et al.,* 1994). CBA imposes the largest requirements of data in order to analyse and support policy choice. The technique becomes controversial when specific numbers are attached to specific and future benefits and costs (Tietenberg, 1996). CBA has been criticised as basis for policy choice (e.g. no attention to distributional effects, practice of discounting, assumption that governments are social-profit maximisers, etc.). However, such criticism has not prevented its use in evaluating a variety of public policies (see e.g. Faure and Skogh, 2003; Freeman, 2003). See Rossi *et al.* (2004) for some pre-conditions that are needed for using CBA in ex-post policy evaluation.

perspective (see also paper V). The mathematical formulation of the CBA rule is defined as:

$$\sum_{t=0}^{T} (B_t - C_t \pm E_t) * (1 + d)^{-t} > 0 \tag{2}$$

where the index t refers to time, B_t are the benefits taking place a time period t, C_t are the costs also at time period t, E_t refers to the value of the environmental change, and d is the discount rate.[43] Both B and C are aggregated across society. The decision rule is that the sum of the benefits less costs plus or minus the value of environmental change must be positive; all discounted to present value.

Statistical analysis. In certain cases, descriptive statistics were used to summarise, organise and describe quantitative information. Frequency statistics, such as the mean, median, and mode were calculated. This also included the standard deviation, range, minimum and maximum values of TWC prices (see paper IV). Furthermore, and taking into account a given confidence level, the sample size of the population was estimated and the margin error calculated when addressing the scale of transaction costs (see papers III and V).

Transaction costs analysis. This type of analysis also included a quantitative component. The research identified and obtained data for the estimation of the scale of transaction costs borne by obliged parties under TWC schemes or similar policy instrument (see papers III and V). Transaction costs borne by beneficiaries of energy efficiency measures were not considered. Taking the results into account, the cost-effectiveness of energy savings was calculated, including financial (or private) and economic (or social) benefits.

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The characteristics of the appended research papers with respect to the methodological elements elaborated in Chapter 2 are summarised in Table 2-1.

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[43] To estimate the value of the environmental change, several techniques can be used (e.g. travel cost, contingent valuation, hedonic prices, replacement cost) All of them are subject to their own advantages and disadvantages (see e.g. Freeman, 2003; Turner *et al.,* 1994).

Table 2-1: Summary of methodological characteristics of the appended papers

	Method of reasoning	Degree of involvement	Countries	Level of policy analysis	Evaluation criteria	Methods for data collection	Method for data analysis
Paper I	Deductive	Independent	EU15+, (Germany, Italy)	Ex-ante evaluation (policy formulation)	Cost-effectiveness, (energy-saving and environmental effectiveness, technical change political feasibility)	Literature review, research workshops	Simulation model
Paper II	Deductive	Independent	EU15+	Ex-ante evaluation (policy formulation, problem definition)	Cost-effectiveness, environmental effectiveness, distributional equity, (energy-saving effectiveness, political feasibility)	Literature review, focus group, research workshops	Discourse/text analysis, systems approach, simulation model
Paper III	Deductive & inductive	Independent & participatory	Great Britain	Policy implement., ex-post evaluation	Transaction costs (cost-effectiveness, environmental effectiveness)	Literature review, interviews, questionnaire, focus group, research workshops	Discourse/text analysis, systems approach, transaction costs analysis, (cost-revenue analysis, statistical analysis)

Note: The methodological research aspects in parenthesis were covered/applied only partially.

Table 2-1: Summary of methodological characteristics of the appended papers (Continuation)

	Method of reasoning	Degree of involvement	Countries	Level of policy analysis	Evaluation criteria	Methods for data collection	Method for data analysis
Paper IV	Deductive & inductive	Independent & participatory	Great Britain, Italy	Policy implement., ex-post	Cost-effectiveness, (energy-saving effectiveness, technical change)	Literature review, interviews, focus group, research workshops	Discourse/text analysis, systems approach, (cost-revenue analysis, statistical analysis)
Paper V	Deductive	Independent	Great Britain, Italy, (France)	Ex-post evaluation (policy formulation, implement.)	Cost-effectiveness, transaction costs, economic efficiency, energy-saving and environmental effect, technical change, adm. burden, political feasibility	Literature review, interviews, questionnaire, research workshops	Discourse/text analysis, systems approach, transaction costs analysis, cost-benefit/revenue analysis

Note: The methodological research aspects in parenthesis were covered/applied only partially.

2.5 Validity and reliability

Several methodological aspects were considered to ascertain how close or far the research was from the truth of a given proposition, inference and/or conclusion. To approach and judge the validity and reliability of the research outcomes, the researcher undertook different methodological steps.

Validity. Concerning the integrity of the outcomes and conclusions that were generated from the research, different aspects of validity can be considered. To begin with, *internal validity* (i.e. whether findings that incorporate a causal relationship between two or more variables are sound) was approached in multiple ways. Once the findings were obtained, the literature reviewed was used to validate causal claims. For instance, literature related to tradable permit schemes in general, and TWC schemes in particular, were used to ascertain the soundness of empirical findings.

In addition, the academic analyses of the research were constantly introduced in the focus group discussions and research workshops in which the researcher participated (described in Section 2.3). In addition, relevant to the validity of the results was the presentation of research findings at several international conferences, which served as useful platforms to present findings for open and critical analysis by external actors/reviewers. Research workshops and international conferences provided an inclusive critical mass of experts (i.e. policy makers, energy companies, research scholars and consultants involved in TWC schemes and energy efficiency policy) for judging the outcomes and the relevance of the research. Of particular importance for internal validity were public authorities in charge of designing, administering and/or enforcing TWC schemes implemented in EU member states. They provided a crucial down-to-earth scrutiny of the results that could not have obtained elsewhere.

The external examination of internal validity also derived from the peer review process of the scientific journals to which the appended papers were submitted. Findings were reviewed and critically analysed by anonymous referees, likely to be experts in the fields of energy (efficiency), policy evaluation and/or TWC schemes. This external examination ensured the dissemination of warranted claims and acceptable interpretations.

In terms of *external validity* (i.e. whether the results can be generalised beyond the specific research topic), some aspects were possible to extrapolate across

the TWC schemes investigated. This included aspects related to transaction costs, and the effectiveness of the portfolio of instruments affecting the performance of TWC schemes, among others. However, due to the fact that the results showed the design and performance of TWC schemes to be case and context specific, generalisations were difficult to make. On the other hand, some lessons and insights were drawn from the evaluation of TWC schemes that were applicable to the field of energy efficiency policy evaluation in general (see Section 5.3).

Reliability. The degree to which the outcomes were consistent was approached via several routes. First, triangulation played an important role in this regard. Information and insights coming from primary and secondary sources were cross-checked. When it came to quantitative results, the researcher undertook several steps. To assess the consistency of the results, findings from (relatively) similar studies were used as benchmarks. For instance, simulation results addressing financial and techno-economic potentials of energy efficiency were consistent with figures used/estimated by the European Commission (see paper II). Likewise, results regarding cost-effectiveness and CBA were consistent with similar studies addressing the British TWC scheme (see papers IV and V). In order to assess the consistency and completeness of the technological database used for the modelling of an EU-wide TWC scheme, two other databases were used as benchmarks: MURE[44] and ICARUS[45] (see papers I and II). In addition, the PRIMES energy system model was used as a benchmark to evaluate the robustness of key modelling outcome parameters (e.g. primary energy supply, energy intensity, CO_2 emissions, final energy consumption) (see paper II).[46] As a result of this exercise, only marginal differences in absolute values were found and both models generated similar trends for the analysed period (2000-2020).

External scrutiny of the reliability of the results, both quantitative and qualitative, also came from the peer review processes already noted. The

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[44] MURE contains approx. 50 detailed measures for the household sector. These measures are grouped into larger categories and subcategories. For further information visit http://www.isis-it.com/mure/

[45] For further details see Alsema (2000).

[46] Note that the PRIMES model was successfully peer-reviewed by the European Commission in 1997-1998. More details about PRIMES can be found at http://www.e3mlab.ntua.gr/manuals/PRIMsd.pdf

methodological trustworthiness of the research was supported by the due and explicit provision of data sources, assumptions and limitations of the analysis. For the specific case of the simulation exercises (papers I and II), note that the documentation of the EU15+ database used is publicly available and fully described in EIA-DOE (2003).

On the whole, all of the material provided by this research, including the appended papers, and other relevant publications by the author also related to this doctoral thesis, serve as the auditable documentation of this complete body of research.

THREE

3. Conceptual framework

This Chapter aims to provide a variety of conceptual considerations related to the aspects investigated. As in any academic research, this doctoral thesis faced the challenge of making conceptual choices or developing certain terminology. Whereas most of the terms used for the various aspects of the research are not new, endless connotations and interpretations can be found in the literature. In fact, it did not take much time for the researcher to discover that common or no standard definitions for a number of concepts yet exist. Furthermore, the application of tradable permit schemes in the field of energy efficiency is new, so there was a strong need to develop a conceptual framework with which to structure the research and frame the analysis. The development of this specific conceptual aspect was based on theoretical constructs related to tradable permit schemes in general, and descriptive material on TWC schemes in particular.

3.1 Energy policy and evaluation

When conducting research on energy policy and evaluation, the first challenge is conceptual rather than analytical or empirical. This is because the task of defining energy policy (in the context of energy efficiency) and evaluation is problematic. There are hundreds, perhaps thousands of publications addressing these themes; although semantic confusion or differences in focus make the task of defining these terms rather overwhelming. To guide this research, some conceptual considerations and emphasis of these terms are presented in the following sections. Due to the fact that evaluation criteria played a significant role in the research, these are described in more detail. Bearing in the mind the research objective and questions, several conceptual choices were made.

3.1.1 Energy policy and policy instruments

To begin with, Dye (1976:1) points out that policy "is whatever governments chose to do or not to do". However, it has to be acknowledged that there is no commonly accepted definition of public policy (Hill, 1997).[47] In addition and in light of the research background, which underscores the need for policy intervention, Dye's definition is unsuitable. At all events, before attempting to outline the meaning of energy policy for the purpose of this research, a specific conceptual positioning is needed concerning public policy and policy analysis. Here, the term *public policy is understood as the governmental actions and decisions designed and implemented to solve social, economic and/or environmental problems.* In addition, and in line with Fischer (1995), the research refers to *policy analysis as the discipline concerned with the evaluation of public policy.* In turn, the research departs from the fact that *public policy, in particular policy instruments, is the object of policy evaluation* (cf. Fischer, 1995).

The task of determining just *what energy policy is* can be completely overwhelming. If one asks "energy people" (i.e. advocates and practitioners dealing with energy issues in general) for a definition of the term, one person will focus on public and/or private decision affecting energy production; another on research and development (R&D) plans addressing energy technologies; someone else will insist that it refers to strategies about how to meet and manage energy demand; another will talk about integrated resource planning; and yet another will insist that it is all about the politics of energy and the institutions dealing with this. However, as Churchman (1979) argues when discussing the concept of the systems approach, it would be naïve to infer that art may not exist because artists describe it in different ways. Indeed, the concept of energy policy seems extensive and it may involve many interpretations and implications.

Back in 1973, the editorial article in the first issue of the Energy Policy Journal characterised *energy policy as a multifaceted subject* (Energy Policy, 1973).

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[47] For instance, Easton (1953:130) points out that "policy …consists of a web of decisions or actions that allocate …values". Hill (1997) notes that policy is usually designed on the basis of the results of various decisions; sometimes highly complex networks of decisions. Smith (1976:13) advocates the concept of policy with a focus on action and inaction; noting that "attention should not focus exclusively on decisions which produce change, but must also be sensitive to those which resist change". The Oxford Dictionary of English (2003) defines public policy "as the principles, often unwritten, on which social laws are based". Fischer (1995:2) notes that public policy is "identified as a political agreement on a course of action (or inaction) designed to resolve or mitigate problems on the political agenda".

However, no definition of the term was given, although different aspects, such as technology, economics, sociology, geography and politics provided a general understanding.[48]

In the early 1990s, the United Nations (1991) noted that energy policy had two meanings. The first refers to the question of what is a country's energy policy, which is argued to be the country's energy plan and its implementation. The second meaning refers to technology assessment. This type of assessment is concerned with "regulations and price structures that affect energy and energy technology use" (United Nations, 1991:3). On the one hand, one could argue that any attempt to define energy policy in more analytical terms may have risked harsh criticism. For instance, an analytical definition could bring in all the debate or semantics about what policy is—as mentioned above. On the contrary, a limited or simple conceptual definition may risk being criticised as inadequate in capturing the complexities of the topic. Lately, and under the auspices of United Nations, *energy policy has been placed in the context of sustainable development*, also addressing environmental, social and institutional aspects (as elaborated in Section 1.1).

The term energy policy can also be addressed as *the approach by which a given actor (public or private) determines to take action concerning energy production, distribution and consumption*. That is, energy policy is concerned with supply sources (e.g. nuclear, oil, renewables), demand (per technology, sector, energy service) and with the social, economic and environmental aspects neighbouring the implementation, operation and functioning of energy systems (i.e. supply, conversion technologies, energy carriers, distribution systems, demand technologies, and demand sectors) (Johansson and Goldemberg, 2002). From different angles and considering a variety of interests, the elements of energy systems listed above are affected by actions and decisions taken by several groups in our society (e.g. policy makers, planners, managers, businessman, politicians, consultants) (Jefferson, 2000; Owen, 2004). *Energy policy could thus be broadly defined as courses of action and decision addressing the use of energy resources.*

According to King (2004), *energy policy determines objectives and supports countries in meeting them.* Energy policies include elements intended to directly address

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[48] Furthermore, much energy policy discourse was found to be dominated heavily by the issue of security of energy supply. This policy issue was underscored as a result of the overall oil crisis in the 1970s and the oil embargo imposed on the US by the Organisation of the Petroleum Exporting Countries in 1973.

multiple objectives. Policies seek to address, for instance, policy objectives related to short and long-term economic, social, legal, technical, institutional and environmental impacts of changes in energy systems (cf. Jefferson, 2000; King, 2004). It is argued that energy policy is also concerned with the long-term sustainability of the energy resources available to society and must be consistent with policies in other areas (e.g. transportation, environment, industry, and taxation) (see Owen, 2004). Furthermore, it is also argued that energy policy refers to collective (public and private) efforts to improve energy security through diversification of energy sources and improved energy efficiency, while ensuring environmental protection and encouraging economic competitiveness (IEA, 2002a).

Perhaps the most explicit attempt to define the concept of energy policy can be attributed to Owen (2004) who notes that "*energy policy addresses the economic, environmental, political, planning and social aspects of energy supply and utilisation that confront decision-makers, corporate planners, managers, consultants, politicians, and researchers*".

Given the background of the research (i.e. energy for sustainable development and the role of increased energy efficiency) and the conceptual considerations elaborated on above (including that referring to public policy) the term *energy policy as applied to the case of energy efficiency is employed here to refer to the sum of governmental actions and decisions addressing energy efficiency improvements and its present and future economic, environmental and social implications.* This conceptual choice was used to guide and scope the overall research. Now the question is what are the measures or procedures that governments use to exercise their power through public policy. According to the literature reviewed, the answer lies in *policy instruments.*

Public policy is formulated and constructed around several elements. *A key building block in public policy involves policy instruments* (see e.g. Bemelmans-Videc *et al.,* 1998; Vedung, 1998). Albeit similar, the research took several different definitions of policy instruments into account. First, Vedung (1998:21) states "*policy instruments are the set of techniques by which governmental authorities wield their power in attempting to ensure support and affect or prevent social change*". Second, policy instruments are hereby understood to have the effect of guiding social considerations targeted by public policy, providing incentives or disincentives and information to subject parties (cf. Mont and Dalhammar, 2005). Third, and significant to this research, is the fact that *policy instruments are understood to be the key means or operational forms for achieving public policy ends* (Fischer, 1995; Vedung, 1998). Likewise, *policy instruments are the levers by which*

governments attempt to modify the behaviour of subject groups and attain policy objectives (Carter, 2001). For a comprehensive overview of policy instruments addressing energy for sustainable development (including energy efficiency) see Jefferson (2000); Johansson and Goldemberg (2002) and Goldemberg and Johansson (2004).

In the public policy literature, two approaches were identified as far the *classification of policy instruments* is concerned: the choice (or continuum) approach and the resource approach (see Howlett, 1991; Vedung, 1998). First, the *choice or continuum approach* is characterised as whether public authorities should intervene or not (i.e. intervention vs. non-intervention). In line with Smith (1976), the choice approach also acknowledges governmental inaction such that societal changes are left to market forces or civil society alone. The continuum approach combines voluntary and mandatory instruments, including the option of doing nothing. Consequently, the approach ranges from "freedom to control" (Vedung, 1998:22). Likewise, according to Howlett and Ramesh (1995), the choice or continuum approach involves voluntary, mandatory (rules, regulations) and mixed instruments. However, most attention is paid to policy instruments addressing governmental activities, with voluntary actions or policy initiatives originating in the market itself (e.g. environmental management system, labelling programmes) being largely ignored. In addition, as Vedung (1998) points out, this typology equates complete freedom with market mechanisms. Therefore, the choice or continuum approach to classifying policy instruments appears problematic (Vedung, 1998), but also inadequate in the context of energy for sustainable development.

The resource approach to classifying policy instruments appeared more appropriate to the research, as it provides room for market mechanisms and excludes non-policy intervention. Under the resource approach, the decision or action to intervene can be taken for granted, entailing a far greater focus on the resources needed to implement the public intervention (Vedung, 1998). The resource approach refers to various instruments that "are categorised according to the nature of the governing resource they employ, for example, fiscal resources or organisational resources" (Howlett; 1991:3). Thus, where governmental intervention is needed, the approach is driven by the rationale of what type of instrument can or should be used (Åstrand, 2005). The task for policy makers and analysts is to examine and (eventually) choose which instruments are capable of addressing the problem driving public intervention (Howlett, 1991). The resource approach focuses on the

differences between different policy instruments (Howlett, 1991; Vedung, 1998).

Using the resource approach as a departure point, two *taxonomies of policy instruments* are briefly described below. The categories depicted *attempt simply to frame certain conceptual considerations when addressing interactions between TWC schemes and other energy efficiency policy instruments.* The intention is not to discuss or clarify the distinction between different categories of policy instruments. This research distances itself from the sometimes highly stylised debate about economic versus regulatory instruments. In contrast, it aims simply to stress what we see in practice: a portfolio of policy instruments. Moreover, the literature does acknowledge that it is *difficult to separate or draw a clear line between policy instruments* as they often share common ground (see e.g. Carter, 2001).[49] Having mentioned these aspects, relevant conceptual considerations of policy instruments are described below.

First, and in line with the resource approach described above, a common taxonomy of policy instruments described in the literature usually includes three categories: *economic*, *regulatory*[50], and *informative*. Although one can argue that this taxonomy might offer a conventional or simplified classification, several conceptual aspects were useful when discussing TWC schemes and connections with other policy instruments.[51] The classification given below,

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[49] For instance Hahn (2000:376), defines an economic instrument as any policy instrument "that is expected to increased economic efficiency relative to the status quo". Thus, a command-and-control instrument can be classified as an economic instrument as long as it leads to improvements in economic efficiency. Likewise, according to Portney (2003:15), market-based policy instruments can be understood as a "clever form of government regulation". Furthermore, some authors stress the difficulties in separating economic and command-control instruments because of subtle conceptual differences (see e.g. Carter, 2001; Harrington *et al.,* 2004). Moreover, some authors claim that what matters in the debate is the fact that regulatory incentives are often more influenced by economic thinking (see e.g. Dalhammar, 2007; Gunningham and Grabosky; 1998; Hahn, 2000). According to Harrington *et al.* (2004) one particular distinction exists between command-and-control and economic instrument. This distinction refers to the level of discretion given to pollution sources to set their pollution discharges. Whereas, in the former, the discretion belongs to the regulator (i.e. regulation sets pollution limits and/or technology), in the latter, the discretion belongs to the regulated firm/source (i.e. it is up to the subject source to determine how to reduce pollution).

[50] Note that in the literature, regulatory policy instruments are also labelled as *mandatory administrative* or *command-and-control* instruments.

[51] Some literature often calls for more categories, including for instance voluntary agreements as a separate one (see e.g. Carter, 2001; Dalhammar, 2007; Mont and Dalhammar, 2005).

including related conceptual aspects, is based on Mont and Dalhammar (2005), van der Doelen (1998), and Vedung (1998). Examples for the case of energy efficiency are also given:[52]

a) *Economic instruments* provide financial incentives or disincentives that alter the economic conditions of subject target participants. In turn, the new economic conditions aim to trigger (or prevent) the change targeted by the instrument (e.g. higher environmental protection). Economic instruments in the field of energy efficiency include, for instance, tax breaks, subsidies, tradable permit schemes, soft loans, rebate programmes and technology public procurement. They are often mandated by and/or implemented/supported through legal means.

b) *Regulatory instruments* refer to measures that involve the mandatory fulfilment of aspects by targeted participants. Through legislation, public authorities formulate laws that oblige various groups in society to attain certain targets or renounce to perform certain activities. Regulatory instruments applicable to the case of energy efficiency include, for instance, building codes, minimum energy performance standards (equipment, facilities, houses), mandatory energy audits and energy labelling of buildings. Legal penalties (e.g. in financial terms) may result in cases of non-compliance.

c) *Informative instruments* work through the provision of information or knowledge as crucial components in accomplishing or preventing social change. The rationale behind informative instruments is that market agents possess asymmetric information meaning they lack some of the knowledge necessary to reach the right decisions. For instance by means of persuasion or increased awareness, it is assumed that with the provision of the necessary information, people will act upon this and behave in a predictable manner. Informative instruments applicable to the case of energy efficiency include, for instance, communication campaigns, rating labelling of equipment, demonstration programmes, educational and advice centres and training programmes.

A second taxonomy of policy instruments comes from the environmental economics literature, in which the common typology of policy instruments

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[52] For detailed descriptions of policy instruments targeting increased energy efficiency see, for instance, IEA (2008), Laponche *et al.,* (1997), Oikonomou and Patel (2004) and Vreuls *et al.* (2005).

differentiates between two types: *command-and-control* and *market-based instrument*s. On the one hand, it is argued that command-and-control instruments (e.g. technology standards) offer little flexibility in the means of meeting environmental policy targets, since they mandate subject participants to uniformly share the burden of pollution control (Stavins, 2004; Tietenberg, 1996). Such lack of flexibility may, for instance, involve firms being forced to implement a given type of pollution control. Consequently, these actors may be prevented from changing their production processes or re-designing their products because they are still forced to employ the compulsory technology (Portney, 2003). As Stavins (2001) notes, whereas command-and-control might be effective in limiting emissions, they can involve high costs because abatement control costs can vary greatly among firms. Thus, a given technology may be economically feasible in one case but not in another.[53] In fact, in the presence of significant differences in abatement costs, command-and-control instruments are very unlikely to be cost-effective (Stavins, 2004; Sterner, 2003).[54]

On the other hand, market-based policy instruments affect the actions of subject parties through market signals (Stavins, 2004). *Market-based policy instruments* are defined as "*regulations that encourage behaviour through market signals rather than explicit directives regarding pollution control levels or methods*" (Stavins, 2001:1). The definition given by Stavins highlights the overlaps and/or synergies between regulatory and economic incentives; which are highly applicable to the case of TWC schemes.

In theory, the central characteristic of market-based instruments is that they allow the achievement of a desired level of environmental quality or pollution at the lowest possible costs (i.e. cost-effectiveness). Instead of equalising pollution levels among firms (e.g. through mandatory uniform standards), market-based instruments equalise the incremental or marginal

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[53] Note however, that modern environmental law has focused more on the outcomes of policy instruments rather than on specific rules about technology and processes. According to Dalhammar (2007), *permitting* and *extended producer responsibility* can be taken as examples. In the former, emissions limits are set with no particular technologies being prescribed. In the latter, producers are forced to collect or recycle a certain amount or percentage of waste, but flexibility is provided concerning the most cost-effective mechanisms or processes to do so.

[54] In the field of law and economics, command-and-control instruments are analysed with the economic efficiency criterion. In fact, normative law and economics make policy recommendations of legal systems based on efficiency in the same way as the analysis of efficiency of economic instruments (see e.g. Faure and Skogh, 2003).

costs that firms spend in controlling pollution (see e.g. Stavins, 2004; Sterner, 2003; Tietenberg, 1996). It is worth noticing that command-and-control instruments can be cost-effective in theory (e.g. if different standards are determined for each polluting firm), but this would require public authorities maintaining detailed data on the compliance costs of each firm (Stavins, 2001). However, such information is very unlikely to be available to the policy makers (Stavins, 2001; Harrington *et al.,* 2004). On the contrary, one of the great advantages of market-based instruments is that a cost-effective level of pollution control among firms is met without requiring public authorities to obtain this type of information (Portney, 2003; Stavins, 2001; Tietenberg, 1996).[55]

Unlike the choice approach, market-based instruments underscore *markets as part of the solution* and not as a source of laissez-faire activities. Although it is recognised that competitive markets can be efficient mechanisms for the allocation of resources and provision of consumer service and satisfaction, they fail to protect the environment and encourage a sustainable energy future (see e.g. IAC, 2007; Jefferson, 2000; Portney, 2003). Therefore, the underlying principle with market-based instruments is to challenge firms and individuals to protect the environment with the very same economic incentives they face with any other market: price mechanism. Through the role of prices in conveying information and providing incentives, the rationale of market-based instruments is to use market forces to work in favour of the environment (Portney, 2003). In other words, the idea of market-based policy instruments is that with better or competitive pricing (including effective regulation), markets can better contribute to high environmental quality and support to overcome the challenges imposed by sustainable development (Jaccard, 2002; Jefferson, 2000; Portney, 2003, Stavins, 2001).

According to Stavins (2001) four types of market-based instruments can be distinguished: *pollution charges*, *tradable permits*, *government subsidy reductions* and *market friction reductions*. From this classification, and in light of the research, some aspects are worth mentioning. First, while government subsidy reductions address the removal of economically and environmentally inefficient subsidies (e.g. on fossil fuels), the provision of subsidies in other areas is not acknowledged (e.g. to support new energy efficiency and

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[55] For detailed descriptions of market-based instruments targeting environmental issues see, for instance EEA (2006), Carter (2001) and Stavins (2001).

renewable technologies). However, it is argued that the provision of subsidies should be afforded equal importance also in the context of energy for sustainable development (e.g. to internalise positive external effects, achieve specific objectives) (see e.g. Johansson and Goldenberg, 2002; Jefferson, 2000). Second, an important instrument missing from Stavin's list, applicable to energy efficiency, is technology procurement. This policy instrument works through economic incentives and the setting of highly innovative technology requirements by major buyers or users (e.g. government agencies). Through the use of purchasing/negotiation power, these actors can accelerate technological innovation, as manufacturers compete for orders (Edquist *et al.,* 2000). Third, market friction reductions include liability rules and information programmes (e.g. product labelling). Unlike the resource approach, in which economic and informative instruments are presented as separate categories, the typology of market-based instruments proposed by Stavins seems to acknowledge the fact that market signals are not exclusively related to purely economic incentives (see also EEA, 2006).

3.1.2 Policy evaluation and evaluation criteria

To begin with, in this research, the term *evaluation* is used to refer to the "*process of determining the merit, worth or value of something or the product of that process*" (Scriven, 1991:139).[56] In more specific terms, evaluation is understood here as the *systematic application of social research procedures for assessing the design and implementation of policy, in particular policy instruments* (cf. Bemelmans-Videc *et al.,* 1998; Fischer, 1995; Rossi *et al.,* 2004). Several expressions are commonly found in the literature to refer to the concept of processes embedded in evaluation, namely assessment, analysis, examination, judgement, study, review, etc. (see e.g. Chen, 1990; Fischer, 1995; Pawson and Tilley, 1997; Rossi *et al.,* 2004; Scriven, 1991). According to Alkin and Christie (2004), evaluation has two main roots or a dual foundation, namely *accountability* and *social enquiry*. This means that regardless of the use/purpose, methods and appraisals used in evaluation, its *accountability base* aims to design and improve policies for society. In addition, the *social enquiry base* of evaluation is concerned with a systematic and

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[56] One can safely say that the literature on evaluation is vast. For a comprehensive overview of history, theories, views and influences in the field of evaluation see e.g. Alkin (2004), Pawson and Tilley (1997) and Chen (1990).

justifiable set of methods for determining accountability (Alkin and Christie, 2004).

Regarding the field of *policy evaluation* as such, key connotations and conceptual considerations were taken into account during the research process. Policy evaluation is considered an applied area of the discipline of evaluation (Scriven, 1991). According to Dye (1976:95), policy evaluation is "the study of policy impacts". Dunn (1981) notes that evaluation is the *activity of applied social science dealing with multiple methods of examination and arguments that support policy-making to solve public problems.* With a retrospective focus, Vedung (1997:3) refers to evaluation as the "careful assessment of the merit, worth and value of the administration, output and outcome of environmental policies". Mickwitz (2003); however, takes Vedung's concept but also includes the ex-ante dimension of evaluation. In fact, Fischer (1995) points out that policy evaluation can focus on the *expected effects* (ex-ante evaluation) or on *actual results* (ex-post evaluation) of policies or programmes. Building upon the conceptual considerations presented in the previous section, the term *energy (efficiency) policy analysis is used in the research to refer to the evaluation of energy policy, in particular policy instruments*. In line with Dye's definition of public policy analysis (1976:1), the research should be broadly understood as the study of "the causes and consequences" (potentially) related to TWC schemes.

Following on policy evaluation, Fischer (1995: 241-242) provides suitable concepts as far as the empirical and normative components of the research were concerned. First, *empirical evaluation* is defined as "the form of evaluation that seeks to determine the degree to which a specific programme or policy empirically fulfils or does not fulfil a particular standard or norm". Then, *normative evaluation* is defined as "the form of evaluation that focuses on the standard(s) or norm(s) employed as a criterion in an empirical programme or policy".

Due to the fact that evaluation is also fundamentally normative in character, *value criteria* are advocated as a basis for normative judgements about any significant effect of public policy (see e.g. Chen, 1990; Cook and Shadish, 1996; Fischer, 1980; Mickwitz, 2003; Bemelmans-Videc *et al.,* 1998). In simple terms, the criteria are evaluative standards that are the framework upon which a policy choice is judged and eventually made (see e.g. Bemelmans-Videc, 1998; Chen, 1990; Mickwitz, 2003; Rossi *et al.,* 2004). This means that evaluation needs some form of measure upon which the merit or success can be determined or verified (cf. Bemelmans-Videc *et al.,*

1998, Rossi *et al.,* 2004). Note that evaluation criteria do not directly judge the policy instrument as such but the expected or actual outcomes and impacts (i.e. effects).[57] In turn, the application of evaluation criteria to the outcomes and impacts also allows the identification of alternative policy instruments that are more likely to achieve their specific objective(s).

From a theoretical point of view, *a great variety of criteria for the evaluation of policy instruments are suggested when reviewing the literature on economics, public policy and evaluation theory.* Commonly found criteria address economic efficiency and cost-effectiveness (see e.g. Clarke and Dawson, 1999; EEA, 2001; Hildén *et al.*, 2002; Rossi *et al.,* 2004; Vedung, 1997; Weiss, 1998). While the economics literature focuses greatly on cost-effectiveness, Bardach (2005) suggests that commonly used criteria in public policy address legality, political acceptability and robustness. Along these lines, Bemelmans-Videc (1998) argues that dominant evaluation criteria refer to effectiveness, economic efficiency, legality and democracy. Addressing institutional rational choice in policy formulation, Ostrom (2007) mentions criteria such as economic efficiency, fiscal equivalence, equity, accountability, and adaptability.

If we focus on the evaluation criteria often cited for market-based instruments applied in the energy/environmental policy field, similar criteria are suggested. The reviewed literature usually mentions economic efficiency, cost- and environmental-effectiveness, legitimacy, equity, administrative burden, transaction costs, and side-effects (e.g. on industrial competitiveness) (see e.g. Anderson *et al.,* 1977; Faure and Skogh, 2003; Nordhaus and Danish, 2003, Opschoor and Turner, 1994; Panayotou, 1998; Turner *et al.,* 1994; Tietenberg, 1996; Sterner, 2003). In the specific field of energy policy, Blok (2006) suggests effectiveness, efficiency and side-effects. In its third assessment report, the Intergovernmental Panel on Climate Change (IPCC) acknowledges many of the criteria listed above, but emphasises the focus on cost-effectiveness (see Bashmakov *et al.,* 2001). More recently, the fourth assessment from the IPCC has broadened its evaluation analysis beyond cost-effectiveness to elaborate explicitly on

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[57] As Bardach (2005) correctly points out, it is common in public policy to say that policy instrument A is better than B—providing a sort of binary appraisal for a 'yes' or 'no' judgement. However, this approach can sometimes create misleading conclusions, so it is suggested that the correct formulation should refer to 'policy instrument A being very likely to attain the (desired) effect X, which we (e.g. policy makers) judge to be best for the society, making A the preferred alternative (see Bardach, 2005).

environmental effectiveness; distributional considerations; and institutional feasibility (see Gupta *et al.,* 2007).

Despite the great variety of criteria suggested above, the literature reviewed does not offer much direction about their suitability for energy/environmental policy evaluation (cf. Gupta *et al.,* 2007). In addition, the applicability of only few criteria is the norm and still limited to a handful of evaluations (cf. Harrington *et al.,* 2004). Exceptions are found in Gupta *et al.* (2007), Harrington *et al.* (2004), Hildén *et al.* (2002), OECD (1997, 2002) and Tietenberg, (2006), for instance. In all, it is argued that more methodical and wider evaluations—stressing ex-post assessments—should be undertaken in order to better understand the effects of policy instruments in general, and tradable permits in particular (see e.g. Harrington *et al.,* 2004; OECD, 2002; Tietenberg, 2006).

In this research, the following criteria were used to evaluate the performance of TWC schemes: *energy-saving and environmental effectiveness, economic efficiency, cost-effectiveness, transaction costs, political feasibility, administrative burden, technical change and distributional equity.* As noted in Section 1.4, the *selection of the evaluation criteria was based on the attributes and/or hypotheses attached to TWC schemes* (see also Section 3.2 for more details). The use of different evaluation criteria also took its point of departure in the fact that a number of criteria are relevant to policy evaluation (see e.g. Jacquet-Lagrèze and Siskos, 2001; Lahdelma *et al.,* 2000; Mickwitz, 2003). Furthermore, policy instruments addressing the interplay of energy and environment issues, such as TWC schemes, usually tackle various policy objectives. In turn, this demands an evaluation from many perspectives, including views from different stakeholders (cf. Fischer, 1995; Greening and Bernow, 2004; Lahdelma *et al.,* 2000; Rossi *et al.,* 2004). On the whole, the selected evaluation criteria were used to provide a comprehensive picture of the TWC schemes. Conceptual considerations of the selected evaluation criteria are given below.

Energy-saving and environmental effectiveness. In general, the effectiveness of a policy measure is understood as the assessment of whether or not it achieves the expected policy target. A fundamental pre-condition for a policy instrument to be effective is the establishment of mandatory target. The effectiveness of the instrument can then be assessed in terms of the degree to which it contributes to the achievement of the policy target (see e.g. Blok, 2006; EEA, 2001). In the case of TWC schemes, this criterion assesses the degree to which the obliged parties meet policy target(s), both in terms of energy savings and emission reductions. Certainly, the environmental effectiveness of an energy efficiency policy instrument can be judged if an

explicit environmental target is set. The energy-saving effectiveness also relies on the ambition level, the non-compliance rules (e.g. financial sanctions) and the effectiveness of enforcement.

Economic efficiency. In public policy, economic efficiency is often mentioned as the most relevant evaluation criterion (see e.g. Bardach, 2005; Ostrom, 2007; Rossi *et al.,* 2004). As a central concept in economics, an outcome is efficient if there is no other allocation of resources, which could make someone better off without making someone else worse-off (i.e. Pareto optimality). Considering an initial (re)allocation of resources, a policy instrument is then said to be efficient if, and only if, each member of society is as well off as they can reasonably be (Harrington *et al.,* 2004). However, essentially no public policy achieves the Pareto efficiency test (Stavins, 2004). Therefore, a more realistic approach to identifying an efficient outcome or potential Pareto improvement refers to the maximisation of the difference between total social benefits and costs. As is known, the Kaldor-Hicks criterion is the key theoretical foundation of the cost-benefit analysis, which is considered the operational and pragmatic formulation by which to approach economic efficiency (Tietenberg, 2006). In fact, economic efficiency analyses usually take the form of a cost-benefit analysis (see e.g. Rossi *et al.,* 2004; Tietenberg, 2006). In the literature, there is a consensus regarding how ambitious and challenging—or sometimes impracticable—it is to perform a cost-benefit analysis and thus measure economic efficiency in policy evaluation (see e.g. Mickwitz, 2003; Sterner, 2003; Tietenberg, 2006).[58] This is largely explained by the intensive data collection and processing that the evaluation of efficiency criterion demands. In the research at hand, economic efficiency was examined in terms of the maximisation of the difference between total social benefits (i.e. energy cost savings and social and environmental benefits) and total programme costs (i.e. investments costs, administrative costs and transaction costs).[59]

Cost-effectiveness. The purpose of evaluating a policy instrument from the standpoint of cost-effectiveness relies on whether the policy instrument minimises compliance costs for a given policy target to be met. Therefore, cost-effectiveness analysis usually entails an optimisation procedure

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[58] It is argued that evaluating the economic efficiency of any tradable permit scheme is a complex and time consuming activity, which is consequently seldom carried out (see Tietenberg, 2006).

[59] One can note that in order to approach economic efficiency, results from the analysis of transaction costs and administrative burden are highly necessary.

(Tietenberg, 1996). Furthermore, the concept of cost-effectiveness is embedded in efficiency, however the latter involves that an optimal policy target is determined in relation to well-being (see e.g. Faure and Skogh, 2003; Sterner, 2003). In turn, efficient policy instruments are cost-effective, however not all cost-effective policy instruments are efficient because the predetermined policy target may well not be efficient (Tietenberg, 1996). A critical condition for cost-effectiveness relies on the equalisation of marginal costs among obliged parties (Baumol and Oates, 1988; Sterner, 2003). Once the target level in a TWC scheme is set, it is up to the obliged parties to decide how to meet their individual targets at the lowest possible cost. Alternatively, or complementary to the approach described above, Tietenberg (2006) suggests a more pragmatic benchmark. That is, to compare the costs of the instrument under analysis in meeting a given target with the costs associated with the most probable policy instrument. As for tradable permits in general, Tietenberg (2006) argues that cost-effectiveness analysis arises as an achievable and alternative approach to economic efficiency (e.g. when benefits cannot be estimated in monetary terms). In fact, a cost-effectiveness analysis is often suggested as a variant of economic efficiency analysis (cf. Farrell *et al.,* 1999; Fischer, 1995; Mickwitz, 2003; Rossi *et al.,* 2004).[60] Furthermore, cost-effectiveness is also defined as the approach to determine the efficacy of an instrument in meeting given impacts and outcomes in relation to its programme cost (Rossi *et al.,* 2004).

Transaction costs. In simple terms, transaction costs (TCs) are defined as all the costs—other than price—faced by market actors to initiate and complete transactions. According to Matthews (1986:906), transaction costs are "the costs of arranging a contract ex-ante and monitoring and enforcing it ex-post, as opposed to production costs". There is extensive and compelling evidence that transaction costs can hamper increased energy efficiency as such (see e.g. Hein and Blok, 1995; Sanstad and Howarth, 1994; Ostertag, 1999; Reddy, 1991). The actual components of TCs in the context of energy efficiency have been debated, particularly in terms of differentiating among transaction costs, hidden costs, and production costs (e.g. Ostertag, 1999; Sanstad and Howarth, 1994). Although it is not totally clear, there seems to be some consensus in the literature that TCs should be considered a subgroup of hidden costs and certainly not part of the actual investment and administrative costs (cf. Ostertag, 1999). It is argued that it is the size and

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[60] Cost-effectiveness is sometimes labelled also as *static efficiency* (cf. Faure and Skogh, 2003; Harrington *et al.,* 2004).

performance of a measure that ultimately determines the burden of TCs in energy efficiency projects (e.g. Björkqvist and Wene, 1993; Michaelowa *et al.* 2003; Sathaye, 2005). There is also evidence that TCs can hamper the performance of tradable permit schemes (e.g. Hahn and Hester, 1989; Atkinson and Tietenberg, 1991; Stavins, 1995; Montero, 1998; Kerr and Maré, 1998; OECD, 2002). TCs can reduce the incentive created by trading and, when trading takes place, they can reduce the number of certificates traded (Stavins, 1995; Tietenberg, 2006). Indeed, TCs are a critical issue influencing the performance of any tradable certificate scheme and one that needs to be taken into account in the evaluation of the scheme's efficiency and cost-effectiveness.

Political feasibility. This evaluation criterion addresses the potential obstacles that hamper or enhance the political feasibility of implementing a TWC scheme. This criterion can focus on the political response that a policy instrument can generate. Intuitively, one can argue that a policy instrument should be politically feasible to be endorsed by a government (cf. van der Doelen, 1998; Bardach, 2005). The hypothesis that dominates in policy evaluation is that a policy instrument is very likely to be politically acceptable if it is efficient, cost-effective and equitable (cf. Bemelmans-Videc *et al.,* 1998; Bardach 2005). Likewise, according to Nordhaus and Danish (2003), the political feasibility of policy instruments also relies on environmental effectiveness and how equitable the regulatory burden is distributed across society. Besides these crucial elements, one can also argue that the political feasibility of any policy instrument is very likely to be affected by the administrative burden (human and financial) faced by public authorities in charge of its management. From the governmental perspective, one should also consider that a policy instrument needs to be compatible with other policy objectives/discourses to be politically supported (see Fischer, 1995; Rossi *et al.,* 2004)—including whether it fits the existing policy culture and paradigm. Similarly, the political acceptance also depends on the authority's experience or familiarity with the new policy approach (Bemelmans-Videc *et al.,* 1998; Nordhaus and Danish, 2003).

Administrative burden. This evaluation criterion specifically addresses the workload that public authorities face when a policy instrument is implemented and enforced (cf. Rist, 1998; Harrington *et al.,* 2004). The criterion can focus on the public authority's administrative efforts triggered by the implementation of a policy instrument. Thus, it relates to the human and financial resources incurred by the authority administering the instrument. Such costs can be heavily related to the design features of the

instrument and policy objectives. According to Sterner (2003), an instrument is administratively feasible if it is workable and its operation does not involve disproportionate financial or informational costs. In turn, an instrument that is impractical to administer is very likely to be economically inefficient and environmentally ineffective (Rist, 1998; Nordhaus and Danish, 2003). While administrative costs do matter in public policy, they are often overlooked in evaluations. Nonetheless, ignoring such costs can generate biases towards the evaluation of policy options (Tietenberg, 2006). Here, administrative costs are defined as the costs of implementing, monitoring and enforcing a given policy instrument. These costs are thus a function of the complexity of the institutional framework, the number of regulated firms, and the accessibility of necessary data about these firms (Nordhaus and Danish, 2003). Furthermore, a critical issue when considering administrative feasibility is concerned with policy makers facing the challenge to find or create the most suitable institution to handle the implementation of the policy (Rist, 1998).

Technical change. In general, tradable certificate schemes are implemented to support the dissemination of economic and energy efficient technologies. However, it is been argued whether or not tradable permits also encourage the development of new technologies (e.g. Ellerman *et al.,* 2000; OECD, 2002; Harrington *et al.*, 2004; Tietenberg, 2006). By applying such a criterion, an attempt is made to assess the response of eligible parties to the policy intervention in terms of dissemination of less mature or new (energy efficient) technologies. The process of supporting emerging (energy efficient) technologies also needs to be analysed using a systems approach (e.g. Hughes, 1983, Freeman, 1988; Lundvall, 1988, 1992; Carlsson, 1995; Edquist, 1997). Applying such an approach permits an analysis of the critical processes of changes in the system affecting technology change. According to this view, the focus is on changes in the so-called selection environment (Nelson and Winter, 1977; Kemp, 1997), and changes related to the role of subject participants and their commitment, behaviour, and organisational development.

Distributional equity. Policy makers need to consider that distributional equity may be a more relevant criterion for public policy. When considering whether a policy instrument is politically feasible, it is crucial to account for how costs and (ancillary) benefits are distributed. If they are unfairly distributed, it could prove politically challenging to gain legitimacy for a policy instrument, since efficiency may be gained at the expense of equity—particularly in countries with broad income disparities (see e.g. Anderson *et*

al., 1997; Panayotou, 1998; Sterner, 2003). In fact, the literature also indicates that economic efficiency should not be a necessary or sufficient condition for public policy (see e.g. Anderson *et al.,* 1997; Arrow *et al.,* 1996; Turner *et al.,* 1994). Even if an instrument meets the efficiency criterion, very little—at best—can be said about the fairness of the distribution of costs and benefits, so efficiency should neither be a required nor satisfactory condition for public policy choice (see e.g. Anderson *et al.,* 1997; Daly 1996; Panayotou, 1998; Sterner, 2003). This is relevant for the research, as TWC schemes have been also implemented to tackle poverty aspects (see Section 3.2).

3.2 Tradable White Certificate schemes

The theoretical efforts of Coase (1960) and Dales (1968) first shed light on the application of tradable permits in creating markets and efficiently addressing environmental problems, as opposed to direct regulatory control. Since then, Baumol and Oates (1971), Montgomery (1972), and Tietenberg (1974), among others, have further demonstrated the theoretical foundations of this policy instrument. With the development of more robust concepts and frameworks, we have witnessed the application of this instrument to many public issues during past decades, becoming a cornerstone of many environmental and energy policy programmes (OECD, 2002). Also called cap-and-trade or target-and-trade schemes, the tradable certificate schemes already implemented have addressed, for instance, atmospheric pollutants, fishing stocks, renewable energy, municipal solid waste, and wastewater. More recently, similar markets have been created in the field of energy efficiency.

3.2.1 Policy objective(s) and economic rationale

In line with the distinct feature of market-based policy instruments, the principle underlying the creation of markets for energy efficiency (so-called Tradable White Certificate [TWC] schemes) is to take full advantage of market forces and their agents to work in favour of increased energy efficiency. In other words, the characteristic theoretical feature of this policy instrument is to rely on competitive market forces to increase energy efficiency.

The creation of tradable certificate schemes applicable to the case of energy efficiency can be attributed to Rader and Norgaard (1996). Discussing the

application of the Renewable Portfolio Standard[61] to increase the use of renewable energy, the authors also assert their application in the field of energy efficiency. By requiring energy suppliers to deliver a minimum amount of energy savings, Rader and Norgaard (1996:45) state that energy suppliers "could be allowed to trade energy saving obligations among each other". The creation of TWC schemes relies on a combination of regulatory aspects (i.e. mandatory energy saving target) with economic flexibility (i.e. it is up to subject parties how they meet their individual target cost-effectively).

Numerous policy objectives are identified behind the implementation (or policy discourse) related to TWC schemes. The initial and most obvious is the economic rationale of increasing energy efficiency cost-effectively (see below). TWC schemes have been also implemented to decentralise the public good resulting from increased energy efficiency (e.g. cleaner air, increased energy security) (see e.g. DEFRA, 2004; Capozza *et al.*, 2006; Pavan, 2002). The reduction of fuel poverty has been also addressed as a significant policy objective (see DEFRA, 2004; NERA, 2006).[62] TWC schemes have also been introduced with the explicit objective of reducing the administrative burden for public authorities and supporting the liberalisation of energy markets (e.g. Monjon, 2006; Pavan, 2002). Innovation and economic benefits for society (and end-users) have been also addressed as policy objectives for implementing TWC schemes (see e.g. Bertoldi and Rezessy, 2006, Capozza *et al.*, 2006; Voogt *et al.,* 2006). Another implicit and initial policy objective is to correct market failures (e.g. imperfect information) and/or overcome market barriers (e.g. a lack of adequate capital) that prevent increased energy efficiency (see papers I, II and III for further details).[63] Finally, another policy objective behind the creation of TWC schemes has been phrased in terms of fostering the energy sector towards a more sustainable path (cf. Bertoldi and Huld, 2006; Capozza *et al.,* 2006; Langniss and Praetorius, 2006).

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[61] Note that, in the US, tradable certificate schemes in the field of renewable energy are often referred as *Renewable Portfolio Standard.*

[62] The British TWC scheme explicitly supports the Fuel Poverty Strategy, which aims to reduce the number of households that spend more than 10% of their income to satisfy energy needs (DEFRA and DTI, 2005).

[63] For an in-depth description and analysis of market failures and barriers affecting increased energy efficiency, see e.g. Scheraga (1994), Jaffe and Stavins (1994), Sanstad and Howarth (1994) and Metcalf (1994).

In theory, *the creation of a TWC scheme is based on the economic rationale of cost-effectiveness*, that is, the achievement of an energy saving target at the lowest possible marginal costs. In other words, a TWC scheme encourages the implementation of eligible energy efficiency measures in the eligible end-use sectors with the lowest marginal costs. A TWC scheme allows policy makers or regulators to achieve a cost-effective allocation of responsibility for increasing energy savings despite their lack of knowledge regarding the individual marginal saving costs of subject parties. Figure 3-1 illustrates, in a simple manner, the concept of cost-effectiveness embedded in TWC schemes.
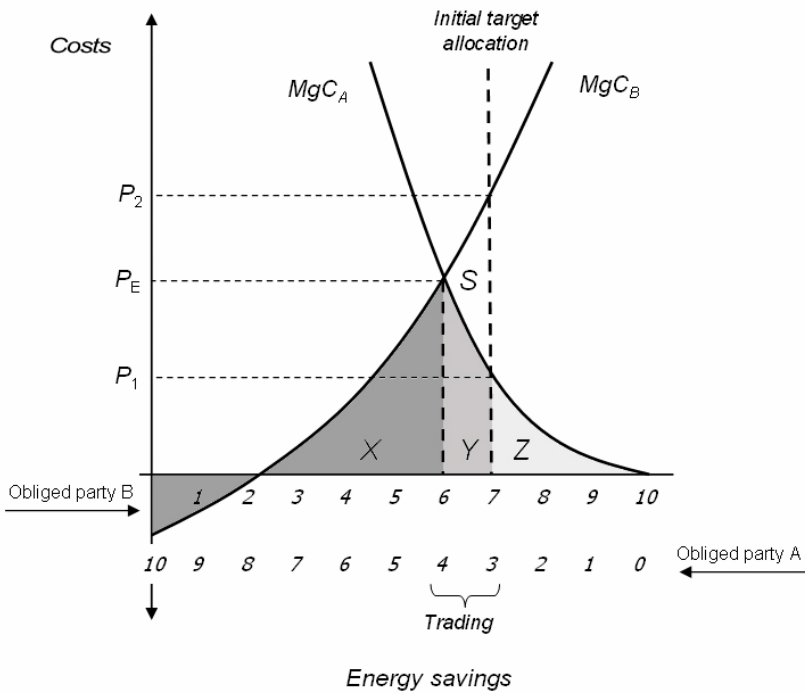
Figure 3-1: Cost-effectiveness in Tradable White Certificate (TWC) schemes

In the figure, parties A and B represent two market actors that are obliged to meet a given energy saving target. The energy saving target set by the authority is 10 energy units. By accessing different end-users located in different eligible end-use sectors, these obliged parties face different marginal costs for realising energy saving. While the marginal costs of energy savings of obliged party A, MgC_A, start on the right side of the x-axis, the

marginal costs of energy savings of obliged party B, MgC_B, start on the left side. Notice that obliged party B can achieve up to 2 units of energy saving at negative costs. All possible allocations of achieved energy savings are depicted in the figure. Thus any combination yields the defined energy saving target—albeit at different compliance costs. Consequently, a cost-effective achievement of the saving target is represented when obliged party A achieves four energy saving units and obliged party B achieves six energy saving units (i.e. $P_{E\,(4,\,6)}$). The equalisation of marginal costs comes at P_E (i.e. equilibrium market price of TWC). Whereas X represents the compliance costs for obliged party B, areas Y and Z represent the compliance costs for obliged party A. Thus, total compliance costs are represented by the sum of areas X, Y and Z. It can subsequently be inferred than any other possible combination results in higher compliance costs or a less cost-effective achievement of the energy saving target.

Crucial to the cost-effectiveness rationale is the fact that both parties have an incentive to engage in trading (see also Figure 3-1). Let us assume an initial target allocation of energy savings whereby obliged party B would have to save, for example, seven energy units before being able to trade, while obliged party A would have to save only three units. Obliged party B gains from trading as long as it can buy TWCs at a lower cost than P_2. Likewise, obliged party A gains from trading as long as it can sell TWCs for a price higher than P_1. Driven by this price mechanism, introduced by the trading component, a TWC scheme allows obliged party A to save more energy and obliged party B to save less. The savings target is still met but at the lowest possible cost. The cost savings derived from trading are represented by area S. However, as investigated during the course of the research, a number of policy and market conditions affect the relative cost-effectiveness of TWC schemes (e.g. transaction costs, performance of portfolio of energy efficiency policy instruments, (co)benefits of increased energy efficiency) (see e.g. papers II, III and V).

It has to be acknowledged that the literature on TWC schemes has grown rapidly in recent years (see e.g. Bertoldi and Rezessy, 2006; Bertoldi and Huld, 2006; Capozza *et al.*, 2006; Hamrin *et al.*, 2007; Langniss and Praetorius, 2006; Monjon, 2006; Oikonomou *et al.*, 2007).

3.2.2 TWC scheme's functioning and flexibilities

In general terms, the following aspects characterise the *functioning of a TWC scheme* (see also papers I to V for further details). First, it involves the

achievement of a *mandatory energy-saving target* set by a public authority (e.g. energy agency) during a given time period. *Authorities* are usually responsible for setting the overall policy design, implementation, administration and enforcement of the scheme. *Obliged parties*—usually energy suppliers or distributors—bear this obligation in terms of being required to meet individual energy-saving targets, which are generally apportioned or allocated among them according to their market share.

Second, obliged parties are required to implement *eligible energy efficient technologies* in *eligible end-use sectors* (e.g. household, commercial). The authorities select/approve these (additional) technologies as qualifying for inclusion in a TWC scheme. To increase the liquidity of the market, authorities also allow *other market agents* (i.e. non-obliged actors, e.g. Energy Service Companies [ESCOs]), which do not bear any obligation but are entitled to implement measures, to earn and trade TWCs. [64] As a whole, *both obliged and non-obliged parties represent the eligible parties* under a TWC scheme.

Third, depending on the *measurement and verification* (M&V) approach defined in the regulatory framework, an *independent organisation* can perform activities related to the M&V of energy savings. *Certificates* are then issued by the authority as evidence of realised energy savings.

Fourth, eligible parties are allowed to *trade* these certificates, which represent a trading commodity with associated physical energy saved units. Like any application, the trading component is not an objective per se but merely a way of enhancing the scheme's efficiency in order to meet a mandatory saving target. The key market strategy for obliged parties depends on the price of TWCs in the market compared to the costs of realising their own energy savings. Parties (obliged or not) can also save or *bank* TWCs for future commitment periods or to speculate on rising market prices. At the end of certain period, obliged parties must *redeem* their TWCs to prove that they have achieved their energy saving target. Obliged parties that are unable to reach their targets pay a *penalty for non-compliance*. This basic market functioning is illustrated in Figure 3-2.

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[64] The term *liquidity* is used to refer to the characteristic of TWCs whereby they can quickly be converted into cash at a reasonably predictable price. Under TWC schemes, high liquidity is affected by a number of critical conditions. For instance, a large number of buyers and sellers, market information that is readily available, a high trading volume, low transaction costs, and minimum regulatory barriers to trade (see Voogt *et al.,* 2006; Mundaca and Neij, 2006).
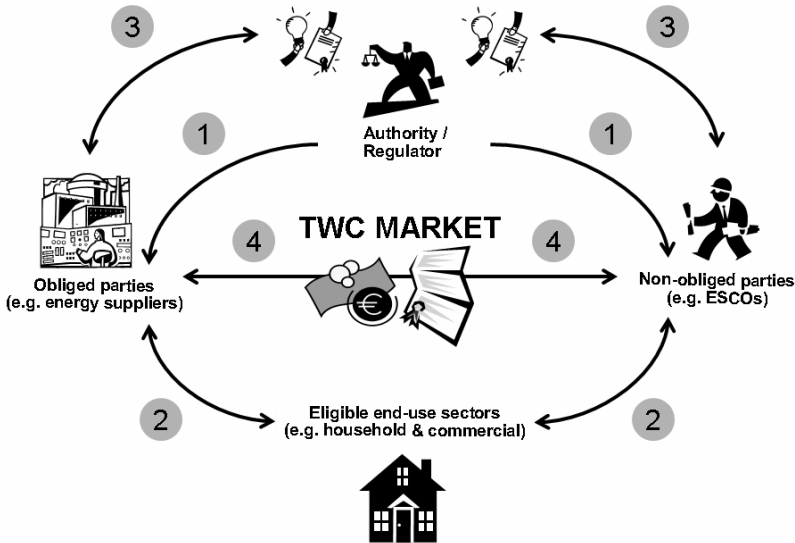
Figure 3-2: Basic functioning of Tradable White Certificate (TWC) schemes

Notes: (1) Authorities impose an energy saving obligation on certain parties and allow non-obliged parties to participate in TWC markets. (2) Eligible parties (i.e. obliged and non-obliged) implement measures in eligible end-use sector so they can obtain certified energy savings. (3) Eligible parties request TWCs from the authority, depending on the M&V approaches of energy efficiency, certificates are issued by the authority to the parties. (4) Eligible parties can trade or bank TWCs.

Whereas there is a tendency to focus on trading as the crucial flexibility in cost-effectively achieving an energy saving target, *many more flexibilities are embedded in TWC schemes*. In fact, the option of trading TWCs allocated to parties to fulfil their targets is not the sole option. As in any tradable certificate/permit scheme, it is the complete set of flexibilities that deserves analytical attention (see e.g. Ellerman *et al.,* 2000; Nordhaus and Danish, 2003; Tietenberg, 2006). The economic rationale for least-cost compliance relies on a number of flexibilities provided to obliged parties. These are described as follows:

a) *Eligible measures used to realise energy savings.* For the first type of flexibility, the promotion of cost-effective measures, investment and technology development is crucial. Policy makers define eligible measures that qualify for the realisation of energy savings and thus yield TWCs.

Consequently, the policy commitment is expressed through technology-based standards (cf. OECD, 1999). The broader the set of eligible measures (i.e. the range of measures intended to yield all potential savings contained, for instance, in area X as shown in Figure 3-1), the greater the flexibility afforded to parties to achieve cost-effective energy saving potentials. Within this flexibility, the definition of additionality is relevant because TWC schemes are intended to encourage energy savings that would not be realised without the incentive given by TWCs. In principle, eligible measures must be surplus to what would have occurred in the absence of TWC a scheme. To date, experience shows the determining of additionality, and consequently of eligible measures, to be highly case-specific and contentious (see next section for details).

b) *Number of eligible end-use sectors.* For the second type of flexibility, the larger the group of eligible end-use sectors in which eligible measures can be implemented, the more options parties have for meeting their energy saving target cost-effectively (e.g. savings that obliged party B can achieve at negative costs in Figure 3-1 were only possible in the household sector). Likewise, the first saving units for obliged party A were only possible in the industrial sector. Nevertheless trade-offs exist because, although increased sector coverage may be desired, a growing number of sources of transaction costs for market actors (e.g. the search for a trading partner) could be expected—in addition to a heavier administrative burden for the authorities in terms of enforcement, for instance.

c) *Banking option for surplus of TWCs.* The third type of flexibility refers to banking. This provision allows obliged parties that over comply with their individual targets to save their surplus TWCs for future commitment periods. In fact, banking is usually denoted as inter-temporal trading (see Rubin, 1996). In other words, it is given as an inter-temporal flexibility for saving credits in order to mitigate the costs of over-investment (OECD, 1999; Ellerman *et al.,* 2000). Although not yet implemented in current TWC schemes at the time of writing, a borrowing option for non-compliance can also be introduced. This means that a party that does not comply with its target commits itself to a greater target for the next compliance period.

d) *Market engagement of non-obliged parties.* The fourth type of flexibility relates to the participation of non-obliged parties. This refers to parties that do not bear any obligation, but who increase market liquidity and supply

TWCs to the market (e.g. ESCOs in Italy). Non-obliged parties are entitled to implement eligible measures, gain TWCs for doing so, and also trade TWCs on the market—as long as they fulfil all of the requirements set by the regulatory framework. To increase liquidity, a large number of parties (obliged and non-obliged) is desired because they are likely to face different marginal costs at similar levels of achieved energy savings (i.e. having more parties with different, possibly lower, marginal costs increases the cost-effectiveness of meeting the target).

e) *Trading option.* The fifth type of flexibility in a TWC scheme is quite straightforward: trading as such. The trading option allows the equalisation of compliance costs among obliged parties. Across the whole scheme, obliged parties that can save energy inexpensively have an incentive to save a larger amount of energy and sell the excess of TWCs. Conversely, parties facing higher-cost options, who thus find meeting their targets costly, can buy TWCs. There is likely to be a demand for TWCs whenever it is cheaper to purchase TWCs on the market than to implement eligible measures in eligible end-use sectors. On the whole, obliged parties use the lowest-cost approach to reach their targets. In theory, as long as an allocation of individual saving targets is not cost-effective, there is always an incentive to trade. Again, the costs of meeting an energy saving target are minimised when marginal savings costs are equalised among obliged parties—depicted by $P_{E\ (4,6)}$ in Figure 3-1. The key challenge for parties is whether implementing their own measures or buying TWCs on the market is the optimal or lowest-cost solution to meeting their individual energy saving targets. Some critical indicators for analysing the trading component of TWC schemes are market prices, volume of trades, number of buyers and sellers, and price dispersion.

3.2.3 Design considerations and applications

In recent years, we have witnessed the design and implementation of TWC schemes. France, Italy and Great Britain have implemented TWC schemes and others have embarked on ex-ante institutional and market feasibility studies (e.g. The Netherlands, Denmark, and Poland). The discourse on policy regarding the practical formulation of TWC schemes should not cause surprise. On the one hand, the use of tradable permit schemes has gained considerably policy ground in Europe since the mid-1990s (Carter, 2001; EEA, 2006; OECD, 1997; 2002). The interplay of energy and climate

change policies has grown steadily and tradable permit schemes applied to renewable energy and greenhouse gas emissions can also be taken as remarkable examples (cf. IAC, 2007; IEA, 2002a; Gupta *et al.,* 2007). On the other hand, growing political interest in TWC schemes seems to be consistent with the historical development of energy efficiency policy, where we have witnessed substantial use of economic instruments (e.g. rebates, subsidies, taxes) (Vreuls *et al.,* 2005).

As Table 3-1 illustrates, the design, and thus application, of the TWC schemes already implemented varies from one country to another (see also papers II and III). Although the economic rationale of any tradable certificate scheme is the same (i.e. lowest-cost compliance; equalisation of marginal compliance costs), the design of a TWC scheme is driven by many elements that are often subject to national policies (cf. Capozza *et al.,* 2006; Voogt *et al.,* 2006).

Table 3-1: Main design characteristics of current national TWC schemes

	Great Britain	**Italy**	**France**
Saving target	468 PJ (130 TWh)	243 PJ (67 TWh)	194 PJ (54 TWh)
Time frame	2005–2008	2005–2009	2006–2008
Obliged parties	Suppliers of gas and electricity with ≥15,000 customers	Distributors of gas and electricity with ≥100,000 customers served	Suppliers of gas, electricity, cooling, and/or heating with annual sales ≥ 0.4 TWh. Suppliers of LPG with annual sales ≥ 0.1 TWh
Eligible actors	Only obliged parties, but sub-contracting is allowed	Obliged parties, non-obliged distributors and ESCOs	Obliged parties, ESCOs and any actor able to achieve ≥ 1GWh in savings
Market size	Eight suppliers covering 99% of energy supply markets	Approx. 24 distributors of natural gas; 10 distributors of electricity; 570 non-obliged distributors, and ≥ 550 ESCOs	Approx. 2,400 energy suppliers, 23 obliged parties capture ≥ 90% obligation
Eligible sectors	Household sector only	All energy end-use sectors, incl. distribution networks. ≥ 50% target to be achieved in elect. and gas savings	All energy end-use sectors including transportation but excluding installations covered by EU-ETS
Eligible technologies	E.g. cavity wall insulation, loft insulation, condensing boilers, A-rated appliances.	Approx. 14 categories, e.g. micro CHP, solar heaters, small PV applications, double glazing, A-rated appliances.	Approx. 100 measures for the household and commercial sectors; approx. 20 for the industrial and 5 for the transport sector.
Type of trading allowed	Bilateral	Bilateral and spot	Bilateral and spot
Penalty for non-compliance	A fine of up to 10% of the obliged party's turnover	Fee that is proportional and greater than investments needed to compensate for non-compliance	2 Euro cents per kWh

As one can observe, design differences exist and they are particularly pronounced in areas such as, obliged parties, eligible sectors and market size.

First, in the case of Great Britain and France, the obliged parties are energy suppliers. On the other hand, under the Italian scheme, distributors—upstream in the energy system—are responsible for meeting the given target. Second, while gas and electricity are the dominant energy carriers covered under the British and Italian schemes, multiple energy carriers are subject under the French system. Third, the number of eligible actors (i.e. obliged and non-obliged parties allowed to participate in trading) is different, having a direct impact on market size and thus market liquidity. Fourth, the number of eligible technologies is driven to a large extent by the number of eligible sectors that a TWC scheme covers. While the British scheme allows savings only in the household sector, more ambitious levels are set by the Italian and French schemes, which allow energy savings in all end-use sectors. For the latter, savings can be realised in all end-use sectors not yet covered by the European Emission Trading scheme, EU-ETS—including the transport sector. Fifth, non-compliance is penalised through different financial burdens. In theory, these financial penalties set the ceiling or upper market price of TWCs (i.e. if energy savings costs are higher than the penalty, obliged parties prefer to pay the penalty).

Regarding trading as such, it should be noted that Italy and France allow both bilateral and spot market (or over-the-counter), trading. For Britain, it has to be acknowledged that the scheme is not a certificate-based mechanism. In other words, no tangible certificate of energy savings as such exists, although a document—duly approved and issued by the authority—is used to trade energy savings and obligations. The trading of obligations means that one obliged party can pay another to fulfil its energy savings obligation. Due to the lack of a trading platform facilitating over-the-counter trading, only bilateral trade is permitted. Despite these technicalities, the British scheme is usually regarded as a TWC scheme (cf. Bertoldi and Rezessy, 2006; Capozza *et al.,* 2006; Oikonomou and Patel, 2004).

Methods of *measurement and verification* (M&V) have probably been among the more complex issues faced by TWC schemes. As the adage says, "you cannot manage what you do not measure". This is highly applicable to TWC schemes and the concept and application of M&V is of prime technical and financial importance—including the development of a baseline. As a credit-based mechanism (see below for details), these aspects are at the very core of TWC schemes because the issuance of TWCs is dependent on the

baseline, the performance of eligible measures and thus the M&V approaches adopted. Unlike applications in the field of renewable energy or atmospheric pollutants, the M&V of increased energy efficiency is a far more challenging aspect. In Great Britain, the scheme grants energy savings based entirely on an ex-ante M&V approach, which involves simplified procedures. Savings and thus baselines are agreed in advance. Energy savings are calculated based on standardised estimates between the reference scenario (or baseline) and the performance of the eligible measure. Savings are then usually discounted over the estimated life of the measure. The authority grants energy savings to the eligible parties before the energy savings are actually realised (see DEFRA, 2004). The approach is largely explained by the fact that the type and performance of the eligible measures are well known. Thus, there is no need for on-site M&V (i.e. ex-post M&V), although there is an inherent level of uncertainty. Estimates regarding costs and engineering aspects are calculated using the best data available. Nonetheless, random monitoring is carried out under the British scheme to check installations and customer satisfaction (see DEFRA, 2004).

In Italy, three M&V approaches are used depending on the type of eligible measure: (i) an ex-ante or deemed saving approach (as in Great Britain), (ii) an engineering approach that requires some on-site M&V but also relies on simplified ex-ante methodologies, and (iii) a monitoring plan, which is basically an ex-post approach based on on-site M&V (see Pavan, 2002, 2008). In practical terms, the engineering approach offers a hybrid M&V approach, combining ex-ante and ex-post approaches. This can be more accurate than an ex-ante approach but less costly than a full ex-post approach.

In France, at the time of writing, the M&V methodologies associated with more than one hundred measures for the household and commercial sectors were still under development. The dominant M&V approach was likely to be an ex-ante one. An interesting development by the French is the differentiation of energy savings according to geographical region due to the countries widely varied climatic zones (Monjon, 2006). Thus, variations of a given M&V methodology will exist for a particular eligible measure. For the transport sector, the French scheme was considering to introduce an ex-ante approach for a variety of measures (e.g. training for fuel efficient bus driving and the use of low-friction tyres). Regarding the industrial sector, both ex-ante and ex-post M&V approaches were likely to be used.

It is worth noting that the design and application of TWC schemes entail a *credit-based mechanism* and not an allowance trading oriented mechanism (e.g. like the European Emission Trading Scheme, EU-ETS). This means that a TWC scheme allows energy savings above and beyond certain (legal) requirements to be certified as tradable certificates (see additionality below). Unlike an allowance trading mechanism, in which a number of allowances may not necessarily be allocated among polluters based on historical regulatory standards, the baseline for certificate trading is determined by technology-based standards (cf. Tietenberg, 2006). In other words, whereas allowance trading does not rely on pre-determined regulatory standards, a TWC scheme does. Therefore, a TWC scheme needs to define a set of eligible technologies above and beyond the historical or current technological standards.

Within the above-described context, the issue of *additionality* is rather critical. As noted previously, this is because TWC schemes encourage energy efficiency measures generating energy savings that would not have otherwise occurred under a business-as-usual (BAU) scenario (i.e. as depicted by the baseline or counterfactual situation). In other words, energy savings depicted by the baseline, or generated by BAU measures, are not additional. Additionality also aims to prevent eligible parties from *free-riding*. In theory, if the (eligible) measures implemented are not considered additional, they are not ultimately eligible and obliged parties cannot claim certificates for the realised energy savings. As a credit-based mechanism, the key question is how the additional component of energy efficiency measures is determined under TWC schemes. This is still a debatable, sometimes unclear and country-specific issue. In principle, the additional component of TWC schemes is implicit when eligible measures are selected. In other words, once measures are selected as eligible, they become additional measures by default. However this is not always the case, as additionality is sometimes determined/discussed after a measure is considered eligible. This is because TWC schemes usually aim to increase the market share of efficient technologies already present under a BAU scenario. Here, TWC schemes aim to encourage the current market share of a given technology above or beyond BAU trends (e.g. up to a minimum level of 10%), thereby achieving an additional volume of energy savings.

In Great Britain, obliged parties must demonstrate that energy efficiency improvements are implemented beyond the BAU scenario (e.g. as determined by building codes). Within the context of additionality, obliged parties must achieve at least 50% of their energy savings in the so-called

"priority group", defined as households that receive "certain income-related benefits and tax credits" (OFGEM, 2005:4). This is because, as mentioned previously, the British scheme aims to support the Fuel Poverty Strategy, aiming to reduce the number of households that spend more than 10% of their income to satisfy energy needs.[65] Additionality can be justified in financial terms (i.e. energy efficiency investments do not take place because home owners or tenants lack capital). For instance, landlords of social housing programmes can support obliged parties by providing written evidence of additionality. To implement eligible energy efficiency measures in low-income households, British obliged parties need to receive a written statement from the landlord stating that the measures would not have been implemented outside the programme.[66] The authorities in Great Britain recognise that it is difficult to draw the line between additional and non-additional eligible measures when local energy efficiency programmes are in place.

In Italy, the additional element of energy efficiency measures is determined as the component exceeding market-trends or legislative (technological) requirements (Capozza *et al.,* 2006; Pavan, 2008). According to the Italian authority in charge of administering the scheme (i.e. Electricity and Natural Gas Regulator [AEEG]) the choice to apply one of these two criteria to a given energy efficiency measures is simply based on whichever sets the strictest level (see Pavan, 2008). For energy efficiency measures that use the ex-ante or engineering M&V approach, the technological baseline is embedded in the M&V calculations. In this case, additional energy savings are estimated by comparing the performance of the measure (e.g. compact fluorescent lamp [CFL]) against its specific technological baseline (e.g. incandescent bulb)—similar to the British ex-ante M&V approach. Concerning the third M&V approach (i.e. monitoring plan), the additional component of any eligible energy efficiency measures has to be established through the careful choice of the technological baseline (cf. Capozza *et al.,* 2006; Pavan, 2008).

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[65] It was estimated that by 1996, approximately 20% of all households in the UK (i.e. Great Britain plus Northern Ireland) were living in fuel poverty (Levine *et al.,* 2007:418). The Family Expenditure Survey in the UK (2000/2001) showed that whereas the top quintile of income distribution spent 1.9% of its total expenditure on gas and electricity consumption, the bottom quintile spent 6.1%.

[66] Personal communication with Charles Hargreaves (September 2005, OFGEM).

In France, the additional component of eligible energy efficiency measures, beyond the requirements of building codes, is tied up with financial and market aspects. The logic behind this approach is that profitable energy efficiency measures would have been implemented even in the absence of the TWC scheme. Here, two distinctions are made: (i) savings realised in the facilities of eligible parties and (ii) savings realised in eligible sectors (Monjon, 2006). For instance, in the event that savings are realised in the obliged party facility, an eligible measure is considered additional as long as its implementation has a long payback period (Monjon, 2006). For a non-obliged party (e.g. ESCOs), energy savings are additional if the energy efficient technology implemented in its own facility does not increase its turnover or is related to innovative products. The French scheme considers an innovative measure additional if it is more efficient than a similar standard technology and if it holds less than 10% of the market share within its category.[67] When it comes to the implementation of eligible technologies in the eligible sectors, French obliged parties face fewer requirements. Here, the additionality of a measure is simply what exceeds the current market trend—similar to the Italian approach. However, non-obliged eligible parties face the same requirements as if they were to implement measures at their own facilities. That is, they can implement measures in eligible sectors as long as savings do not increase their turnover or are related to innovative products. This requirement is likely to hamper the participation of ESCOs in the French scheme.

In TWC schemes—as in any energy efficiency related policy programme—the so-called *rebound effect* can hamper the overall performance of the policy approach. The term rebound effect refers to the increased energy demand as a result of efficiency improvements that reduce the costs for end-users (Khazzoom, 1980). In order to lessen the rebound effect of implemented eligible measures, the TWC scheme in Great Britain has taken some precautions despite inherent uncertainties. The so-called "comfort taking effect" (i.e. the energy savings deducted from those realised as a consequence of improved household comfort) is used when estimating and granting ex-ante savings generated by insulation measures—15-45% (see DEFRA, 2004:22-24).

Finally, and based on the conceptual consideration regarding both TWC schemes and the taxonomy of policy instruments given, Figure 3-3 illustrates

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[67] Personal communication with Stéphanie Monjon (March 2006, ADEME).

an attempt to position TWC schemes within the portfolio of energy efficiency policy instruments targeting the introduction and diffusion of more efficient products. Curve (A) represents the initial market distribution of any energy-using product in relation to its energy performance. In contrast, curve (B) shows the market distribution as a result of the implementation of different types of policy instruments: (i) mandatory minimum standards force or push manufacturers to improve the performance of products up to a certain threshold, although standards do not provide incentives beyond that level; (ii) then, and to the disadvantage of inefficient products, tax breaks, subsidies, information campaigns, training programmes and/or TWC schemes provide further incentives to increase and pull the market share of existing energy efficient products; and finally (iii) R&D, demonstration programmes and/or technology procurement 'pull' and support innovation processes that bring new and more efficient products into the market.
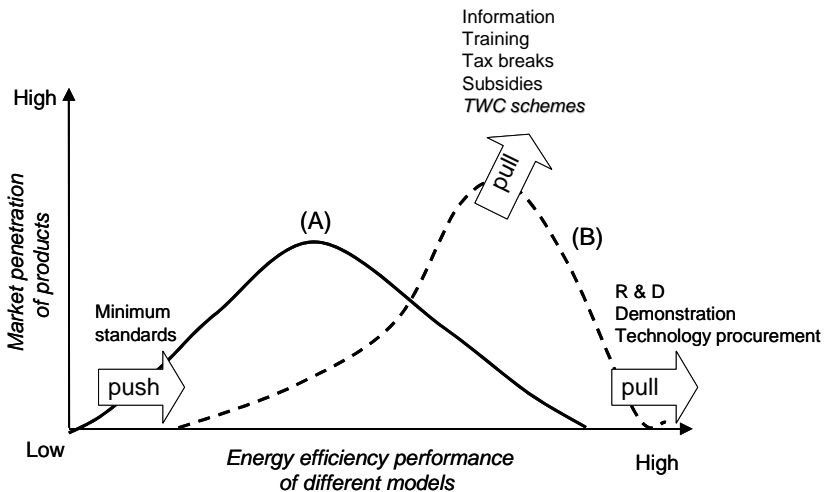
Figure 3-3: Positioning of TWC schemes within the portfolio of energy efficiency policy instruments[68]

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[68] Adapted from Laponche *et al.* (1997) and Vreuls *et al.* (2005), with inputs from Lena Neij, Chris Van Rossem and Håkan Rodhe from the International Institute for Industrial Environmental Economics at Lund University.

Four

4. Key findings and analysis

The purpose of this Chapter is to summarise the main findings and analysis of the papers included in the appendices of this doctoral thesis. In accordance with the research objective, research questions and the research methodology applied, the objective, main findings, key observations and conclusions are elaborated on paper-by-paper. Throughout the Chapter, explanations are also provided regarding the relationships between the different papers and how they build on one another. Additional detailed analysis and research findings are contained within the individual papers.

4.1 Paper I – point of departure

4.1.1 Objective

Within the context of the research, the purpose of this paper was initially to explore the potential impacts of TWC schemes. The fact that the researcher was able to make a limited contribution to the overall modelling exercise proved enlightening. The indications discerned among the results were eye-opening and thus served as a departure point for continued research.

In line with the scope of the research, the modelling exercise had the *objective* of analysing and performing an ex-ante evaluation of TWC schemes applicable to the pre-expansion (1994) EU states and to Germany and Italy individually. The main focus on the research was on energy costs.

4.1.2 Main findings

When it came to assessing the performance of TWC schemes through the use of *evaluation criteria*, the modelling work showed interesting, but only indicative results.

First, the response of the EU15+[69] Reference Energy System (RES) showed indications of *cost-effectiveness*. Initial indications were obtained by running the model and finding optimal solutions for all of the cases analysed. Furthermore, it was found that for the EU15+ market there was a techno-economic potential to increase energy efficiency by approx. 15% by 2020 at negative costs. In this case, it was found that the average unit cost of the energy system, following the implementation of a TWC scheme intended to achieve a reduction of 15% (-3 EJ approx.) in the overall energy consumption of residential and service sectors with respect to the BAU scenario, was estimated to be equal to the average unit cost of the energy system in the BAU scenario. With due limitations and assumptions (elaborated in the next section), the modelling exercise showed that the increased energy efficiency was cost free. For the case of Germany, the estimated value of TWCs, during the analysed period (2005 to 2030), was initially 6 €/MWh, then peaking at 9 €/MWh, and later returning to 6 €/MWh. The estimated peak price (in 2020) was heavily influenced by the phase-out of nuclear power. Using electricity prices as benchmarks (approx. 55 to 60 €/MWh), estimated values of TWCs were much lower. In the case of Italy, no attempt was made to approach the issue of cost-effectiveness. On the whole, however, there was a need to explicitly address the cost-effectiveness of TWC schemes.

Second, all case of the studies included in the analysis (i.e. Germany, Italy and EU15+) met the *energy-saving effectiveness* criterion. By forcing the RES for each country or region to meet a user-defined energy saving target, the applied saving targets were technically met in every case and under different scenarios.[70] This specific evaluation criterion was approached by lowering the amount of final energy consumption compared to the BAU scenario,

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[69] Note that this refers to the 15 EU member states plus Norway, Switzerland, Malta, Iceland, Gibraltar and Greenland, hereafter EU15+.

[70] For Germany, the following energy saving targets were applied: a 5, 10 and 15% reduction in natural gas and electricity consumption by the household and commercial sectors by 2030, 2010 and 2020 respectively compared to the base case scenario. Due to the fact that the introduction of energy saving targets increased the use of district heating generation using biomass, a second scenario (albeit with the same target levels) was modelled, including district heating as part of the overall scheme. This was done in order to explore greater possibilities of energy efficiency in the household and commercial sectors. For further details see Blesl (2004). For Italy, the following energy saving targets were applied (in primary energy equivalent reduction): 1.6 Mtoe of electricity and 1.4 Mtoe of thermal energy by 2010 for all eligible end-use sectors under the TWC schemes. For further details see Gracceva *et al.* (2004).

while always keeping energy service demands satisfied. Regarding the so-called rebound effect, as a threat to the effectiveness in terms of energy savings under TWC schemes, no sign of this could be observed in the modelled TWC schemes (EU15+ and Germany). However, this was due to the nature of the modelling approach rather than an outcome ascribed to the modelled TWC schemes as such. This is because the mandatory energy saving targets were imposed as caps or maximum levels of final energy consumption. Consequently, the eligible end-use sectors in the RES were not allowed to use more energy than the amount defined by the modeller.

Third, and concerning *environmental effectiveness*, emission reductions did occur as a result of the modelled TWC schemes in all cases studies. In addition to the emissions reductions reported in paper I, the German case, for instance, showed other significant emissions reductions.[71] Indexed in relation to the baseline year 2000, CO_2 emissions reductions from the household and commercial sectors ranged from 5% (by 2010) to 27% (by 2030). However, no explicit evaluation was conducted to determine the merit of TWC schemes in this regard. On the whole, the modelling exercise revealed the need for a better approach regarding this evaluation criterion and to use explicit benchmark(s) to determine the performance of TWC schemes.

4.1.3 Key observations

Several *advantages* and *limitations* were encountered when using MARKAL as an evaluation method. In terms of advantages, this optimisation modelling tool (and its components such as VEDA[72] and ANSWER[73]) showed itself to be a resourceful tool for creating analysis models for systems, including those in all energy sectors from primary energy units to energy services (e.g. expressed in specific units, such as passenger/km), or those limited to energy supply and/or selected end-use sectors of final energy demand. In addition, and always with a systems approach emphasis on the entire RES, using MARKAL served to determine intra-temporal equilibriums and inter-temporal perfect foresight. These aspects were considered critical when analysing TWC schemes in energy systems with large technological

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[71] Due to the extensive amount of results, note that not all the findings could be reported in paper I. See Blesl (2004) for further details about the German case.

[72] For information about VEDA visit http://www.kanors.com/userguidebe.htm

[73] For information about ANSWER visit http://www.noblesoft.com.au/

databases that include an enormous amounts of data and hundreds of variables that need to be handled simultaneously.

In contrast, certain limitations or challenges were also found when using MARKAL to ascertain the performance of TWC schemes. For instance, the modelling tool does not capture investment decision processes and behavioural aspects (cf. Hourcade *et al.,* 2006). Driven by a cost-minimisation objective function, MARKAL is a model generator that seeks minimum cost, assuming that market forces will automatically reach this techno-economic potential. Therefore, it has limited capacity to simulate market failures (e.g. imperfect information) and approach the market potential for increased efficiency. In the model, (technical) information is freely available and the capital necessary for investment is also available. In the light of the research, these aspects were critical because there is compelling evidence that multiple market conditions prevent increased energy efficiency (see e.g. Jaffe and Stavins, 1994a, Sanstad and Howarth, 1994). Therefore, there was a need to discuss policy implications arising from these limitations (see paper II). In addition, and regarding TWC schemes as such, MARKAL fell short in capturing market size, price speculations, volume of TWCs banked and transaction costs. These aspects were captured in subsequent papers when performing ex-post evaluations.

Based on the results of this first ex-ante modelling exercise, the analysis identified the *core analytical framework for further in-depth studies*. For a future modelling exercise (as elaborated in paper II), there was a need to explicitly address certain important, although only initial, sets of evaluation criteria, such as cost-effectiveness and environmental effectiveness. For instance cost figures in paper I were related to average energy system costs. However, estimates regarding marginal energy savings costs are more useful in the light of TWC schemes and their economic rationale. In addition, it was necessary to utilise the opportunity, provided by MARKAL, to explore in detail the energy demand side. Although this gave certain indications regarding the supply of TWCs, much work and analysis remained to identify specific key sources of increased energy efficiency (e.g. per eligible end-use sector, fuels and energy service demand). Finally, underlying modelling assumptions had to be explicitly addressed in the light of policy implications when designing and/or implementing TWC schemes. Among others, the aspects listed above served to develop the analytical framework applied in paper II.

The limitations of the modelling approach also confirmed the *need to expand the use of evaluation criteria*. This supported the initial research design regarding

the analysis of aspects not possible to capture with the applied optimisation tool (as elaborated in paper I and paper II).

For instance to support the modelling work, the initial review of existing TWC schemes—in particular the Italian one—gave early indications about the challenges faced by TWC schemes in terms of *political feasibility*. At the time of writing paper I, the Italian scheme was giving strong signals of delayed implementation due to political difficulties; which were also linked to technical issues. Among others, critical difficulties were found to be (i) the need to consider a wide range of eligible technologies and developing M&V approaches for the certification of a variety of eligible options; (ii) the uncertain role of regional governments in the scheme, and their disagreement with the central government on the decentralisation of energy issues; and (iii) the negative or passive attitude of distributors of electricity and gas to become obliged parties thereby being forced to carry out demand-side management activities. These aspects started to show that the initial claims of high political feasibility in the discourse to support the implementation of TWC schemes appeared to exaggerate what could reasonably be anticipated. The aspects affecting the political feasibility of the Italian TWC scheme were re-visited at the end of research (see paper V).

Following on the need to expand the evaluation framework was the fact that, as previously noted, *transaction costs* were not addressed during the modelling exercises. This limitation supported the initial research plan to examine transaction costs, in particular from an ex-post standpoint as evidence is derived mainly from experience (cf. Stavins, 1995; Tietenberg, 2006). The study on transaction costs (see paper III) also included market behavioural aspects. Furthermore, the optimisation tool did not capture the dynamic of TWC markets as such. This crucial research aspect led to the development of a specific analytical framework around the concept of *flexibilities* granted to obliged parties to achieve their energy savings targets cost-effectively. This approach was developed with the aim of providing a comprehensive picture of market behaviour under TWC schemes (see paper IV). Additional evaluation criteria not captured in the modelling approach, such as *administrative burden* and *economic efficiency,* were addressed in paper V.

4.1.4 Conclusion

Paper I was an important but only initial building block for this doctoral thesis. Given several basic assumptions, results suggested that a TWC scheme has the capability of realising the techno-economic energy efficiency

potential. In this context, certain preliminary policy conditions were identified. First, supportive policy instruments are needed to reduce or eliminate the lack of information and uncertainties regarding the technical and financial performance of eligible measures. Second, results also underscored the need to address and overcome capital barriers to ensure the availability of financial resources needed for investment. Third, policy makers need to define approaches that reduce the burden of transaction costs for obliged parties related to M&V of energy savings. The findings strongly indicated that the evaluation of TWC schemes required much more complementary research and that the modelling approach needed a more explicit evaluation framework. Furthermore, the research findings also supported initial research concerns regarding the use of additional methods and criteria to complement modelling studies and evaluate TWC schemes. In particular, limitations of the modelling approach stressed the need to investigate aspects such as market behaviour and transaction costs.

4.2 Paper II – a broader ex-ante evaluation

4.2.1 Objective

The objective of paper II was to *perform an ex-ante evaluation of a hypothetical EU-wide TWC scheme* (i.e. national TWC schemes are implemented and international trade of TWCs is allowed). The research focused on analysing the potential effects of implementing an EU-wide TWC scheme considering three evaluation criteria: *cost-effectiveness*[74]*, environmental effectiveness and distributional equity*. Assumed designed features of the modelled EU-wide TWC are found in paper II.

The evaluation criteria were addressed by research different methods. The first two evaluation criteria were approached using the mathematical E^3 simulation model (as in paper I). The modelling exercise carried out in paper II allowed the analysis of energy service demands yielding the most cost-effective energy saving potentials. The third evaluation criterion

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[74] Note that as an evaluation criterion, *cost-effectiveness* is defined as whether a policy instrument minimises the costs of meeting the imposed (energy saving) policy target (i.e. achieving the target at the lowest possible cost). On the other hand, *cost-effectiveness of energy savings* is defined as the lowest marginal lifecycle costs per unit of energy saved (i.e. Euros per extra unit of final energy saved). In other words, high marginal lifecycle costs per unit of final energy saved mean that an EU-wide TWC scheme is *less* cost-effective.

complements the quantitative part of this study. It addressed the potential cost distribution and benefits embedded in a TWC scheme.

4.2.2 Main findings

Indications of *cost-effectiveness* came from different angles. First, it was possible to identify optimal solutions in the model for all of the energy saving targets investigated.[75] By meeting energy service demands in all cases, results showed that different energy saving targets were met at the lowest possible cost. Second, minimum and maximum household energy fuel costs (excluding taxes and value-added tax) of countries included in the EU15+ model were used as benchmarks for comparison (see Figure 4-1).

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[75] Different cumulative annual saving targets relative to the base case (final energy consumption) were modelled: (i) *target-A* represents a low-ambition target, with 1% per year from 2005 to 2010; and 0.3%/year from 2010 to 2020. This leads to cumulative energy savings of 10% by 2020. In absolute terms, this account for 1,938 PJ (or 538 TWh), (ii) *target-B* represents a relatively more ambitious target, with 1% per year from 2005 to 2010; and 2% per year from 2010 to 2020. This leads to cumulative energy savings of 27% by 2020. In absolute terms, this cumulative target accounts for 5,108 PJ (or 1419 TWh), (iii) *target-C* represents an ambitious target, with 2% per year from 2005 to 2010; and 4% per year from 2010 to 2020. This leads to cumulative energy savings of 56% by 2020. In absolute terms, this cumulative saving level represents 10,404 PJ (or 2890 TWh).
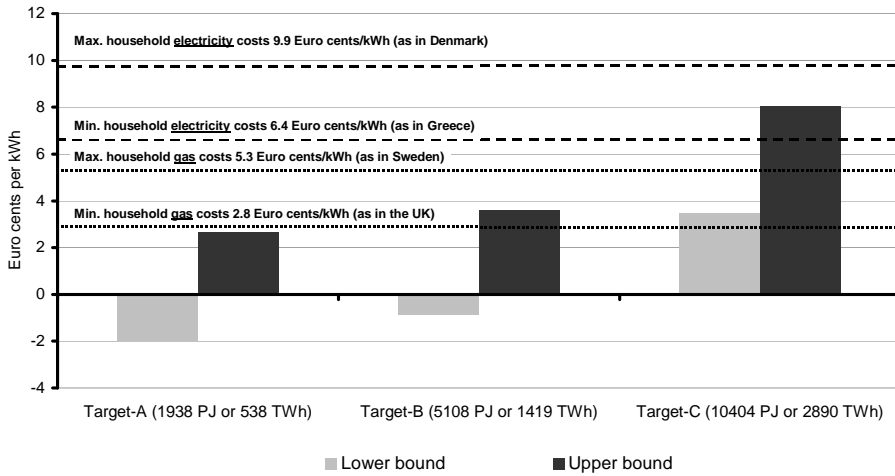
Figure 4-1: Lowest and highest marginal lifecycle energy savings costs under different cumulative energy saving targets (2005–2020)

For the different energy saving targets that were analysed, Figure 4-1 shows marginal lifecycle energy savings costs ranging from –2 to 8 Euro cents/kWh. The results showed that depending on what fuel is saved to create a TWC, different techno-financial (i.e. no externalities included) cost-effective potentials of energy savings could be identified. Using energy prices as benchmarks, this approach showed that cost-effective compliance could range from 530 TWh (i.e. 10% of cumulative energy savings) to approx. 1,500 TWh (i.e. up to 27% cumulative energy savings) approx. For instance, one can observe minimum and maximum nominal electricity costs corresponding to Greece (lowest) and Denmark (highest), respectively. Based on these values, both targets A and B were met cost-effectively. In others words, even if the lowest electricity costs (as in Greece) are used as a benchmark, more than 1,500 TWh of techno-economic potential exists to generate financial benefits by 2020. One can also observe that a minimum gas price alone can ensure financially cost-effective savings under target A, and for most of target B (approx. 20% target). Results were consistent with other studies that had estimated cost-effective potentials of 27% and 30%

for the household and commercial sectors respectively (see European Commission, 2006a:5-6).[76]

When exploring the cost-effective supply of the TWCs, the research looked at three different levels: eligible sector, eligible fuels and energy service demands. Based on the results, the cost-effective supply of TWCs was predominant in the household sector for all of the energy-saving targets applied. In terms of eligible fuels, gas dominated the supply of TWCs. Electricity savings were also significant in the household sector. In the commercial sector—in which electricity savings were slightly higher than gas savings—savings related to both fuels were equally relevant throughout the period analysed. In all cases, electricity and gas represented the main sources of cost-effective savings, yielding 85, 82 and 77% of cumulative energy savings by 2020 under targets A, B and C respectively. Concerning the sources of TWCs as regards energy service demand, results showed that whereas space heating represented the dominant source of savings within the household sector, lighting and space heating were equally relevant within the commercial sector. Trends were consistent in all scenarios for both sectors and the main types of fuel under analysis. As an example, Figure 4-2 illustrates some of the results obtained.

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[76] The results also were consistent with previous studies that show technical and economic cost-effective energy efficiency potentials of around 20% for the EU-15 as a whole (see European Commission, 2005:4).
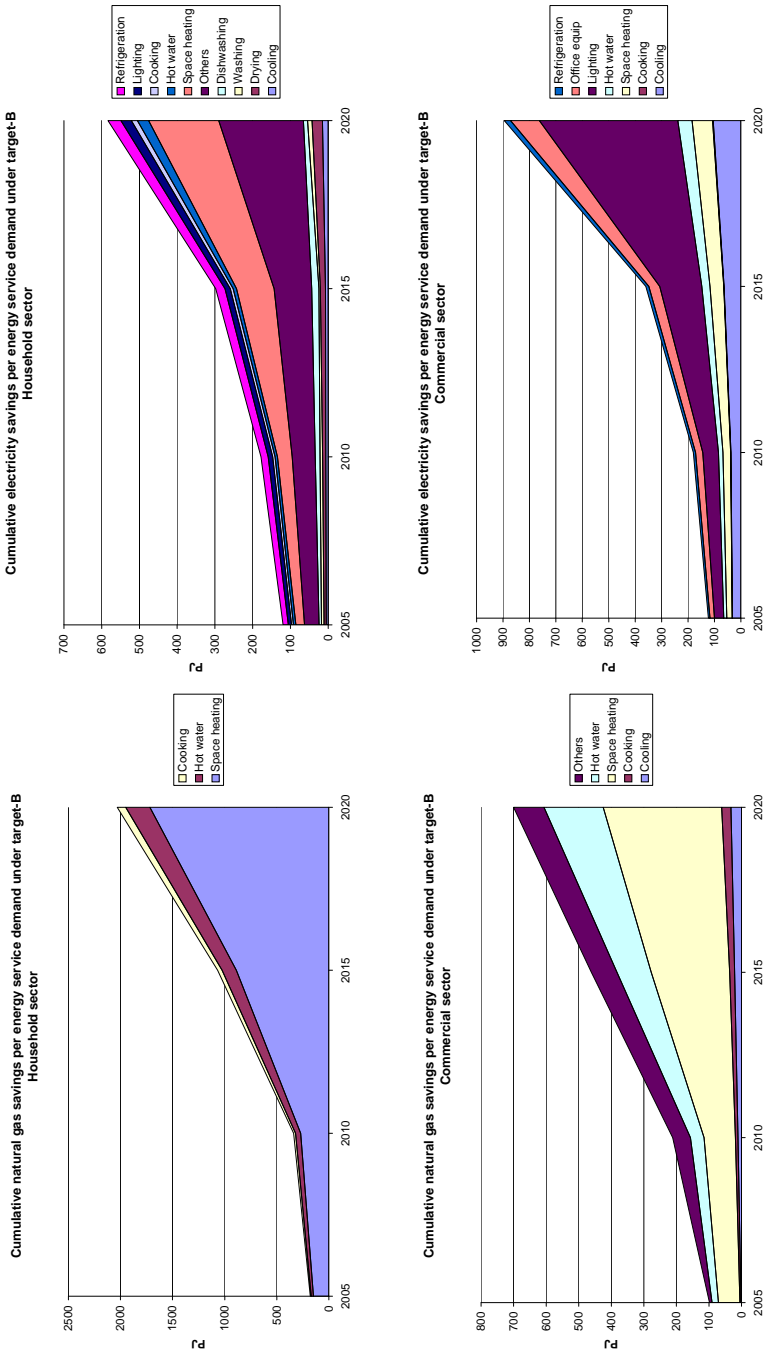
Figure 4-2: Supply of TWCs under target-B. Sources are shown per eligible sector, eligible fuel and energy saving demand

A third indication of cost-effectiveness came when investigating cost figures from the societal point of view (i.e. externalities included). Data on external costs generated by the ExternE Project[77] were used to derive a cost-effective techno-economic potential. Based on this data source, negative external costs of *electricity* production/consumption were estimated to range from 0.8 to 4.6 Euro cents/kWh. In turn, these values represented the lower and upper levels of economic benefits, or avoided external costs, when electricity is saved. Taking into account an average external cost of 2.7 Euro cents/kWh, as well as average marginal energy savings costs for the different analysed energy saving targets, a cost-effective techno-economic potential from the societal point of view was estimated (see Figure 4-3).
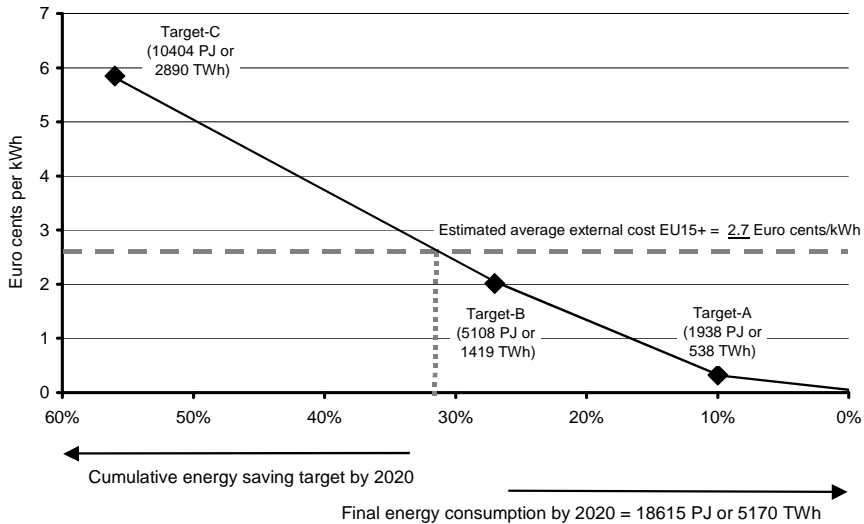
Figure 4-3: Estimated societal cost-effective potential of cumulative energy savings by 2020

One can observe that using a single market price of social and environmental damage costs of energy production—even though marginal external costs are unlikely to be constant—it is economically worth it for the society to save energy up to a level of approximately 32%, in which marginal

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[77] For further information visit http://externe.jrc.es/

energy savings costs are equal to the damage costs of energy production/consumption.

From the evaluation standpoint, the *environmental-effectiveness* criterion considered whether the modelled TWC scheme achieved a given environmental target. However, in the absence of an explicit environmental policy target, it was assumed that the EU-wide TWC scheme aimed to support the attainment of the EU 'bubble' Kyoto target of approx. 340 Mt CO_{2-eq}, by 2008–2012 compared to 1990 emission levels. This target was taken as a benchmark for comparison. Thus, the modelling exercise focused on 2010, as this year is usually taken as the "centre of gravity" relative to the first Kyoto commitment period (2008–2012). On the whole, the estimated contribution of the modelled TWC scheme at any target level by 2010 ranged from 57 to 60% of the EU 'bubble' Kyoto target.

To complement the modelling results, the study explored *distributional equity* aspects from the qualitative standpoint. Two issues were considered: burden of compliance costs and ancillary benefits. In terms of *compliance costs*, investment cost-recovery mechanisms can play a key role because obliged parties are entitled to recover their compliance costs through energy tariffs. While obliged parties are responsible for meeting the target from the operational standpoint, end-users are, in principle, financially responsible. In fact, under TWC schemes equity aspects are relevant because it would be unfair if some end-users were to benefit financially from improved energy efficiency while passing on the costs of such investments to others. Prima facie, one could argue that investment costs could be equally distributed across all end-users. Therefore, cross subsidies may be occurring and (low-income) households that have *not* implemented measures could be facing an unfair financial burden. It could be thus argued that distributional effects of TWC schemes may be regressive if the net benefits represent a larger share of the disposable income of the rich than of the poor.

Regarding *ancillary benefits*, it was found that TWC schemes can bring/trigger positive effects at the local/national level because of increased energy efficiency. Potential co-benefits were identified as: (i) increased competitiveness and employment generation, (ii) reduced fuel poverty, (iii) reduced atmospheric pollution, (iv) improved housing stock and (v) security of energy supply. The findings clearly suggested that if co-benefits are taken into account, a higher level of energy saving is encouraged and the economic attractiveness of an EU-wide TWC scheme increases. While ancillary benefits might be realised anyway if targets are met, the key issue is how

these co-benefits may be distributed. Here, and driven by the economic rationale of TWC schemes, one can easily infer that local ancillary benefits can be obtained in EU countries that realise energy savings with the lowest marginal costs.[78]

4.2.3 Key observations

On the whole, the *order of magnitude of the quantitative economic and energy outcomes depended heavily on the level of ambition expressed by the applied energy saving target.* This finding strongly suggested that if TWC schemes are to play a policy relevant in the energy/environment interplay, high ambitious targets are critical design elements. In addition, the results also confirmed policy aspects regarding the timing and speed of the market transformation required to cope with different levels of mandatory energy saving targets. On the whole, modelling results were consistent for each case analysed (i.e. per end-use sector, eligible fuel, and energy service demand) regardless of the variations in energy saving targets. The estimates were also consistent with figures for the household and commercial sectors included in the European Action Plan for Energy Efficiency. These aspects seemed to point out the robustness of the model. Quantitative findings underscored the need to identify the actual level of ambition of energy saving targets under current TWC schemes in ex-post evaluations.

Most of the GHG emissions reductions occurred upstream in the energy system. The *results confirmed some concerns regarding potential linkages between a TWC scheme and the EU Emission Trading Scheme (EU-ETS).* This is because electricity savings resulting from a TWC scheme frees up allowances on the supply side, creating in principle, certificates in two different markets.[79] For instance, this can trigger free-riding effects in the EU-ETS if electricity related emission reductions due to a TWC scheme are not taken into account in GHG national allocation plans. Thus, there is a risk that the

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[78] Due to the aggregated nature of the EU15+ MARKAL database, it was assumed that a common EU mandatory energy saving target is determined through a top-down policy process; then apportioned nationally and in absolute terms according to the market share of obliged parties. Thus, international trade can exist because TWCs can then be traded on the EU TWC market.

[79] An offset value can be attached to a TWC; which can be estimated by a carbon emission conversion factor given by the electricity mix.

environmental integrity of the EU-ETS scheme is hampered.[80] In all, results indicate that claims about GHG emission reductions from electricity savings under a TWC scheme become technically complex in the presence of the EU-ETS.

Some *trade-offs were clearly identified when analysing the feasibility of an EU-wide TWC scheme.* If the key policy goal is to increase energy savings at the least-possible cost, cost-effectiveness can be taken as the key criterion and international trading is much more advantageous. An EU-wide TWC scheme substantially increases the number of eligible parties—a key condition for high market liquidity—and reduces the risk of market power because a high concentration of the obligation in only one party is less likely.[81] In turn, this reduces the risk of creating monopolistic and/or monopsonistic market conditions. However, one can also assume those EU member countries that, inter alia, offer high cost-effective potentials and fewer market barriers can probably benefit most from the distribution of ancillary benefits that a TWC scheme can trigger. In turn, this implies a disadvantage for EU countries that have been historically committed to increased energy efficiency. This potential scenario clearly indicates a trade-off between cost-effectiveness and distributional equity (i.e. how to safeguard equity without hindering cost-effectiveness).

In addition, the *trade-off between distributional equity and cost-effectiveness also underscored the importance of political feasibility as a dependent criterion.* This raised a variety of policy concerns. For instance, would end-users from country A be willing to afford, via higher energy tariffs, energy efficiency improvements in country B? Would there be any interest in supporting the national implementation of eligible energy efficiency measures that are not necessarily cost-effective but yield attractive co-benefits? How can ancillary benefits embedded in national TWC schemes be secured when trade in TWCs is conducted internationally? Some of these early policy indications turned out to be validated later on when performing ex-post evaluations. As found and further elaborated in papers III and IV, ex-post results showed indications of autarky compliance strategies adopted by obliged parties to guarantee commercial benefits of increased energy efficiency.

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[80] See Bertoldi and Rezessy (2006) and NERA (2005) for more on interactions between TWC schemes and the EU-ETS.

[81] Market power is herein understood as how an obliged party under a TWC scheme can manipulate the market to its own advantage (i.e. influence the price of TWCs).

As far as the *policy implications of the results for the assumptions of this study were concerned*, certain key policy aspects and conditions could be identified. First, the theoretical benefits presented in the study should not underestimate the challenges associated with getting a TWC scheme to work effectively. For instance, a crucial assumption was the harmonisation of current national frameworks that would allow the operation of an EU-wide TWC scheme. However, one could expect that this task is likely to be cumbersome for policy makers before an EU-wide TWC scheme is implemented. Policy challenges could relate to agreements on energy savings target level; the set of eligible parties, sectors and measures; non-compliance rules; additionality; and M&V approaches.[82]

Second, *the successful performance of any TWC scheme also depends on the actual range of eligible measures, transaction costs, and the rebound effect*. Whereas the modelling exercise assumed that all relevant technologies are in fact eligible, in practice the definition and due enforcement of additionality may have a significant impact on the portfolio of measures, and thus the estimated order of magnitude of cost-effective potentials. The broader the set of eligible measures, the more flexibility is given to parties to achieve their target cost-effectively. However, a larger set could, in practice, trigger free-riding effects and higher transaction costs resulting from M&V activities. The study carried out in paper II also assumed low or zero transaction costs for both obliged parties and end-users. However this is unlikely to hold in practice—as analysed in paper III. When it came to the so-called rebound effect, no sign of this was observed in the modelled EU-wide TWC scheme. Once again, this was due to the nature of the modelling approach rather than an outcome accredited to the modelled TWC scheme as such.[83] On the one hand, both the rebound effect and transaction costs indicated that the estimated cost-effective potentials under this study were overestimated. On

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[82] Note that when comparing ex-ante M&V approaches used in current TWC schemes, substantial differences were observed, even if well understood technical eligible technologies are considered. For instance, lifetime savings attributed to a compact fluorescent lamp (CFL) can range from 100 to 330 kWh across countries. Assumptions driving this wide range of estimates are: (a) different discount rates (from 3.5 to 6%), (b) different lifetimes (from 6 to 14 years), and (c) usage (or not) of "comfort taking" factors (cf. Capozza *et al*, 2006:140).

[83] For the household sector, it is argued that the direct rebound effect is likely to be around 30% and may be lower in the future due to saturated energy demand (see Greening *et al.,* 2000:398; Sorrell, 2007:36-39). Whereas concerns about the rebound effect are valid for any instrument targeting energy efficiency, it is worth noticing that empirical evidence shows that the rebound effect is likely to be small—in the range of 0 to 15% (see Berkhout *et al.,* 2000:425).[83]

the other hand, updated estimates of the damage of climate change and increasing fuel prices may suggest that potentials were underestimated.

Third, and taking into account the limitations of the E³ mathematical simulation model, *the study assumed that fewer market failures and barriers facilitate the penetration of eligible energy efficiency technologies.* For an EU-wide TWC scheme to perform as the quantitative part of the study showed, assumptions undertaken strongly indicated that high effectiveness of supportive policy instruments was necessary to encourage a more rational behaviour of end-users:

- Uncertainties and risks about technical and financial performance are reduced for end-users because of information provided by equipment manufacturers/dealers, obliged parties, ESCOs, and public authorities.

- Transaction costs for obtaining reliable information are reduced for end-users due to fact that information gathering and the learning process about the functioning of new technologies is organised and facilitated by obliged parties (also contractors working on their behalf), retailers, ESCOs, and information centres providing specific and practical information about new technologies.

- More and cheaper energy efficiency equipment is available in retail stores because obliged parties and retailers work together to target end-users, leading to an eventual aggressive marketing campaign and thus increased awareness among end-users.

- Low-income households have more access to capital because of supportive financial mechanisms set by obliged parties and public authorities for eligible measures in which incremental costs are high.

- End-users are keen to implement new technologies because some of them are entirely or partly subsidised by obliged parties or governmental programmes.

- Increased awareness amongst end-users exists because of extensive information campaign launched by public authorities about the individual and societal benefits of increased energy efficiency as well the functioning of a TWC in particular. In turn, this reduces transaction costs for obliged parties in relation to their search for customers willing to implement measures.

Several of the policy aspects listed above were identified later in the research on critical policy conditions affecting the performance of TWC schemes (see papers III, IV and V).

4.2.4 Conclusion

It was concluded that an EU-wide TWC scheme appears to meet the criteria for cost-effectiveness and environmental effectiveness—assuming full compliance with energy saving targets and ensuring that energy service demands are always met. Quantitative results suggested that an EU-wide TWC scheme could largely contribute to realising cost-effective energy saving potentials in the household and commercial sector. Adding the social and environmental benefits of energy saved, the arguments for energy efficiency improvements under an EU-wide TWC scheme are strengthened. To be equitable, the costs of energy savings should be borne by those who benefit from increased energy efficiency. Due to the fact that there are many potential co-benefits, EU countries may oppose an EU-wide TWC scheme in order to capture these benefits nationally, i.e. a national autarky compliance strategy that attempts to maximise net present welfare without international trading. Consequently, the policy choice grows complex because of the trade-off between cost-effectiveness and distributional equity. Assumptions undertaken by the modelling approach strongly indicated that a high level of effectiveness is necessary in the supportive policy instruments for an EU-wide TWC scheme to deliver cost-effective energy savings. On the one hand, informative policy instruments are required to reduce uncertainties and transaction costs, and to support related technological learning processes. On the other hand, economic policy instruments that provide adequate capital are critical in supporting the necessary investments in new energy-efficient technologies.

4.3 Paper III – transaction costs and early indications of market behaviour

4.3.1 Objective

The objective of paper III was to *perform an ex-post evaluation focused on transaction costs* (TCs). Taking the first phase (2002–2005) of the scheme implemented in Great Britain as a case study, paper III identified and analysed the nature and scale of TCs borne by obliged parties (e.g. search for

information, due diligence, negotiation of contracts, M&V). The paper also investigated whether TCs had prevented or hampered trading of energy savings. At the time of research, very little attention had been given to the evaluation of TWC schemes in general, and the literature addressing the topic was limited and being confined to theoretical aspects (see e.g. Bertoldi and Rezessy, 2006; Langniss and Praetorius, 2006).

4.3.2 Main findings

Although the study was narrowed to TCs only, a substantial amount of information was obtained. Furthermore, the analysis of TCs revealed early patterns of market behaviour under TWC schemes.

The *nature of TCs* was examined first. Following the lifecycle of certificates under TWC schemes (described in Section 2.4.1), Figure 4-4 illustrates the sources of TCs identified that are further elaborated below:
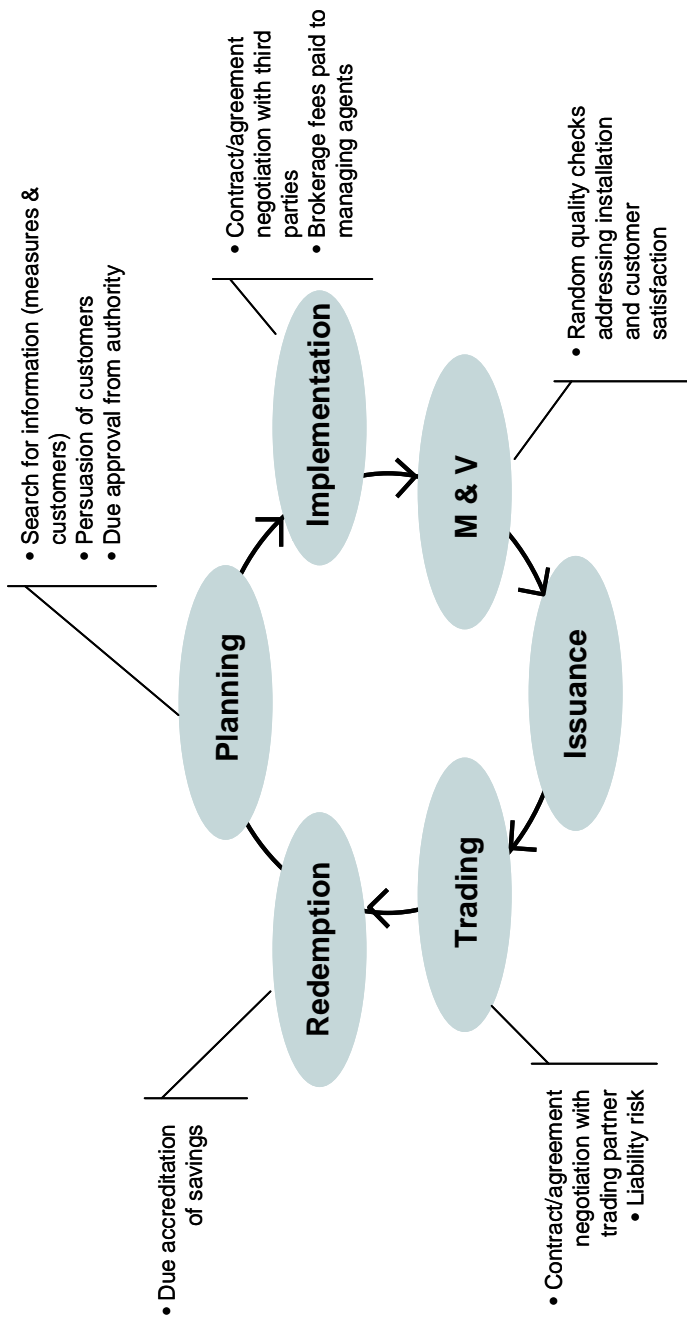
Figure 4-4: Identified sources of transaction costs under the British TWC scheme

a) *TCs related to the planning of eligible measures.* The first source was related to the *search for information*, in terms of what measures to use and what customers were willing to implement. Finding customers willing to implement measures, in particular labour-intensive measures (e.g. cavity wall insulation), was cumbersome. The second source of TCs was related to the *persuasion of customers* to implement measures. This led to intensive negotiation efforts and co-operation between obliged parties and third parties (e.g. social housing programmes, retailers). The cause of this source of TCs was the apathy and the lack of awareness of households regarding implementation of energy efficiency measures as such. The third source of TCs is associated with the *due approval of proposed measures* from the regulator (i.e. Office of Gas and Electricity Markets [OFGEM]). Having the correct information was critical for the obliged parties, as endorsement by the regulator was needed before implementation can take place.[84]

b) *TCs related to implementation of eligible measures.* Basically, there was one general source of TCs under this phase, namely, *negotiation of agreements/contracts with third parties* (i.e. consultants, contractors and retailers). First, obliged parties hired professional services to handle their obligation. This included managing agents or middlemen in charge of administering the planning and implementation of measures, including identification of customers. For instance, managing agents charged up to € 14 per customer identified as willing to implement insulation measures. Second, obliged parties hired insulation contractors. The relationship between suppliers and contractors was identified as critical for meeting the supplier's obligation, because nearly 100% of insulation was outsourced. Third, obliged parties worked with retail companies to increase the penetration of efficient appliances (e.g. A-rated refrigerators). Parties provided financial incentives to retailers to stock more efficient appliances in return of strong marketing efforts related to efficient appliances.

c) *TCs related to M&V.* The main source of TCs is directly linked to *random quality checks* activities performed by obliged parties in relation to installation and customer satisfaction—as required by the regulatory framework. Once eligible measures were implemented, obliged parties

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[84] The authority's task was—and still is—to check whether a proposed measure qualifies under the British TWC scheme in terms of being *additional* when compared with BAU trends.

were required to monitor a proportion of all installations (e.g. 5%) with respect to the exact number of measures implemented (e.g. fulfilment of quality standards, how consumers utilised the measures). According to the obliged parties, telephone interviews, questionnaires, and random home visits were undertaken for monitoring. Due to the apathy or indifference on the part of customers regarding feedback, suppliers often provided incentives (e.g. free television sets).

d) *TCs related to trading*. Results showed that TCs did not prevent the trading of energy savings and/or energy saving obligations. It was revealed that the low level of trading (see below for details) was, to some extent, caused by *perceived TCs related to contract negotiation* and *liability risks in case of non-compliance*. Obliged parties perceived that when negotiating bilateral trading of energy savings, strategically sensitive information (e.g. compliance costs) could hypothetically be disclosed to a buyer/seller who was actually also a competitor, resulting in negative commercial effects. Obliged parties also found it risky to embark on trading in the absence of clear legal frameworks for determining liability in case of non-compliance.[85]

e) *TCs related to redemption*.[86] Only one source of TCs was identified. This was associated with the *due accreditation of savings* from the regulator to the suppliers. Here, TCs were related to the person-to-person costs of researching and assessing information during the quarterly process of declaring savings to the authority. At this stage, documentation was critical in terms of suppliers being accredited with energy savings to offset their obligations.

The above-listed sources led to an aggregate estimation of the *scale of TCs*. For electricity savings derived from CFLs, it was estimated that TCs increased the costs of energy savings by 8 to 12%. Concerning gas savings realised through cavity wall insulation, the study showed that TCs entailed a financial burden that ranged from 24 to 36% per kWh saved. Taking into account the estimated scale of TCs, energy savings costs were calculated to be approx. 0.8 and 1.3 Euro cents/kWh for electricity and gas savings

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[85] TCs related to search for trading partner were not identified. This can be attributed to the fact that the number of obliged parties was rather limited, accounting for only eight energy suppliers.

[86] Note that under the British TWC scheme, there is no *redemption* of certificates as such, but a *declaration* of energy savings.

respectively.[87] Taking considering energy prices (i.e. operating costs) paid by households in 2004 as benchmarks[88], net financial savings for end-users were estimated to range from 2.8 to 8.6 Euro cents/kWh for electricity savings and about 1 Euro cent/kWh for gas savings. When the external costs avoided through electricity savings were included, the estimated economic benefits ranged from 4.7 to 11.8 Euro cents/kWh approx. In fact, the cost-benefit analysis performed under paper V confirmed net benefits for British society.

Regarding *TCs and trading*, the study brought to light many important aspects that were further investigated in paper IV. First, international observers of the British scheme speculated that no trading had occurred during the first phase. However, it was found that trading did occur. On the one hand, six obliged parties retroactively bought energy savings generated under other governmental programmes. On the other hand, two trades of energy saving obligations also took place, with some parties trying to jointly achieve their energy saving obligations (see papers III and IV for details).[89] Second, some policy makers and scholars also argued that TCs negatively affected the level of trading, and that this had been the reason why trading did not occur. Contrary to expectations, the study found that only perceived TCs had affected the low level of trading. The key question was then, *why did a low level of trading activity characterise the first phase of the British TWC scheme?* A number of interrelated aspects were found:

a) *Cost-effectiveness and excess of energy savings supply.* For energy suppliers, it was cheaper to implement their own measures to meet targets than to buy energy savings from other suppliers. Individual excess of supply also hindered trade among obliged parties.

b) *Penalty for non-compliance.* The excess of supply of energy savings was also driven by the fact that suppliers wanted to avoid as much as possible the financial risks related to the penalty for non-compliance (i.e. up to 10% of obliged party turnover)

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[87] These estimates include investment costs borne by both obliged parties and end-users.

[88] Approx. 9.4 and 2.3 Euro cents/kWh for electricity and gas respectively (excluding VAT).

[89] As already noted, the British TWC scheme is not a certificate-based scheme as such. However, it gives obliged parties the flexibility to trade bilaterally their obligations and realized energy savings. Therefore, the British scheme is usually regarded as a TWC scheme.

c) *Banking option and approval from the authority*. Obliged parties saw the scheme as a rolling programme and decided to bank the excess savings rather than trade them. In addition, trades require the approval of the regulator, which also inhibited obliged parties from engaging in trading.

d) *Strategic learning approach*. Energy efficiency still represented a relatively new area of activity for obliged parties. They argued that implementing their own measures was strategically important to gain knowledge and experience in a long-term perspective.

e) *Low market liquidity and financial gains*. The liquidity of the market was restricted because only obliged parties (a total of eight at the time of research) were allowed to trade. Furthermore, as suppliers dealt mainly with the same insulation contractors, they faced very similar purchase costs. Thus, there were only marginal differences in costs, which provided few financial incentives for trading.

f) *Increased competitiveness*. By implementing their own set of eligible measures, certain obliged parties were able to expand their product and customer portfolios and improve customer relations. Buying energy savings from another obliged party was perceived as supporting a competitor's branding. Thus, increased competitiveness was seen as an important commercial benefit of non-trading. This was a major research insight from the study that was further investigated in paper IV.

4.3.3 Key observations

Regarding the specific *nature* of TCs, the information gathered showed that searching for information and persuading customers were important sources of TCs. Results suggested a number of market conditions explaining this situation. For instance, results showed that there was a *perception gap* among households regarding investment costs. People believed eligible measures would cost, say € 1,500 – € 3,000 when the actual amount was around € 140 – € 280[90] depending on whether the household belonged to a "priority" or "non-priority" group.[91] Furthermore, the *split-incentive problem* (see Howard

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[90] Personal communication with Charles Hargreaves (September 2005, OFGEM).

[91] As mentioned in previous sections, it has to borne in mind that the British TWC scheme aims to reduce fuel poverty. Thus, obliged parties must target the so-called priority group, defined as households receiving "certain income-related benefits and tax credits" (OFGEM,

and Sanstad, 1995) was identified, with tenants reluctant to implement eligible measures because they might move out before realising the financial savings of increased energy efficiency. In addition, active co-operation between obliged parties and third parties was highly necessary because of householders' confusion and ultimately their mistrust of the obliged parties (i.e. energy suppliers under the British scheme), who were urging them to save energy.

The *apathy* or *lack of awareness* among households underscored the fact that the performance of a TWC scheme depends on how effectively awareness is raised among end-users. Aware of this scenario, the British government launched the "EEC Campaign"[92] in early 2005 to raise awareness. Although the campaign had a € 3.3 M budget, it had only a marginal influence on increasing awareness about energy efficiency and the British scheme as such (EST, 2005). The findings suggested that, for a TWC scheme to deliver cost-effective energy savings, the effectiveness of informative policy instruments needed to be sufficiently high upstream in a TWC scheme. In addition, the indifference of householders to energy efficiency could also be explained by fuel pricing. Since 1990, gas and electricity prices paid by UK consumers fell in real terms by approximately 16% and 25% respectively, compared to 2004. Thus, lowering returns on investments in energy efficiency. As one interviewee put it, low energy prices mean that "there is very little appetite for energy efficiency" in households. Although the scheme was intended to change individual behaviour regarding energy efficiency, interviewees agreed that much of the success in terms of delivered savings was due to the efforts of obliged parties, rather than the enthusiasm of householders (i.e. *market push* rather than *consumer pull*).

Regarding estimates of the cost-effectiveness of energy savings, it has to be acknowledged that *administrative and marketing costs* were not considered. However, this was because of a lack of specific accounting by obliged parties. To overcome this limitation, other sources were investigated. For instance, looking at energy efficiency programmes in the US, Joskow and Marron (1992:15) argue that administrative costs can increase the costs per kWh saved by 10% to 20%. Then, even if 20% of administrative costs per

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2005:4). As a requirement, at least 50% of energy savings must be realized within this specific group.

[92] Note that the official name of the TWC scheme in Great Britain is Energy Efficiency Commitment (EEC).

kWh saved had been included in the estimations, the outcome would have been the same for the measures analysed that were eligible under the British scheme. That is, positive estimated financial benefits for end-users.

The study also shed light on the *energy-saving effectiveness* of the British scheme. The energy saving target for the first compliance period was set at 62 TWh. The measures implemented counting towards the saving target yielded almost 61 TWh (OFGEM, 2005:8). According to the regulator, the slight deficit (approx. 2%) during the first phase was due to two parties going out of business (OFGEM, 2005). Thus, one can interpret this performance as 98% energy-saving effective. However, a different view could be obtained if one considers the total amount of savings—those counted towards the achievement of the target plus the remaining surplus to be used in subsequent periods due to the banking provision. In this case, the total amount of savings realised during the first phase reached 86.8 TWh, or 140% energy-saving effectiveness in relation to the required target set for the end of first phase (see also paper IV). Nonetheless, whereas a high level of energy-saving effectiveness was observed, there was still the need to ascertain the actual ambition level of the energy saving target. This was explicitly addressed in paper V.

Despite the fact that the main objective of paper III was the topic of TCs as such, *many aspects were revealed related to trading activity under the British scheme.* Uncertainties concerning the actual level of trading activity and the factors driving it were reduced, as the research showed that trading had occurred. Furthermore, whereas most of the attention had been directed at the trading phase and the level of trading under the TWC schemes, the study identified and showed the importance of increased competitiveness as a potential benefit of non-trading. This aspect started to challenge the conventional paradigm concerning the economic unbounded rational behaviour of parties under TWC schemes. In fact, obliged parties claimed that an autarky compliance strategy was rationally (bounded) from the business point of view. This suggested than commercial benefits were higher than the cost savings from trading. Furthermore, early policy discussions had been concentrated on the challenging task of encouraging energy suppliers to become energy savers (see Mundaca and McCormick, 2004). However, the unexpected interest that was identified among obliged parties in increased energy efficiency seemed to reduce that policy concern.

Several *advantages* and *limitations* were encountered when using the developed TCs research approach. The methodological approach of the study was

based on (i) interviews with key stakeholders, (ii) a questionnaire circulated among obliged parties, and (iii) a review of official documentation and related studies. The overall research approach allowed a comprehensive portrait to be obtained of TCs under the British TWC scheme. As a result, not only TCs were identified but also important insights into market behaviour, trading patterns and other evaluation criteria. Whereas the intention was not to perform a broad ex-post assessment, the overall evaluation approach generated rich information, so the scope of the study turned out to be larger than expected. This provided certain key building blocks for further research (e.g. the to-trade-or-not-to-trade dilemma as investigated in paper IV).

On the other hand, an important limitation was related to obliged parties being key sources of primary data. The analysis of TCs comes mostly from experience, and the study targeted TCs borne by obliged parties. Therefore, there was a strong need to have a sample with high statistical significance—in particular for the scale of TCs. This was not possible to achieve due to the fact that some obliged parties did not want to participate in the research. This limitation gave further relevance to the triangulation approach, which attempted to offset this constraint and provide a more balanced set of information regarding the nature of TCs. For those parties that did participate, problems of accounting were identified regarding the scale of TCs (see also Joskow and Marron, 1992). This meant that while participants were sometimes fully aware of the existence of TCs and their characteristics, they did not keep track of them. Thus, once the sources of TCs were identified, only estimates of their scale were given.[93]

4.3.4 Conclusion

The study showed that multiple sources of TCs can exist in TWC schemes. However, despite the presence and magnitude of TCs, increased energy efficiency was estimated to be cost-effective and yield financial savings from the end-user perspective. The results underscored the broader view needed when analysing TCs under TWC schemes, in particular upstream in the

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[93] Estimates concerning the *scale* of TCs were given as a percentage of direct investment costs. However, the estimated scale should not be interpreted as a constant and positive correlation between the size and performance of the measures and the actual *burden* of TCs. The burden may decrease as energy savings increase because of the fixed component of certain sources of TCs (e.g. negotiation of contract/agreements with third parties). This indicates decreasing marginal TCs and the existence of economies of scale (cf. Stavins, 1995).

TWC lifecycle. The trading was subject to (perceived) TCs, but also the development of eligible measures leading to the issuance of TWC as such. Indeed, if a TWC scheme is to deliver cost-effective energy savings, the lessons drawn from the British scheme indicate that a high level of effectiveness among informative policy instruments in raising awareness upstream among end-users is critical. It was concluded that TCs under any TWC scheme are very likely to differ because of a number of endogenous elements (e.g. design, coverage, programme requirements, data reliability) and exogenous determinants (e.g. market conditions, geographical context, portfolio of policy instruments) explaining and affecting their nature and scale. Another major insight from the research came from the indication of increased competitiveness as a potential benefit and driver of non-trading.

4.4 Paper IV – a closer look at market behaviour and the to-trade-or-not-to-trade dilemma

4.4.1 Objective

The objective of paper IV was to provide an *empirical analysis of market behaviour under TWC schemes*. It focused on the entire set of *flexibilities*—as described in Section 3.2.2—granted to obliged parties to help them meet mandatory energy saving targets cost-effectively, i.e. (i) eligible measures, (ii) eligible end-use sectors, (iii) banking provisions, (iv) market engagement of non-obliged parties, and (v) actual trading. At the time of research, most of the attention of policy makers and scholars had been heavily concentrated on the trading activity under TWC schemes (see e.g. Bertoldi and Rezessy, 2006; Capozza *et al.,* 2006). Paper III had already shown that trading had occurred under the British scheme, albeit to a limited extent. In turn, a low level of trading prompted the general opinion that TWC markets show little, if any, dynamism. Missing from the discussion was the fact that the extent to which a TWC market achieves energy savings cost-effectively depends on how obliged parties take advantage of all the given flexibilities in reducing their compliance costs. A detailed TWC market behaviour analysis had not yet been performed due to a lack of empirical evidence. Paper IV attempted to redress this.

Elaborating mostly upon *cost-effectiveness*, the ex-post evaluation focused on whether policy design, market conditions, and corporate aspects could inhibit parties from taking full advantage of given flexibilities or encourage them to do so. The analysis took the early experience of the Italian and

British TWC (mostly first-phase) schemes as case studies. France was also used as case study, albeit to a lesser extent.

4.4.2 Main findings

Overall, the findings demonstrated emergent and dynamic market behaviour under TWC schemes. The *use of flexibilities* can be summarised as follows:

a)   *Eligible measures used to realise energy savings.* Concerning *Italy*, 286,837 TWCs were issued between January 2005 and the end of May 2006.[94] It was found that more than 60% of total savings were achieved realising saving potentials through micro-scale size and low-hanging fruits in the commercial and household sectors. Almost 20% of total savings were achieved by district heating, either through the implementation of new grids or the extension of existing ones (see Figure 4-5). All technologies were found to be mature and available commercially. However, it was found that implemented measures were unlikely to reflect actual market behaviour. This is because Italian parties can retroactively claim energy savings implemented from 2001 and onwards to fulfil their targets (even though the scheme started in 2005).[95] Therefore, a substantial share of measures (approx. 60%) did not actually result from the TWC scheme but were implemented prior to 2005—suggesting free-riding effects. It was estimated that end-users possibly obtained financial benefits under the Italian TWC scheme. Taking market prices of TWCs as proxies of actual marginal saving costs, and energy prices paid by Italian households in 2006 as benchmarks, net financial savings for end-users were estimated to be 5 and 6 Euro cents/kWh of electricity and natural gas saved, respectively.[96]

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[94] Note that in Italy 1 TWC = 1 tonne of oil equivalent.

[95] An early action provision was awarded to eligible parties. Savings can be claimed retroactively as long as implemented measures have not received any governmental, regional or local support (Capozza *et al.*, 2006; Pavan, 2008).

[96] This was estimated assuming average TWC prices of € 71 and € 94 in 2006 for electricity and gas, respectively. Furthermore, national tariffs of electricity and natural gas of ca. 5.6 and 6.8 Euro cents/kWh respectively were considered for the estimates.
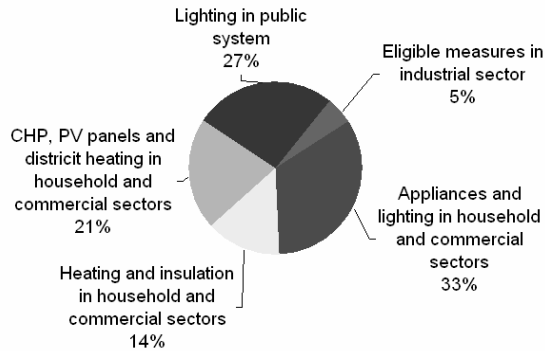
Figure 4-5: Distribution of implemented eligible measures in relation to energy savings (286,837 toe) under the Italian TWC scheme (from January 2005 to May 2006)[97]

In *Great Britain*, the dominance of insulation measures was evident during the first phase of the scheme, in particular cavity wall and loft insulation (see Table 4-1). Due to large cost-effective potentials in the household sector, these measures contributed to 56% of the total savings achieved, or nearly 38% of the savings redeemed (see Figure 4-6). For each category, almost all measures were found to be mature and commercially available. For the second phase of the scheme (2005-2008), data showed very similar market trends. Although with an inevitable level of uncertainty, one could argue that the use of "deadweight" factors counteracted the free-riding effect in Great Britain.[98] In fact, as a result of the M&V approach, a deadweight factor was—and still is—applied when energy savings from eligible measures are estimated. However, Lees (2006) identified some free-riding effects for the condensing boiler market.

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[97] Data source AEEG (2006:20).

[98] Under the British TWC scheme, a *deadweight* factor refers to the level of investment activity carried out under BAU conditions.

Table 4-1: Eligible measures implemented under the first phase of the British TWC scheme.[99]

Category/type of eligible measure		No. of measures installed	Achieved savings (GWh)
Insulation	Cavity wall insulation	791,524	25,069
	Loft insulation (top up)	528,496	4,138
	Loft insulation (virgin)	226,245	9,696
	Do-it-yourself insulation (m²)	15,979,367	8,101
	Draught stripping	22,743	38
	Tank insulation	195,832	433
	Radiators panels (m²)	38,878	13
	Solid wall insulation	23,730	972
	Other insulation	2,625	21
Appliances	Energy efficient cold appliances	2,956,084	7,381
	Energy efficient wet appliances	3,551,737	2,260
	Other appliances	93,837	42
Heating	A and B rated boilers	278,991	2,361
	A and B rated boilers + heating controls	87,497	1,233
	Heating controls upgrade	2,366,128	1,220
	Fuel switching	41,077	2,763
	Combine heat and power (CHP)*	615	39
	Other	202	4
Lighting	Compact fluorescent lamp (CFL)	39,737,570	20,976
TOTAL		**66,923,178**	**86,760**

(*) Note: Number of household benefiting.

With due caution, one can notice that the implementation of insulation and heating related eligible technologies in Great Britain seemed to be in line with the ex-ante results obtained under paper II regarding cost-effective supply of TWCs. From the end-user perspective (as already addressed under paper III), end-users seem to be obtaining net financial benefits as a result of implemented eligible technologies under the British TWC scheme. Using energy prices paid by households in 2004 as benchmarks, net financial benefits for end-users are estimated to be 8~8.6 Euro cents/kWh for electricity savings and 1~1.6 Euro cents/kWh for gas savings (see papers III, IV and V for further details).

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[99] Data source: OFGEM (2005:47-66).
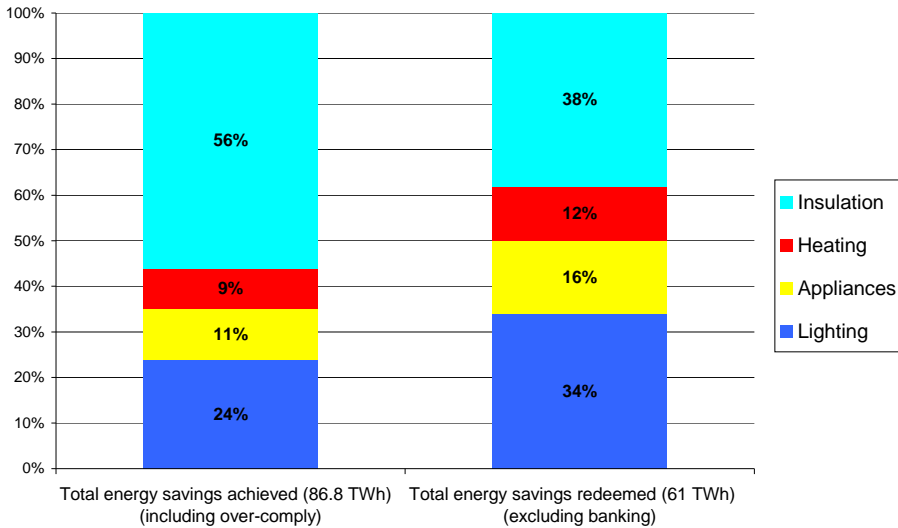
Figure 4-6: Distribution of implemented eligible measures in relation to energy savings under the first phase of the British TWC scheme (2002–2005)[100]

b) *Number of eligible end-use sectors.* In *Italy*, energy savings can be realised in any end-use sector and also in energy distribution networks. At the time of writing, Italian market actors had largely focused on the household and commercial sectors. However, this trend was largely explained by the option of claiming energy savings retroactively because complex M&V issues had prevented eligible actors from claiming savings in the industrial sector. Concerning *Great Britain*, the scheme covers the household sector only. Nevertheless, obliged parties have faced the requirement that at least 50% of savings must be realised in the so-called "priority group"—considered to be a sub-eligible sector.[101] During the first phase, obliged parties met this requirement by achieving 42 TWh of savings in the priority group, against the 32 TWh required (OFGEM, 2005:9).

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[100] Data source OFGEM (2005:11-66).

[101] The so-called *priority group* is defined as those households that receive certain income-related benefits and tax credits (see OFGEM, 2005:4).

c) *Banking option for surplus of TWCs.* For *Italy*, it was estimated the number of bankable TWCs for 2006 was approx. 130,926. This estimation corresponded to the total number of TWCs issued in 2005 (i.e. 286,837) minus the number of certificates needed to achieve the saving target for 2005 (i.e. 155,911). If the number of obliged parties had not increased, the obligation for 2006 would have been equal to approx. 312,000 TWCs. Considering that the amount of banking is unlimited, this would had implied that about 42% of the 2006 target could have been achieved by using the 130,926 TWCs not redeemed in 2005. In *Great Britain*, parties were allowed to bank an unlimited surplus of energy savings from the first to the second phase. Under the first phase, six parties banked savings corresponding to 25 TWh. Changes in the methodology for accrediting energy savings (e.g. lower discount rate) were critical to determine the level of banking. In fact, the above-mentioned 25 TWh from the first phase were equivalent to 35 TWh savings under the second phase. Thus, savings with higher values under the second phase (e.g. savings from cavity wall insulation) were not used to meet the target of the first phase, but carried over to the second phase. This pattern can be observed by comparing the two bars in Figure 4-6.

d) *Market engagement of non-obliged parties.* Besides obliged parties in *Italy* (approx. 34), another 573 gas and/or electricity distribution companies were entitled to participate in the TWC market. Furthermore, the Authority had accredited more than 550 ESCOs by May 2006. It was found that the activity level of the ESCOs had been much higher than that of the obliged parties (see Table 4-2). However, design features of the scheme explained this high activity level, as the authority established a broad or less stringent definition of ESCOs.[102] In practical terms though, most of these ESCOs could be classified as simple providers or

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[102] In Italy, companies submitting an energy efficiency project for certification to the AEEG can be considered "ESCOs" if their business purpose includes the provision of integrated services for the realisation of and the subsequent possible management of energy saving measures. The definition of ESCOs given by the Directive on Energy End-use Efficiency and Energy Services defines an ESCO as "a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria".

installers of energy efficiency equipment.[103] This finding also gave indications of a free-riding effect.

Table 4-2: Activity level of eligible parties under the Italian TWC scheme (first compliance year)[104]

Eligible Party	Issued TWCs (%)
Obliged distributors of electricity	9.1
Obliged distributors of gas	23.8
Non-obliged distributors of electricity and gas	2.5
ESCOs	64.6

In *Great Britain*, only obliged parties are allowed to trade (bilateral). However, as already identified in paper III, it was found that obliged parties worked strategically with multiple actors to deliver and implement measures, and thus reduce compliance costs. In other words, (i) obliged parties relied heavily on subcontracting insulation companies to realise savings, (ii) parties also relied on managing agents or middlemen to plan and implement eligible measures, (iii) parties also partnered with social housing programmes (SHPs) and charity organisations to identify customers and deliver eligible measures, in particular within the priority group, (iv) a number of obliged parties also partnered with housing developers to implement measures[105], and finally (v) parties set up partnerships with retailers and manufacturers in order to increase the penetration of efficient appliances (e.g. more than 6.5 million A-rated appliances were delivered via a partnership of this type).

e)   *Trading option.* In *Italy*, trading patterns showed a clearer *tendency towards to-trade*. In the first compliance year 145,796 TWCs were traded—17% on the spot market and 83% through bilateral contracts (i.e. company-

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[103] Personal communication with Marcella Pavan (June, 2007, AEEG) and Nicola Labanca (September 2007, eERG Politecnico di Milano).

[104] Data source AEEG (2006:19).

[105] This co-operation had taken the form of parties providing necessary funding to implement insulation measures in new houses to exceed current building requirements.

to-company). There were indications that the market actors' preference was towards bilateral trade. For instance, some obliged parties explicitly created certain ESCOs, encouraging intra-obliged party trading. On the spot market, TWC type-I dominated spot trades (15,253), followed by TWC type-II (10,086) (see Figure 4-7).[106] In contrast, TWC type-III was marginally traded. This could be explained by the fact that the investment cost-recovery mechanism established by the authority does not apply to savings related to TWC type-III.[107]

As shown in Figure 4-7, prices on the spot market fluctuated slightly and fell slowly during the analysed period, in particular those for electricity savings during the second year. This trend could be explained by: (i) an excess of TWCs generated by the option of claiming savings retroactively and the participation of "ESCOs", (ii) the low ambition level of energy savings targets (i.e. low scarcity level or demand of TWCs as set by the target—see paper V), (iii) the market power exercised by some obliged parties, and (iv) the rent-seeking behaviour triggered by the investment cost-recovery mechanism. The latter aspect raised distributional equity concerns, as it was possible for obliged parties to obtain windfall profits at the expense of taxpayers.

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[106] Note that under the Italian TWC scheme, there are three types of certificates. TWC type-I refers to electricity savings, TWC type-II refers to gas savings and TWC type-III refers to savings related to other fuels.

[107] The regulatory framework of the Italian TWC scheme grants € 100 per TWC redeemed by obliged parties.
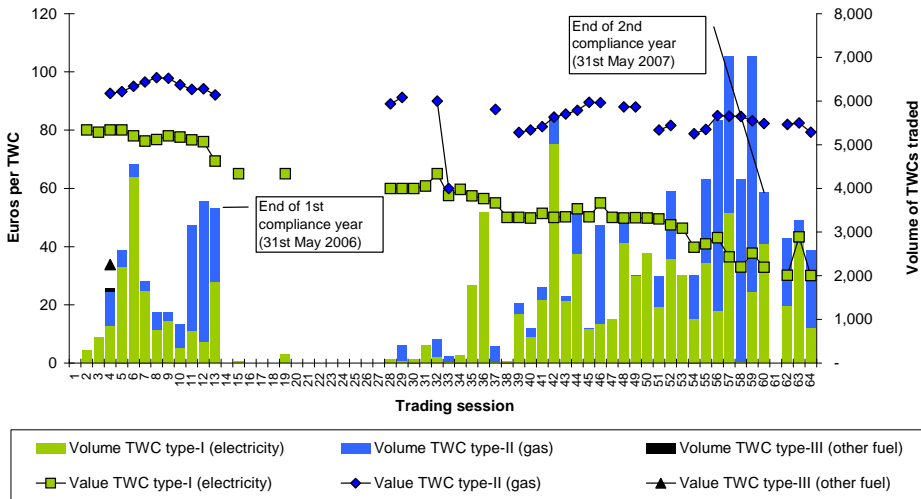
Figure 4-7: Price and volume of TWCs traded on the Italian spot TWC market[108]

Concerning trading activity in *Great Britain*, market behaviour showed a clear *tendency towards not-to-trade*. As already found under paper III, trading occurred but to a much lesser extent than in Italy. For the trading of obligations, two trades were identified. In terms of energy savings trading, six obliged parties purchased energy savings retroactively. All trades were reported to the authority; although, parties were not required to submit any related financial data. As noted in paper III, the lack of trading was affected by a number of factors, including a high concentration in the level of obligation on certain actors, the need for approval from the authority, and the fact that certain obliged parties decided not to trade in order to boost their competitiveness.

Bearing in mind the economic rationale of TWC schemes and the analysis of flexibilities, the study attempted to apply the *cost-effectiveness* evaluation criterion. Regarding *Italy*, and using a rather narrow definition of cost-effectiveness, pre-conditions such as common price and trading between parties facing different costs were identified.[109] However, the potential free-

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[108] Data source GME (2007). Note that each trading session corresponds to 1 day. At the time of writing, there were 3 to 4 sessions per month.

[109] Ellerman (2003:8) and Ellerman *et al.* (2000:225) use a similar conceptual approach to address cost-effectiveness under the sulphur dioxide (SO_2) cap-and-trade programme in the

riding effect and the possible market power exercised by some obliged parties added uncertainties to claims regarding cost-effectiveness.

In the case of *Great Britain,* indications of ex-post *cost-effectiveness* came from several angles. Energy savings costs have been estimated to be around 0.8~1.4 Euro cents/kWh for lighting measures and approx. 0.7~1.3 Euro cents/kWh for insulation measures (see Lees, 2006:27 and paper III). These figures were lower than the estimated average savings costs of 2.5 Euro cents/kWh generated by the most likely alternative policy option (see OFGEM and EST, 2003:17)—and certainly much lower than energy prices paid by households. Furthermore, it was found that energy savings cost estimates were approx. 20% lower than those predicted by the authority (see Lees, 2006:30). Due to the limited trading activity and obliged parties not being required to report financial data about transactions, it was not possible to obtain firm evidence of equalisation regarding marginal costs. However, obliged parties indicated that trading was not necessary because compliance costs were already equated during the competitive bidding process for subcontracting insulation measures—which heavily dominated the realised savings.

Due to the fact that a non-trading pattern has been already identified in paper III, the *to-trade-or-not-to-trade dilemma was further investigated.* The lack of trading activity prompted concerns among observers that obliged parties were not taking advantage of the cost savings that trading can generate. In particular, there was a strong need to investigate the drivers behind commercial benefits encouraging non-trading behaviour among obliged parties. The study focused on Great Britain and France.

a) *Great Britain.* The first commercial benefit of non-trading relates to *attaining strategic knowledge regarding energy efficiency.* Although the scheme was built upon the Energy Efficiency Standards of Performance Programme (EESoP)[110], which ran from 1994 until 2002, energy efficiency was still a new activity for obliged parties. Thus, instead of relying on a competitor for meeting their obligations, parties autonomously embarked on meeting their own targets. As the scheme becomes a rolling programme, a strategic learning process has been

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US. The authors look at the emergence of the market and volume of permits traded as initial evidence for cost-effectiveness.

[110] See OFGEM and EST (2003) for further information about the EESoP.

crucial for obliged parties to gain the operational knowledge necessary to meet their obligations in the long term. In turn, this knowledge has served as a key building block for parties who have taken energy efficiency as a business opportunity. The second benefit relates to *increased competitiveness*. Some obliged parties have considered energy efficiency a business opportunity, enlarging their product and customer portfolios. Findings revealed that, working as part of a mixture of policy instruments, the scheme might be changing the business paradigm of some obliged parties, leading to corporate efforts to enhance customer loyalty and branding through increased energy efficiency (see also paper III). A concluding argument in this aspect also came from the fact that, for some parties, buying energy savings from another was perceived as strategic nonsense, as it would imply direct financial support to competitors' brands. Supplementary and more explicit indications about how the TWC scheme was being used to boost the competitiveness of obliged parties were observed when reviewing their annual reports.

b) *France.* Early trends in the French TWC scheme also indicated that *commercial benefits of non-trading might encourage a not-to-trade preference.* The focus was on EDF, as this is the largest obliged party, bearing 55% (30 TWh) of the total obligation (54 TWh)—among 2,400 energy suppliers. EDF claimed that a TWC scheme represents an opportunity to strengthen and thus materialise a new business model, in which the provision of energy services plays a crucial role (see Urvoas, 2007; Urvoas *et al.,* 2007). The company has stated that it aims to increase its competitiveness by meeting its obligation autonomously. Among multiple reasons, it is argued that by integrating energy efficiency into its core business, increased competitiveness becomes a relevant benefit resulting from the (intended) decision to dismiss the trading option a priori (see Urvoas, 2007; Urvoas *et al.,* 2007). Indications of the intended autarky approach derived from EDF: (i) introducing energy efficiency in all market segments, with specific targets for marketing and sales staff, (ii) increasing capacity building for the supply of energy services, partnering with ESCOs, manufacturers, retailers and contractors of efficient measures, (iii) increasing demand for energy efficiency by launching customer awareness campaigns and advice centres, including the provision of soft loans, (iv) building up R&D programmes for integrated solutions and customer behaviour, and (v) purchasing TWCs from third parties only when the market price is substantially lower than the party's own energy savings costs.

4.4.3 Key observations

The issue of non-trading raised a variety of policy aspects. As Ellerman *et al.* (2000) argue, competitive *trading markets will develop when policy design and implementation are encouraging.* Although trading activity in Italy and Great Britain demonstrated opposing patterns, a number of exogenous and endogenous factors influencing trading were identified. Among them, fierce customer competition, market liquidity, early/retroactive savings activity, the existence (or lack) of a trading platform, (perceived) transaction costs, cost-effective saving potentials, additionality, banking, commercial benefits of non-trading, the need for approval from the authority, and familiarity with trading markets. Regarding the latter, it was clear that the newness of TWC schemes meant that obliged parties lacked trading experience and/or business models to cope with this new policy instrument.[111]

The lack of trading activity in Great Britain and indications of autarky compliance strategies also reminded us that *trading is a relevant flexibility, but not an objective per se in TWC schemes*—as in any tradable certificate scheme. The trading component aims at enhancing the scheme's cost-effectiveness in meeting mandatory energy savings targets at the lowest possible cost. In line with some critics in the context of a cap-and-trade scheme for GHG (see Greenspan Bell, 2005), it is important to point out that what really matters in TWC schemes is the energy saving target as such. A crucial pre-condition to determining the demand level for TWCs is the establishment of ambitious mandatory energy saving targets. However, as found later, in paper V, the level of ambition of the mandatory saving targets of all implemented TWC schemes was found to be low as far as final energy consumption (on an annual basis) of the eligible sectors is concerned.

The findings on *non-trading behaviour revealed commercial benefits of increased energy efficiency.* Whereas regulators and observers were mainly concerned with the cost savings that can be accomplished through trading, obliged parties—at least in Great Britain and France—seemed interested in the commercial benefits arising from increased energy efficiency. Findings suggested that benefits associated with *increased branding* and *customer loyalty* could yield higher financial gains for parties than the cost savings resulting from trading. In combination with many aspects, increased competitiveness and strategic

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[111] This is consistent with other tradable permit schemes. Evidence shows that many obliged parties were unfamiliar with trading during the beginning of the SO_2 cap-and-trade programme in the US. This aspect motivated parties to exercise an autarky compliance policy (see Bohi, 1994).

knowledge encourage an autarky compliance strategy. However, it remains to be seen whether this approach is an optimal choice for parties.

Now, why were these beneficial aspects of non-trading not identified in Italy? A possible explanation lies in the design of the scheme. Italian obliged parties are distributors of energy, not suppliers as in Britain or France. For energy distributors, the commercial benefits of increased energy efficiency might be less appealing or difficult to capitalise, as distributors lack direct access to end-users. Contrary to the situation in Great Britain, for instance, Italian obliged parties do not have to deal with increasing customer mobility, as their direct clients are energy suppliers instead. On the whole, the findings seem to indicate that the potential commercial benefits of non-trading offset the complex political means by which policy makers seek to force energy suppliers to realise energy savings.

Regarding the potential *free-riding effect* in Italy, several indications were identified. First, in their broad definition, ESCOs may be encouraging market liquidity (at least in terms of market players), but they may also be stimulating free-riding effects. One can argue that the so-called "ESCOs" would have sold or implemented energy efficiency measures even in the absence of the scheme. The active participation of ESCOs largely influenced the excess of TWCs. Second, the free-riding effect could have been magnified by the option of claiming savings retroactively; which would also have resulted in an excess of TWCs. This early action provision was given due to the fact that the scheme was supposed to be implemented in 2002. However, several aspects challenged its political feasibility and the scheme was finally implemented in 2005 (see papers I and V and Section 4.5 for further details). Concerns about the free-riding effect in relation to the early action provision are valid because it is unclear how many eligible technologies were actually implemented in anticipation of the scheme, or as a result of BAU market trends. The early action provision could also have a negative impact on future compliance year/periods because the regulatory framework allows an unlimited amount of banking. Third, the free-riding effect also questions the additional component of the selected eligible measures. As mentioned in previous sections, TWC schemes are supposed to encourage energy efficiency measures that would not have implemented under the BAU scenario (i.e. as depicted by the baseline).[112] Even though

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[112] Under the Italian TWC scheme, eligible measures are additional because they generate energy savings over and above market trends or legislative requirements.

the Italian regulatory framework addresses the additional component of measures explicitly, the findings underscored the importance of effective enforcement.

When analysing (non) trading activity, *market power* arose as an important aspect to be taken into account.[113] An essential assumption when creating TWC schemes is that eligible parties are price takers. However, one has to consider that due to the high concentration of the obligation in only one party, market power is likely to arise. For instance in Italy, 90% of the apportioned electricity saving obligation in 2005 was concentrated on a single party. Facing an excess of TWCs on the market, one can argue that this firm might have created monopsonistic market conditions (i.e. mainly one buyer), driving lower TWC prices. Likewise, in France, one could argue that market power could arise because the main obliged party holds 55% of the total obligation. This firm could influence the performance of the TWC market by setting TWC prices, which would create either monopolistic (seller) or monopsonistic (buyer) conditions. The high obligation share is rooted in two aspects: (i) energy targets are allocated according to the respective market share of the obliged parties, and (ii) the slow progress towards competitive energy markets with dominant energy companies acting in certain countries.[114] Nonetheless, one must also bear in mind that the supply and demand of TWCs could be very sensitive to price changes, affecting an autarky or self-sufficient compliance strategy. For instance, the supply of TWCs from various eligible parties to the largest obliged party could be very sensitive to price changes. This could deter an obliged party with market power from benefiting from its large share of the overall obligation (cf. Hahn, 1984).

Finally, the *ex-post evaluation approach based on the entire set of flexibilities of the British and Italian TWC schemes posed some methodological challenges but also offered some advantages.* Two main challenges or limitations were faced. The first was related to the identification of a credible *baseline or counterfactual situation*, posing a crucial policy evaluation question: What would have happened in

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[113] As noted previously, the term *market power* is used to refer as how an obliged party under a TWC scheme can manipulate the market to its own advantage (i.e. influence the price of TWCs).

[114] The new European energy policy stresses the need to move faster towards competitive energy markets. A clear separation between energy production and energy distribution (i.e. unbundling) is often mentioned as crucial factors in achieving a complete internal competitive European energy market.

the absence of the TWC scheme? Building a plausible counterfactual situation is always a challenging task for the evaluator—an intrinsic evaluation difficulty (see e.g. Frondel and Schmidt, 2001; Ellerman, 2003; Tietenberg, 2006). This challenging aspect had already been addressed in paper II when performing the ex-ante evaluation of an EU-wide TWC scheme. Under paper IV, and from the ex-post perspective, the British case offered two significant resources to overcome this limitation. An ex-ante evaluation had been performed and it was possible to identify an alternative policy instrument. In contrast, for the Italian TWC scheme, the identification of an alternative policy instrument and/or a counterfactual situation was not possible. This aspect remains a challenge in assessing the Italian TWC scheme from an ex-post perspective.

The second challenge related to *the effects of disentangling TWC schemes from the portfolio of instruments*—the so-called "impact problem" (Scriven, 1991). For the British scheme, disentangling the effects of the TWC scheme from the effects of all other policy instruments was not possible. Thus, one could argue that the ex-post evaluation of the scheme addressed, to some extent (possibly a large extent), the combined effects of the portfolio of policy instruments.

Regarding advantages of the evaluation approach, the ex-post evaluation based on flexibilities allowed a comprehensive portrait of TWC schemes to be obtained. The findings clearly supported the claims that it is the whole set of flexibilities that deserves analytical attention under tradable permits (see e.g. Ellerman *et al.,* 2000; Nordhaus and Danish, 2003). Furthermore, aspects related to non-trading patterns strongly suggested that the performance of TWC schemes should not be evaluated exclusively on the basis of trading.

4.4.4 Conclusion

Contrary to expectations, the analysis based on the entire set of flexibilities showed that overall market behaviour in TWC schemes was dynamic and slowly emerging. The analysed market behaviour and identified performance responded to the unique design, policy and market conditions in which the studied TWC schemes were implemented. In terms of cost-effectiveness, clearer indications were drawn for Great Britain than for Italy. Concerning trading, initial market and institutional conditions strongly suggested that trading might not be an immediate outcome of TWC schemes. A secured long-term policy horizon is relevant to reducing regulatory uncertainties so

obliged parties can factor the costs and benefits of increased energy efficiency into their business plans. Political commitment was found to be critical in ensuring confidence in emerging TWC markets. Finally, an interesting, perhaps unexpected outcome of TWC schemes—working in a portfolio of instruments—seems to be their ability to change the conventional business paradigm of energy suppliers towards increased energy efficiency.

4.5 Paper V – a broader multi-criteria ex-post evaluation

4.5.1 Objective

The objective of paper V was to *develop and apply a framework for a broad ex-post evaluation of TWC schemes* in order to gain a more holistic view. The framework built on a multi-criteria approach targeting relevant claims or anticipated effects regarding TWC schemes. The following criteria were used: *energy-saving and environmental effectiveness, economic efficiency, cost-effectiveness, transaction costs, political feasibility, administrative burden and technical change.* Paper V attempted to exemplify the application of the ex-post evaluation framework rather than to provide an overall value judgement about the specific performances of the TWC schemes under analysis. Great Britain and Italy were used as case studies. The French TWC scheme was also addressed but to a rather limited extent due to lack of data.

At the time of conducting this study, the growing interest in TWC schemes had brought an increased awareness of their evaluation and justification. On the one hand, much of the actual implementation of TWC schemes had relied on the rationale of benefits resulting from increased energy efficiency (e.g. climate change mitigation, improved energy security) and a lack of evaluation methods could be discerned. On the other hand, and despite the complexities involved in TWC schemes, the handful of analyses that have been conducted used economic modelling tools, mainly addressing, implicitly or explicitly, the cost-effectiveness criterion (see Oikonomou *et al.,* 2007; Perrels and Tuovinen, 2007; and paper I).

4.5.2 Main findings

On the whole, the study generated an extensive amount of information that also complemented the findings of papers III and IV. Furthermore, findings were also built upon previous papers.

Energy-saving and environmental effectiveness. A high level of energy-saving effectiveness had been already ascertained for the *British TWC scheme* in papers III and IV. However, two important regulatory aspects influenced this high level of performance. First, the penalty imposed to address non-compliance was strong—up to 10% of turnover in cases where parties fail to comply. This provided a direct incentive to obliged parties to (over) comply with their targets. Second, the *level of ambition of the saving target was found to be low* relative to the annual energy consumption of the eligible sector (i.e. households). On an annual basis, the energy saving target was estimated to reduce household energy consumption by 0.6%. This figure raised the question of whether high energy-saving effectiveness was met at the expense of soft targets, reflecting autonomous energy efficiency improvements trends. One could argue that the high compliance level has simply reduced the growth rate of energy consumption, but with little effect on consumption levels as such (see also Marsh, 2004; Owen, 2004). In fact, it was also found that the levels of ambition were also low in the Italian and French TWC schemes (see Table 4-3).

Table 4-3: Level of ambition of energy saving targets in TWC schemes – as a share (%) of the annual energy consumption of sectors covered

Great Britain	Italy	France
0.6 % [i]	0.3% [ii]	0.14% [iii]

Notes: (i) On an annual, undiscounted basis, the target of the British scheme of 62 TWh (first phase) is equivalent to approx. 3.36 TWh (Personal communication with Penny Dunbabin, November 2007, DEFRA). By 2004, total household energy consumption in the UK was 48.5 Mtoe (based on DTI statistics), which equates with approx. 564 TWh. Notice that energy consumption here refers to the UK, which includes Northern Ireland. However, that country does *not* form part of Great Britain, the region in which the TWC scheme is implemented. Therefore, the figure presented in the table is likely to be underestimated. (ii) Figures are derived from energy consumption in 2004. Energy consumption due to electricity and gas end-uses reached about 25 Mtoe for electricity and about 41 Mtoe for gas in 2004 in Italy (Personal communication with Nicola Labanca, November 2006, eERG Politecnico di Milano). The savings target for 2005 was 0.2 Mtoe. (iii) Personal communication with Stéphanie Monjon (October 2007, ADEME).

High energy-saving effectiveness was also found for the Italian TWC scheme. During the first year of compliance, certified energy savings

accounted for 286,837 toe (AEEG, 2006).[115] As already found in paper IV, this level of achievement was higher than the required level of 155,911 toe. Consequently, the total certificates issued by 2005 corresponded to 184% of energy-saving effectiveness.[116] However, several regulatory aspects could have weakened the integrity of this achievement. First, as shown in the Table above, the ambition level can be categorised as low. The original saving targets of 200,000 toe represented only 0.3% of the total electricity and gas consumed in the sectors covered. Second, the option to claim savings retroactively, combined with the broad definition of "ESCOs", gave indications of the free-riding effect, which may also question the actual level of additionality among the eligible measures (see also paper IV). The above-listed aspects did not permit any serious assertions to be drawn regarding the energy-saving effectiveness of the Italian scheme. In addition, it was not possible to identify an estimated baseline for comparison.

Regarding *environmental effectiveness* as such, the reduction of GHG emissions is explicitly stated as key policy goal in Great Britain, but not for any of the other TWC schemes. The target for first phase was set at 0.5 MtC/year in 2010. Once implemented, energy efficiency measures counting towards the target (i.e. excluding banking) were estimated to achieve emissions reductions equalling 0.4 MtC (DEFRA, 2006:1). This meant that the environmental effectiveness was estimated to be approx. 80%. Now, if one considers total carbon emissions to be approx. 150 MtC/year in the UK, of which household emissions contribute 40 MtC/year, the achieved emission reductions represent approx. 1%.[117]

Economic efficiency. An ex-post cost-benefit analysis was performed for the first phase of the British scheme. First, total costs were estimated to be approx. € 842 M. This included investments, administrative and transaction costs. Second, total benefits (i.e. energy cost savings plus social and environmental benefits) range from € 2,606 M to € 2,783 M (see details in

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[115] Note that under the Italian scheme, 1 TWC =1 tonne of oil equivalent (toe).

[116] It has to be acknowledged that the actual target to be met by obliged parties (155,911 toe) was below the original target of 200,000 toe. The reason lay in the fact that around 54,099 toe could not be apportioned between energy distributors with less than 100,000 customers. This number was set by the authority as the minimum market threshold used for allocating the overall energy saving target.

[117] Notice that carbon emissions refer to the UK, which includes Northern Ireland. However, that country does *not* form part of Great Britain, the region in which the TWC scheme is implemented. Therefore, the figure is likely to be underestimated.

paper V). Only social and environmental benefits (lower and upper bounds) resulting from electricity savings were accounted for. Correspondingly, this implied an overall benefit-cost ratio of approx. 3.09 to 3.32. Certainly, energy cost savings (€ 2,398 M) alone represented the majority of the programme's economic benefits (around 86% to 92% respectively for the upper and lower ends of the range). Even though the figures used to ascertain the efficiency of the British scheme attempted to depict a conservative scenario, the estimated internal rate of return was remarkably high in both cases (about 33-36%). Considering the official test discount rate of 6%, net present values were estimated to be in the range of approx. € 1,660 M to € 1,830 M. If the lower bound of social and environmental benefits was considered, the discounted payback period was estimated to be approx. 3 years for the first phase of the scheme (see Figure 4-8). Figures from the cost-benefit analysis were consistent with other ex-post studies (cf. DEFRA, 2006:9; Lees, 2006:32).
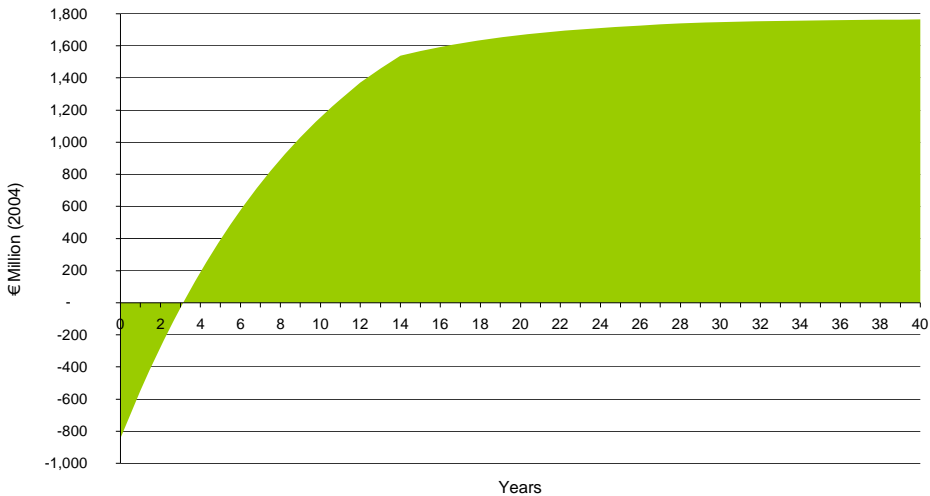
Figure 4-8: Estimated net total benefits and payback period under the British TWC scheme (first phase) in € Million (2004)[118]

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[118] Discounted cumulative economic flow at 6% using the lower bound of social and environmental benefits, and upper bounds of transaction costs.

Cost-effectiveness. This part of study was mostly built upon he results obtained in paper IV. Regarding Great Britain, indications of cost-effectiveness came from three sources: (i) the energy savings costs that were lower than expected and lower than energy prices paid by households, (ii) the estimated energy savings costs that were lower than estimated costs of an alternative policy option, and (iii) the potential equalisation of marginal costs during the bidding process for insulation measures. Concerning Italy, indications of cost-effectiveness came from two pre-conditions: (i) the emergence of the market and (ii) the volume of permits traded and a common TWC price on the spot market. Despite intense trading activity, it was not possible to estimate cost savings attributable to trading due to the lack of a counterfactual baseline. Nor, furthermore, was it possible to support claims of cost-effectiveness, since no alternative policy instrument could be identified.

Transaction costs. Whereas transaction costs (TCs) under the British scheme had been fully investigated in paper III, there was still a need to better knowledge in this area was still needed. Data were not available to evaluate TCs under the Italian or French TWC schemes.[119] However, a somewhat similar policy instrument was examined as a supplementary case study. One such scheme is the Free-of-Charge Energy Audit (FCEA) programme in Denmark.[120] As a case study, the FCEA was relevant because the organisational and administrative settings implemented by companies to meet their obligations under the programme can be analysed in the context of the efforts undertaken by obliged parties under TWC schemes to meet their mandatory saving targets (see Mundaca and Neij 2007a).

It was found that many sources of TCs were clearly driven by the design of the FCEA as such. Findings indicated that the search for information in relation to customers seemed critical and relevant for the planning phase. This correlated well with the fact that finding customers willing to implement measures had been a rather demanding task for obliged parties

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[119] At the time of writing, one could argue that a significant source of transaction costs for obliged parties under the Italian and French TWC scheme lies in the political uncertainty surrounding the future of the schemes.

[120] The FCEA programme is an informative policy instrument aimed at providing suitable information to organizations about energy efficiency improvements. Under the FCEA, electricity grid companies are obliged to provide energy audits to all public and private organizations that have an annual consumption of more than 20 MWh. For a detailed description of the FCEA see Dyhr-Mykkelsen *et al.* (2005) and IEA (2005).

and thus a key source of TCs in the British TWC scheme (see paper III). Likewise, similarities between the FCEA and the British TWC scheme indicated that the search for information related to the follow-up of measures is likely to be a critical source of TCs under TWC schemes, particularly if actual ex-post M&V is required. The given estimates of the scale of TCs under the FCEA were scattered (i.e. ranging from 5% to 20% of total investment costs). However if one looks at the entire development of energy efficiency projects, there are reasons to believe that these estimates might entail a lower level of uncertainty compared to the British case. This is because the requirements and the very nature of the FCEA, as well as the administrative procedures established by the authority, inter alia, were found to be important reasons for keeping track of any kind of costs that arise from the FCEA. The analysis of the FCEA showed that the scale of TCs is higher when dealing with small end-use companies rather than larger ones.

Political feasibility. It was found that the political feasibility of TWC schemes faces different scenarios. As early pointed out in paper I, the Italian scheme already tested the hypothesis that TWC schemes were highly feasible from a political standpoint. This criterion was explicitly used in paper V, nearly three years after those early indications. These early concerns proved to be correct. The Italian experience showed that several obstacles exist even if there is strong political consensus on policy objectives. The scheme was supposed to commence in 2002 (as decreed in April 2001), but it was finally implemented in 2005. This three-year delay was heavily influenced by lengthy discussions among stakeholders and time consuming negotiations regarding four main aspects: (i) the level of ambition of the energy saving targets (see Figure 4-9), (ii) the development of M&V approaches, (iii) the allocation of savings obligations, and (iv) the investment cost-recovery mechanism.[121]

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[121] Personal communications with Stefano Alaimo (September 2004, GME), Marcella Pavan (June 2007, AEEG), Antonio Capozza (September 2004, CESI), Walter Grattieri (September 2004, CESI), Daniele Russolillo (December 2007, Fondazione per l'Ambiente) and Nicola Labanca (December 2007, eERG Politecnico di Milano).
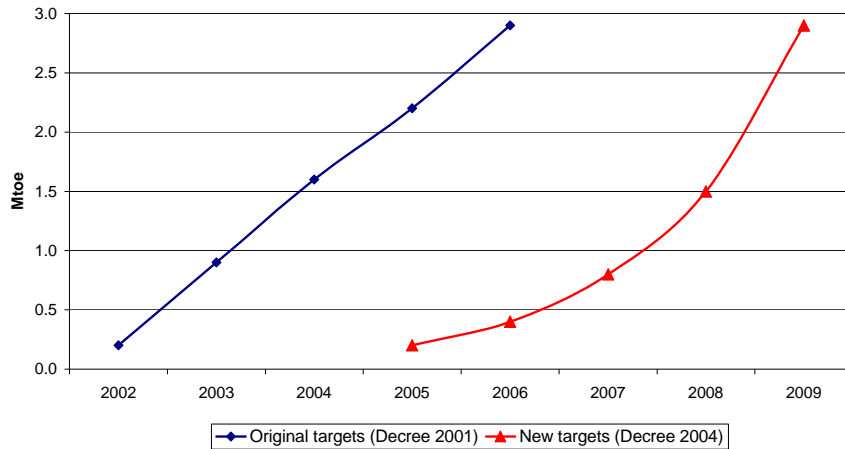
Figure 4-9: Proposed and final energy savings target (in Mtoe) under the Italian TWC scheme

Interviews with Italian stakeholders revealed that the level of ambition of the mandatory target, as well as the allocation of responsibility to meet it were, by far, the two most critical design elements affecting the political acceptability of the scheme.[122]

Regarding the political feasibility of the British scheme, many of the difficulties listed above (e.g. target negotiation/opposition, development of M&V methodology for eligible measures) could also be applicable to some extent. However, the implementation of the scheme was not delayed and its political feasibility seemed not to be jeopardised. This could be explained by a number of factors: (i) a high level of political commitment towards policies to reduce GHG emissions and increased energy efficiency, (ii) the ex-ante evaluation of the scheme's impacts (on a measure-by-measure basis and also

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[122] In addition to critical design elements, operational considerations have also slowed the implementation of the scheme at the regional level. For instance, after institutional modifications were made at the national level in 2004, regional governments, in co-operation with the relevant ministries, were asked to identify eligible projects and implement/promote best practices in the public sector. However, this task was only completed in 2007 (e.g. Piemonte region). Furthermore, obliged parties have failed to prepare—as requested by the 2004 Decrees—an annual portfolio of eligible projects compatible with regional energy plans (see also paper I).

at the aggregate level), (iii) an extensive and statutory consultation process prior to the implementation of the scheme, (iv) key stakeholders (i.e. policy makers, regulator, and obliged parties) already being familiar with the operation of the new scheme because it was built upon the EESoP, (v) the limited coverage of the scheme (i.e. the household sector only), making it a workable policy instrument for the authorities and (vi) the fact that the scheme also supports the Fuel Poverty Strategy.

Administrative burden. The British scheme showed a relatively low burden for the regulator. This was addressed in monetary terms. The institution in charge of the scheme's administration in Great Britain reported first phase costs of € 1.4 M (OFGEM, 2005:4). With a team of around six professionals, this figure represented around € 460,000 a year—a relatively marginal burden compared to the regulator's total budget of approx. € 560 M. The largest share of costs was related to the external auditor and management of the database keeping track of the progress of each obliged party. Of the € 1.4 M in administrative costs, random M&V activities represented 15%. The costs for the first audit were around € 125,000 and for the second nearly € 85,000. According to the authority, an internal learning process allowed it to reduce the costs for the second audit.[123] Research findings suggested that the limited coverage of the British scheme (i.e. with only one eligible sector) combined with an ex-ante M&V approach regarding energy savings, was a workable design for the regulator to keep administrative costs at a low level.

For Italy and France, no information was available concerning the administrative burden on the relevant authorities. However one can envisage that, due to the extensive coverage of these schemes, including ex-post M&V of savings, they are likely to involve a higher level of regulatory oversight. Consequently, the administrative burden is likely to be much greater than under the British scheme. For instance, in France, no official information on administrative burden was available at the time of research; although, it was found that the scheme required the equivalent of 15 to 20 full-time employees to support the development, implementation and enforcement of the scheme.[124]

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[123] Personal communication with Charles Hargreaves (September 2005, OFGEM).

[124] Personal communication with Luc Bodineau (January 2008, ADEME).

Technical change. It was found that both the British and Italian schemes mostly supported the dissemination of commercially available, mature technologies (cf. AEEG, 2006; Lees, 2006; OFGEM, 2005). This trend was expected, as TWC schemes promote the cheapest technological options (see also paper IV). Market trends suggested that the eligible measures being implemented are the most cost-effective technologies. In addition, they offered a lower degree of uncertainty in terms of performance than innovative or cutting-edge technologies (cf. DEFRA, 2007). For instance, in Britain, it is very likely that micro-generation (e.g. solar photovoltaic [PV] panels or micro-wind turbines) will make only a marginal contribution in the short and medium term due to the fact that eligible measures of this type are far less cost-effective than insulation measures (cf. DEFRA, 2007). Moreover, it has been already concluded that, due to their extensive potential in the heating segment, cavity wall and loft insulation will continue to represent mature technologies during the third phase of the British scheme (see DEFRA, 2007).[125] In all events, it was found that the implementation of eligible technologies in Britain has also been encouraged by other policy initiatives, such as the EU energy labelling programme, consumer advice from specialised centres, building regulations, etc. (cf. Lees, 2006; Rohr, 2004).[126]

With regard to players' involvement in the innovation chain to leverage technical change, papers III and IV showed that the British scheme has increased obliged parties' interest in energy efficiency. The scheme has triggered a business opportunity through which companies can extend their product and customer portfolios, and enhance customer loyalty and branding. This process has supported competence building to fulfil targets at the lowest possible cost, increase familiarity with key eligible measures and enhance energy efficiency in general. Furthermore, obliged parties have developed numerous partnerships with various actors (see papers III and IV). In turn, this process has enhanced human (individual learning) and structural capital (organisational learning).

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[125] Note that in 2008, it is estimated that half of the UK housing stock will have loft insulation inferior to that required by law (see NIA, 2006:4).

[126] For instance Lees (2006) identifies that building regulations from 2005 were a critical driver in the transformation of the condensing boiler market. In this case, subsidies given under the British scheme, in conjunction with efforts by other institutions (e.g. the Energy Saving Trust) were still relevant in supporting that market transformation.

4.5.3 Key observations

This paper indicated a *need for* and *selection of numerous evaluation criteria* that can capture and characterise the multiple attributes of TWC schemes and the policy context in which they work. This is necessary to provide decision makers with adequate and comprehensive information on the performance of the scheme. It can be argued that that the evaluation of new energy efficiency policy instruments requires a comprehensive evaluation approach—one that can capture their broad set of attributes and complement/improve results from cost-driven energy system models. Certainly, not all of the criteria are likely to have the same significance. Alternatively, some criteria are likely to be more helpful in addressing specific effects (cf. Mickwitz, 2003). The criteria used for the study offered the potential to characterise the relative importance of many attributes related to a TWC scheme. This can be achieved by means of a weighting or scaling method that can be driven by the specific policy and market conditions that frame the discussions about increased energy efficiency in general, and/or TWCs in particular. However, this process can become a significant challenge for policy makers and evaluation practitioners.

The *triangulation-based multi-criteria evaluation approach was time and information-intensive*. The study indicated that the evaluation approach used required a vast amount of data and adequate estimates. When applied to a single case, data availability was rather crucial to cover all aspects. Although the evaluation was challenging due to a lack of information, it was possible. Nevertheless, processes to ensure adequate data should be devised and implemented with each new TWC scheme. While the use of economic criteria constantly poses conceptual and practical problems, monetary valuation is argued to be relevant because economic aspects are of prime importance in public policy (cf. Bardach, 2005; Mickwitz, 2006; Rossi *et al.,* 2004). Finally, although the ex-post evaluation exercise was time consuming, it is argued that multi-criteria analyses can take much less time relative to the overall policy formulation process (see Lahdelma *et al.,* 2000).

The broad ex-post evaluation confirmed that the *performance of the analysed schemes is rather unique due to case and country-specific regulatory and market conditions* (see also paper IV). Energy saving measures may not be as cost-effective in other countries as in Great Britain—transaction costs may differ between countries due to regulatory frameworks and market conditions. As is usually the case, things are somewhat less clear when examined in depth. Results from a TWC scheme in one country could not be generalised and applied to a TWC scheme in another. Although not the primary objective of this paper,

the results strongly indicated that continuous case and country-specific ex-post evaluations are needed to improve the performance of implemented TWC schemes.

The results stressed the *trade-off analysis resulting from multi-criteria evaluations*; which should duly be taken into account. One can observe that the object of each criterion used is not completely apparent or totally independent from the rest, raising the problem of conflicting objectives (cf. Fischer, 1995; Sterner, 2003). The trade-off analysis regarding TWC schemes can be extensive and complex. For instance, high ambitious targets can trigger large effects and higher levels of technical change, while political feasibility may be low. Likewise, higher cost-effectiveness can be gained with a broader set of eligible measures and sectors, but it also can increase administrative costs for authorities and entail higher transaction costs for obliged parties. Once a TWC scheme is considered politically feasible, it is crucial to take into account how cost and (ancillary) benefits are distributed (see paper II). In fact, even if an instrument meets the efficiency criterion, very little—at best—can be said about the fairness of the distribution of costs and benefits. If alternative designs for TWC schemes are evaluated, design elements should be translated into impacts and outcomes before a tangible trade-off analysis takes place. Then, competing impacts and/or outcomes can actually be confronted.

Considering the application of the multi-criteria framework, as well as the resulting findings, *several advantages and disadvantages were identified when applying the proposed multi-criteria framework.*

Advantages:

- As TWC schemes have unique designs and cover many possible flexibilities to meet their set objectives and interact with country-specific policy contexts, a multi-criteria evaluation policy framework permits a better understanding of the broad effects, attributes and complexities of TWC schemes.

- The evaluation process allows the inclusion not only of economic and energy-related aspects, but also socio-political, organisational and commercial factors, making it possible to identify trade-offs and (co)benefits from increased energy efficiency under TWC schemes.

- Due to the multi-disciplinary nature of the evaluation approach, a variety of specific results were produced, allowing a broader analysis compared to an evaluation using a single criterion and/or discipline. This avoids generalisations.

- By no means exhaustive, the chosen criteria cover aspects that are of particular analytical relevance—still to be tailored to specific policy and market conditions—offering a basic template for the evaluation of current and future TWC schemes.

- The approach yields a variety of detailed results that provide a wider basis for a more balanced discussion concerning design and implementation aspects. In turn, this can contribute to better communication among stakeholders.

Disadvantages:

- There is a need for available, reliable, timely and useful data—in particular for quantitative analyses.

- Depending on the scope and ambition level, the approach requires an evaluator(s) with skills in a variety of conceptual tools and social research methods.

- While there is a need to use different evaluation methods, these are likely to yield somewhat conflicting results, which may add complexity to the overall analysis. Due to a lack of data, an assessment that covers all aspects may prove rather challenging.

- Due to the multi-disciplinary nature of this approach, results may be criticised for being too scattered, as opposed to an evaluation performed using a single criterion from a single discipline—which would likely yield a more precise but narrower analysis.

4.5.4 Conclusion

The proposed framework offered an approach to bridge the fact-value dichotomy that has been long debated in public policy evaluation. It attempted to cover a number of empirical and normative aspects related to TWC schemes. The results showed the design and performance of TWC

schemes to be case and context specific, meaning that generalisations regarding performance are often inappropriate. The findings of the paper also showed the advantages of using a multi-criteria framework and complementary methods to better understand the scope, dynamics, complexities, and, thereby, the effects (impacts and outcomes) of TWC schemes. Specifically, the results indicated the need for evaluations and methods to complement cost-minimisation models to evaluate the effects of TWC schemes (as was done in papers I and II). Furthermore, the use of multiple criteria underscored (i) the triangulation approach, because no single dataset can be relevant to the analysis of all evaluation criteria, and (ii) the multidisciplinary nature of the evaluation. However, the accessibility, availability and reliability of data pose a significant challenge for ex-post studies. On the whole, it was concluded that instead of analysing detailed information from a narrow (economic) perspective, the analysis of a wide range of information by different methods could yield more useful and valuable results.

Five

5. Conclusions and reflections

The aim of this Chapter is to highlight the main results and contributions of the research as a whole. Based on the outcomes of the research, the purpose is (i) to indicate the contributions of this thesis to the current body of knowledge, (ii) to provide answers to the research questions, (iii) to draw certain implications for energy efficiency policy evaluation in general, (iv) to suggest a number of policy considerations addressing the design and implementation of TWC schemes, and (v) to identify issues for further research.

5.1 Contribution of the thesis

This research contributes to different aspects related to the interplay of TWC schemes and energy efficiency policy evaluation as such.

First, *the research responded to the lack of evaluations of energy efficiency policy instruments*. By conducting a wide evaluation of TWC schemes, the research outcomes support the need to bring evaluation practices in the energy (efficiency) policy field into the mainstream. In turn, the thesis also responded to calls from scholars and international organisations to increased our knowledge of tradable certificate schemes in general (see e.g. OECD, 2002; Tietenberg, 2006).

Second, *the research provided a broad evaluation of TWC schemes*. Despite growing political interest in creating and experimenting with TWC schemes in Europe (and elsewhere), evaluation studies about the potential or actual performance of these created markets had received very little attention. The research presented in this thesis included the first ex-ante evaluation of an EU-wide TWC scheme. Similarly, the research provided the first study on transaction costs related to TWC schemes and empirical evidence about their actual performance in this particular regard. The thesis also revealed the to-trade-or-not-to-trade dilemma faced by certain obliged parties. The research also involved out a multi-criteria analysis and provided a closer look

at the economic efficiency resulting from the implementation of this policy instrument. Framed in the context of policy-oriented research, the thesis provides a number of policy recommendations related to the design and implementation of TWC schemes (see Section 5.4). Within this context, the researcher presented the results of this thesis at a number of international workshops, conferences and industry association meetings. This included discussions with obliged parties under TWC schemes, and policy makers both at the national and EU level. The dissemination of results also attempted to contribute to a more balanced discussion and better communication among stakeholders.

Third, *the research applied and combined different methods and criteria to the evaluation of TWC schemes.* Supported by several disciplines, the contribution of the thesis lies in the combination of several evaluation methods and criteria that provide an empirical and normative understanding of TWC schemes. By using different but complementary qualitative and quantitative evaluation approaches, the thesis offers an evaluation template for the assessment of current or future TWC schemes. For countries that are (i) about to embark on discussions of whether a TWC scheme represents the right policy choice for them, or that (ii) want to perform ex-post evaluations, the research shows what to evaluate and suggests how to do it. In particular, the research contributes to bridging the fact-value dichotomy in public policy evaluation. It indicates the need for evaluations and methods to complement cost-minimisation models in the evaluation of TWC schemes. Furthermore, by stressing that there is no single best method for policy evaluation, the contribution of the research also lies in the application (and appropriateness) of the triangulation of both data collection and analytical methods in the field of energy efficiency policy evaluation.

Fourth, *the research developed a broad framework for the analysis of transaction costs under TWC schemes.* Whereas much discussion related to transaction costs had been heavily concentrated on the *trading* phase, the research shed light on the wider analytical view that observers must bear in mind when discussing/investigating transaction costs under TWC schemes. The research provided a deeper understanding of the nature of transaction costs. The analysis showed that not only the trading phase can be subject to transaction costs, but also the planning and implementation of eligible measures leading to the issuance of certificates. In turn, the identification of transaction costs upstream in the lifecycle of certificates underscored the importance of a high level of effectiveness among supporting informative instruments addressing increased energy efficiency. Furthermore, the results

indicated that despite the presence and scale of transaction costs, the energy savings realised under the British TWC scheme delivered net societal benefits. By broadening the analysis of transaction costs under TWC schemes, the research further contributes to the literature on the transaction costs of tradable certificate schemes in general, which mainly appear to be focused on trading activity (see e.g. Kerr and Maré, 1998; Stavins, 1995; Tietenberg, 2006). Finally, the research also responded to calls for extensive further research regarding the various forms of transaction costs affecting tradable permit schemes in general (see OECD, 2002).

Fifth, *the research revealed (limited) trading activity but also identified several drivers for non-trading preferences under TWC schemes.* On the one hand, and despite the fact that international observers of the British scheme speculated that no trading had occurred during the first phase, the research found that (limited) trading did occur. On the other hand, whilst policy makers and analysts were mainly concerned with the (expected) trading activity—and cost savings that could be accomplished through trading—the research revealed an autarky compliance strategy and several drivers behind this behaviour. Importantly, the research found that a preference for non-trading was also driven by corporate and commercial strategies among energy suppliers—in Great Britain and France—aimed at capitalising several commercial benefits of increased energy efficiency. Consistent with the development of other tradable certificate markets (e.g. the US and Chile), findings show that policy makers and interested observers should be modest in their expectations that trading activity will flourish under TWC schemes in the short term.

5.2 Main conclusions regarding the research questions

The results of this thesis show that the *performance of TWC schemes is rather unique and context-specific.* Therefore, even though the economic rationale of cost-effectiveness is the same under TWC schemes, generalisations or extrapolations are difficult to make (see review of initial hypotheses below). At the same time, the use of different methods for data collection and analysis stresses the appropriateness of triangulation.

RQ 1: How do TWC schemes perform from the perspective of a broad evaluation? What are the critical aspects/conditions that affect their performance?

Taking into account ex-ante and ex-post results. The initial *hypotheses* that guided the research and also the selection of the evaluation criteria are now revisited. Findings show that the (expected) performance of TWC schemes is somewhat less clear when examined in depth:

Hypothesis 1: Given non-compliance rules and effective enforcement, TWC schemes can achieve an energy-saving and/or environmental target(s) with a high degree of certainty. Findings show that for a TWC scheme to be relevant in terms of energy and environmental considerations (and in the context of energy for sustainable development), ambitious energy savings targets must be set. From an ex-ante perspective, results show that a TWC scheme can achieve ambitious targets. However from an ex-post perspective, the cases analysed suggest a poor level of ambition regarding energy savings targets. Although a "high" level of effectiveness was observed, this may be the outcome of soft savings targets and/or pitfalls in the regulatory framework. At the time of research, no cases existed where more stringent targets had been set. Besides the level of ambition, ex-post results show that the integrity of energy-saving (and environmental) effectiveness also relied on non-compliance rules (in particular financial penalties), due enforcement and policy measures to prevent free-riding effects. To ascertain the environmental effectiveness as such, explicit (and relevant) targets are required. Finally, TWC schemes need to work with and be supported by an effective portfolio of policy instruments. Further research is needed to de-link the effects from various policy instruments. Otherwise, biased assertions can be made.

Hypothesis 2: Due to increased energy efficiency, society obtains net economic benefits under a TWC scheme. Findings showed that energy cost savings represent the majority of the economic benefits. Adding the social and environmental benefits of increased energy efficiency, the justification for energy efficiency improvements is strengthened. This hypothesis is supported by the cost-benefit analysis addressing the British TWC scheme. Even assuming a high burden of transaction costs among obliged parties and a low level of socio-economic environmental benefits, it was estimated that the British TWC scheme nonetheless delivered net benefits for society. These results seemed to confirm the socio-economic and environmental benefits of increased energy efficiency. As for Italy and France, much more data is needed to ascertain whether or not society has benefited from the TWC schemes. In all events, additional research is needed to gain a wider and better quantification of all socio-economic benefits related to increased energy efficiency as such and other policy instruments. This poses a remarkable challenge for a thorough (comparative) evaluation.

Hypothesis 3: TWC schemes can deliver energy savings at low(est possible) costs. Findings show that the modelled EU-wide TWC scheme appeared to meet the cost-effectiveness criterion, even when ambitious saving targets were imposed. However, results were subject to several assumptions and derived from a package of policy instruments to correct/eliminate several market conditions inhibiting increased energy efficiency. The British scheme supports both this hypothesis and outcomes from modelling studies—although caution is required given the relative nature of cost-effectiveness. Whereas liquidity is limited and a real TWC scheme did not emerge during its first phase, several indications of cost-effectiveness were observed under the British case. In Italy, pre-conditions for cost-effectiveness were identified, namely (i) the emergence of a TWC market (both spot and bilateral) and (ii) the volume of permits traded and a common TWC price on the spot market. However, indications of free-riding and the market power exercised by some obliged parties added complexity and uncertainties in ascertaining potential cost-effective outcomes under the Italian scheme. Comparative analyses between TWC schemes and alternative policy instruments are required.

Hypothesis 4: Transaction costs hamper the trading of certificates under TWC schemes. Findings show that whereas numerous sources of transaction costs were borne by obliged parties under the British scheme, possibly entailing high costs, results suggested that the scheme was nonetheless cost-effective and economically efficient. Despite the fact that only perceived transaction costs had affected the low level of trading, several sources of transaction costs were also found upstream in the lifecycle of certificates. No estimates were drawn for the Italian and French cases, so further research is needed. In all, the nature and scale of transaction costs are likely to be different for each scheme due to endogenous and exogenous determinants, so no general assertions can be made.

Hypothesis 5: TWC schemes can involve a low administrative burden for public authorities. Findings show that the limited coverage of the British scheme (i.e. only one eligible sector) combined with an ex-ante M&V approach, is a workable design for keeping the administrative burden on public authorities at a low level. However, the broader coverage of the Italian and French schemes, which also include ex-post M&V of energy savings, could prove the opposite. Results also show that the simplicity and cost-effectiveness of M&V approaches have to be balanced with robustness and reliability. In all events, results regarding administrative burden are likely to be case-specific, so this criterion once again underscored the importance of endogeneity (i.e.

design and thereby coverage). Furthermore, a comparative analysis with other policy instruments is necessary to support or reject this hypothesis.

Hypothesis 6: Technical change is encouraged by TWC schemes so that new technologies are introduced. Ex-ante studies show that under highly ambitious targets, a TWC scheme can encourage innovative technologies. On the contrary, ex-post findings do not support this hypothesis. TWC schemes have basically encouraged the dissemination and implementation of mature technologies that are already commercially available. In addition, indications of free-riding effects may bring into question the additional component of eligible technologies. Combined with ambitious saving targets and/or a stringent and enforceable definition of additionality, a different and truly additional set of eligible measures could emerge. Consequently, this criterion also underscored the importance of endogeneity, as the degree of technical change is driven by design elements—in particular, ambitious targets and/or criteria for additionality and resulting set of eligible technologies.

Hypothesis 7: TWC schemes enjoy a high degree of political legitimacy. Findings show that the Italian case does not support this hypothesis. In addition, at the time of research, there was no political certainty regarding the future of the scheme (i.e. post 2009). Nevertheless, the British scheme suggests the contrary, with several policy aspects influencing a higher level of political feasibility. Findings regarding the potential commercial benefits for obliged parties of increased energy efficiency could lever the legitimacy of TWC schemes. This may avoid conflict with the beliefs and interests of energy suppliers due to increased competitiveness.

Hypothesis 8: Due to increased energy efficiency, (low-income) households derive financial benefits as a result of the implementation of TWC schemes. Findings suggest that households may obtain net financial benefits. However, fair and transparent investment cost-recovery mechanisms play a critical role. Otherwise, cross subsidies can occur and (low-income) households that have *not* implemented measures could shoulder an unfair financial burden. Prima facie, one can argue that investment costs are likely to be equally distributed across all end-users. Furthermore, obliged parties might be taking investment decisions on behalf of end-users, although it is the latter group that could face the technical and financial risks related to the performance of eligible measures. Finally, the rent-seeking behaviour identified under the Italian TWC scheme raised distributional concerns, as obliged parties (i.e. energy distributors) may be obtaining windfall profits at the expense of taxpayers.

Although of all these attributes (and resulting hypotheses) have been explicitly or implicitly associated with TWC schemes, it must be acknowledged that *not all of the criteria are likely to be used for evaluating TWC schemes*. In fact, the choice of suitable evaluation criteria will depend on the specific circumstances that define the barriers and opportunities to increased energy efficiency and also specific (national) policies (e.g. energy efficiency, climate change, fuel poverty). At the time of research, the most relevant criteria seemed to be cost-effectiveness, energy-saving and environmental effectiveness, transaction costs, distributional equity and technical change. Certainly, interdependence and trade-offs between these criteria exist. If TWC schemes are to be relevant for energy efficiency and environmental policy, the importance of *relevance* as an evaluation criterion is underscored (see next section).

In general, *three crucial aspects/conditions affecting the performance of TWC schemes were found*. First, *design, and thus coverage* (i.e. endogeneity), plays a significant role. The choice of design elements can affect several aspects of operation and implementation that are sometimes considered exogenous to the evaluation. However, these are indeed crucial elements of instrument design. They include the targeted level of ambition of the energy savings targets, the size of the market, the provision of information readily available for market agents, minimum regulatory barriers to trade, the extent of technical change, the viability of implementation, the approach and strength of M&V activities and enforcement. To a large extent, these elements can determine, in particular, the order of magnitude of the effects (impacts and outcomes), sources of transaction costs, the dynamics of trading activity and the level of compliance.

Second, several *market conditions* also affect the performance of TWC schemes, in particular those that inhibit the adoption of energy efficiency technologies. Among such conditions, it was found that information problems, the split incentive problem, and the need to mobilise adequate capital to support investments could substantially affect the performance of TWC schemes. In addition, energy efficiency potentials in the sectors under coverage and the structure of energy markets also play an important role. For the latter, energy prices, the right of consumers to choose their energy suppliers and the involvement of different market actors in the scheme (e.g. contractors, retailers, ESCOs) were found to be significant elements shaping the market dynamics and effects of TWC schemes.

Third, *policy conditions* were also identified to influence the performance of TWC schemes. On the whole, the ex-ante and ex-post studies carried out suggest that a high level of effectiveness in the portfolio of supportive policy instruments targeting increased energy efficiency is needed for a TWC scheme to deliver cost-effective energy savings. On one hand, *informative policy instruments* are required to reduce uncertainties and transaction costs and support related technological learning processes. On the other hand, *economic policy instruments* that provide adequate capital are critical to support the necessary investments in new energy-efficient technologies. The interdependence of energy efficiency policy instruments posed a significant challenge to asserting the added value of TWC schemes. Neglecting connections and synergies between instruments can lead to biased assertions. In addition to the portfolio of policy instruments, in certain cases, TWC schemes also pursue policy objectives that are not necessarily related to energy (efficiency) as such (e.g. fuel poverty). These specific policy objectives also drive the behaviour of market participants, which makes the performance of a TWC scheme even more case-specific (e.g. greater consideration to low-income households). In addition, TWC trading markets can work when policy design and implementation are encouraging.

Finally, at the risk of oversimplifying, results suggest that *if TWC schemes are to play a relevant policy role in the context of energy for sustainable development, endogeneity is crucial.* In particular, highly ambitious energy saving targets, fair and transparent investment cost-recovery mechanisms, non-compliance rules and effective enforcement can play a fundamental role. As a result of the implementation of TWC schemes, multiple policy implications were found, ranging from clear trade-offs (i.e. one policy objective can be maximised at the expense of other) to the need for an effective and supportive portfolio of policy instruments. Ex-post results suggest that TWC schemes can be a valuable policy instrument, albeit not a panacea or wholesale solution for increasing energy efficiency and ushering energy systems towards a sustainable trend. A TWC scheme is a complex policy instrument and some designs may work better than others. Results strongly suggest that continuous ex-post evaluations are needed for each individual TWC scheme to improve its regulatory framework and evolving performance. In all events, comparative evaluation studies between TWC schemes and other policy instruments are highly recommended to ascertain a better policy judgement.

RQ 2: What are the limitations/obstacles and strengths/advantages of the evaluation methods used to assess the performance of TWC schemes?

Undoubtedly, the application of each evaluation method used in the research shows advantages but also disadvantages.

As a result of the ex-ante evaluation studies (papers I and II), the *E³ mathematical simulation model* made it possible to introduce a TWC scheme and build key design elements into the model. In turn, this bottom-up computational model proved to be a versatile tool for identifying and quantifying potential impacts of TWC schemes (e.g. energy savings, saving costs, GHG emission reductions) when dealing with large and complex energy systems databases. However, the simulation model failed or had a limited capacity in sufficiently integrating the market complexity embedded in TWC schemes (e.g. the market for trading, transaction costs and market failures preventing increased energy efficiency). In turn, assumptions made in the modelling approach strongly indicated that a high level of effectiveness among supporting policy instruments was needed for a TWC scheme to be cost-effective. From the evaluation standpoint, limitations in the modelling approach underscored the challenge of developing a credible baseline. Furthermore, the thesis also underscored the need to analyse TWC schemes with an extended evaluation framework and additional evaluation methods, as a complement to cost-minimisation modelling tools.

The *transaction cost analysis* (paper III) met the research objective by providing a comprehensive picture of transaction costs borne by obliged parties under the British TWC scheme. This evaluation approach generated significant insights into market behaviour (e.g. trading activity) and market conditions preventing increased energy efficiency (e.g. the split-incentive problem and imperfect information) under TWC schemes. It also made possible the identification of policy outcomes resulting from the implementation of TWC schemes (i.e. responses to the scheme by obliged parties). In turn, the analysis of transaction costs provided key building blocks for further research (e.g. the potential benefits of non-trading behaviour). On the other hand, and concerning the scale of transaction costs, the evaluation approach relied on input data from obliged parties; although, the sample had a limited statistical significance. This limitation stressed the importance of the triangulation approach for collecting data. At all events, it could still be argued that the practical significance of the results, which cannot be determined statistically (McCloskey, 1985), was high. This was due to the

lack of any similar study or debate on transaction costs under TWC schemes. At the time of research, the efforts of the researcher and the resulting outcomes were indeed timely and unique.

The *evaluation approach based on the entire set of flexibilities* (paper IV) faced limitations but also showed strengths. On the whole, the approach confirmed claims that it is the entire set of flexibilities (not only trading) that deserves analytical attention under a tradable certificate scheme (see e.g. Ellerman *et al.,* 2000; Nordhaus and Danish, 2003). In addition, the approach revealed several policy *outcomes* as a result of TWC schemes, such as the involvement of non-obliged actors, and the awareness and behaviour of obliged parties towards energy efficiency. At the time of research, this was the first attempt to document and provide a comprehensive ex-post portrait of TWC schemes. The evaluation approach also highlighted three methodological challenges. The first was related to the identification of a credible baseline or counterfactual situation. The lack of a counterfactual situation (as in the Italian and French TWC schemes) could have multiple interpretations For instance, the development of a baseline—the so-called "evaluation problem" (see Frondel and Schmidt, 2001)—is likely to be controversial and a complex challenge for policy makers and evaluators.[127] No baseline can be actually observed, and many elements must build on several assumptions subject to critical—and eventually public—analysis. The lack of a baseline may also confirm the hypothesis that there is still little tradition (and few resources) for evaluating energy efficiency policy instruments.[128] The second methodological challenge was related to the disentangling of the effects of TWC schemes from the effects of other policy instruments—the so-called "impact problem" (see Scriven, 1991). The challenge of de-linking the effects of TWC schemes from different policy instruments also depended on the disaggregation of the data available. In this particular regard, the third challenge related to the accessibility, reliability and availability of data. To be able to conduct the research, multiple data sources had to be used. However, data restrictions limited the

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[127] Although the development of a counterfactual situation is a difficult task, several methodological approaches do exist, see e.g. Frondel and Schmidt (2001), SRC *et al.* (2001); Vine and Sathaye (2000); and Vreuls *et al.* (2005).

[128] One can also argue that the development of a convincing baseline(s) also depends on strong support and input from obliged parties and related organizations (e.g. research institutions). If such support is lacking, public authorities face a serious challenge understanding the evolution of key variables is and thus building (one or multiple) plausible baselines.

analysis for certain flexibilities (e.g. eligible measures under the Italian scheme and financial data related to trading under the British scheme). Needless to say, obliged parties were reluctant to disclose information.

Finally, several advantages and disadvantages were identified when using the *multi-criteria evaluation framework* (paper V). As noted in the previous Chapter, the approach facilitated a holistic understanding of the broad effects, attributes and complexities of TWC schemes. In turn, this permitted the production of more and detailed results compared to using a single-criterion evaluation approach (e.g. based on cost-effectiveness). The paramount obstacle—as also faced in paper IV—was related to available, reliable and useful data. In fact, the approach was time and information-intensive and a lack of data (and resources) prevented an assessment of all of the aspects investigated. Needless to say, the "impact problem" of de-linking effects among policy instruments was also faced. Neglecting the interdependence of policy instruments can lead to biased evaluation results. Furthermore, the cost-benefit analysis undertaken posed a substantial a challenge as its reliability depends on the accessibility of estimates and their level of uncertainty—including the chosen social discount rate. All in all, the analysis of wide-ranging results provided a larger foundation for judging the merit of TWC schemes. In particular, the multi-criteria evaluation approach stressed the importance of a trade-off analysis and thus the dependences between different evaluation criteria.[129] On the whole, the multi-criteria approach indicated the need for evaluations and methods to complement cost-driven mathematical simulation models to evaluate the effects of TWC schemes.

To conclude, the appropriateness of *triangulation* was confirmed throughout the entire research endeavour. That is to say, a variety of methods for data collection and analysis were needed to approach the empirical and normative understanding of TWC schemes. Limitations in one evaluation approach were covered or compensated by another, with uncertainty remaining an inherent component throughout the evaluation process. Consequently, the research showed that no single-best method or dataset could be relevant to provide a comprehensive analysis of TWC schemes. What is needed is a portfolio of methods for data collection and analyses to perform the overall evaluation and comparison for alternative policy instruments.

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[129] To address the trade-off analysis, Fischer (1995:74) suggests determining which policy objective and/or criteria takes precedence over the others. This can become a significant challenge for policy makers and evaluation practitioners.

5.3 Implications for energy efficiency policy evaluation

Certain implications for energy (efficiency) policy in general can be drawn from the research as a whole.

To begin with, the justification and results of the research support the *need to mainstream energy efficiency policy evaluation as an integral or part of the public policy process.*[130] On the whole, the justification and results of the research revealed that there is still only a limited tradition of policy evaluation in energy efficiency policy-making. Surely, no advancement in energy efficiency policy evaluation will take place if evaluation is not an integral part of the political process. As argued in Chapter 1, there are still a limited number of evaluation studies addressing energy (efficiency) policy instruments. On the one hand, a lack of ex-ante evaluation may result in the implementation of energy efficiency policy instruments that may contribute very little, if anything, to overcoming the problems that justify their implementation. Some instruments may only (further) distort current market and policy conditions that hinder increased energy efficiency and its potential contribution to a more sustainable energy future. On the other hand, a lack of ex-post policy evaluation can result in the maintenance of ineffective and inefficient policy instruments, wasting public and private resources. Furthermore, there is a risk that some policy instruments continue to be implemented long after they should have been improved or removed. Therefore, public authorities need to recognise the significance of policy evaluation. Furthermore, policy experimentation needs to work closely with methodical policy evaluation to support policy design and the choice of instruments. Otherwise we may continue trying to increase energy efficiency on the basis of limited knowledge.

Whereas (a comprehensive) policy evaluation can sometimes be a complex, challenging and resource-intensive process, it is a doable exercise that provides a continuous learning process. Among several benefits, policy evaluation supports/improves policy design and the choice of instruments, generates public accountability and helps to ensure that the public policy process truly contributes to resolving the problem requiring the implementation of such policy instrument(s). For instance, although evaluation can be time consuming, it us argued that

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[130] To support this lesson, note that, at the time of writing, the IEA was about to embark on multiple initiatives, including one to increase the profile of energy efficiency policy evaluation in member countries (see Dowd, 2008).

(multi-criteria) evaluation can take much less time than the overall policy formulation process (see Lahdelma *et al.,* 2000). Mechanisms, incentives and resources need to be in place to develop, incorporate and implement policy evaluation. Lessons from the research strongly suggest that the accessibility, quality and availability of data must be considered when policies are formulated.

As identified during the course of the research, there is a *risk that high energy-saving effectiveness can be achieved but at the expense of soft energy saving targets.* If targets are set and thus evaluated, energy efficiency policy evaluation needs to pay careful attention to the actual level of ambition, the design and operation of the policy instrument, and the political context in which energy saving targets are set. Energy efficiency policies without clearly defined and ambitious targets—a contentious design element in TWC schemes—are likely to fail in making real progress towards sustainable development (cf. Johansson and Goldemberg, 2002). One can argue that saving targets with a low level of ambition probably reflect what is politically feasible.[131] However, one should also bear in mind that the so-called *regulatory capture* problem arises. The term refers to the situation in which (environmental or energy) targets reflect BAU trends (see OECD, 2003). This means that energy efficiency improvements would have taken place regardless, so the regulatory capture and the free-riding effect can seriously affect the integrity of the policy instrument and its related policy development process—including public resources.

The policy scenario triggered by the setting of soft energy saving targets stresses *relevance* as an important evaluation criterion. This evaluation criterion is concerned with the validation of policy objectives and/or targets (cf. Fischer, 1995; Mickwitz, 2003). To begin with, the use of this criterion should address the relevance of the policy instrument as such. Second, the criterion should address whether the energy saving targets truly contribute to the problem/opportunity justifying the implementation of TWC schemes. In other words, the criterion guides the evaluation judgement towards the appropriateness of policy targets. It should aim to answer the following question: is the policy instrument's energy saving target relevant to the problem situation? In the light of the rather significant problem of climate change, the evaluation (and setting) of the relevance of energy saving targets

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[131] The setting of ambitious energy saving targets could also tests the willingness and commitment of public authorities to prevent lobbying groups from damaging the public interest.

should be conducted bearing in mind the long-term societal and environmental benefits of increased energy efficiency, including the avoidance of rising damage costs.[132] As a criterion, the use of relevance stresses the normative character of policy evaluation.

The regulatory capture also underscores the importance of having *alternative and credible counterfactual situations*. The development of alternative counterfactuals can be critical in ascertaining the robustness and sensitivity of the evaluated effects to the assumptions and limitations embedded in different counterfactuals (such as in the SO_2 cap-and-trade programme in the US) (see Ellerman *et al.,* 2000; OECD, 2002).[133] In turn, the regulatory capture also indicates the *necessity of meaningful and enforceable additional criteria when eligible technologies are selected*. Due to the fact that energy efficiency is a moving target, additionality, assumptions and data related to eligible technologies need to be carefully scrutinised and periodically updated. One can also argue that additionality might not be needed in the presence of a highly ambitious energy saving target. In the long run, cost-effective potentials would be used up and more and new additional technologies would nonetheless have to be implemented.

Several *embedded ancillary benefits of increased energy efficiency call for their integration in the evaluation and policy decision-making process*. The number of (potential) ancillary benefits identified during the research was substantial, although these are not usually included in evaluation studies (cf. Levine *et al.,* 2007). The research attempted to do this by including only environmental and societal benefits for which data were available in the analysis. As a result, the economic value of energy savings increased by 40% or more. The key lesson here is that the inclusion of a wider set of co-benefits resulting from increased energy efficiency will simply strengthen the socio-economic attractiveness of higher levels of energy efficiency improvements. Certainly, a broad and explicit quantification (including monetary aspects) of co-benefits poses a serious challenge for a thorough evaluation. Thus, specific methodological aspects need to be developed for integrating workable co-

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[132] See Fischer (1995) for an in-depth review and discussion about *relevance* as a criterion for public policy evaluation.

[133] Although not mutually exclusive, the evaluation in relation to alternative baselines could take three approaches: (i) based on a non-energy efficiency policy or business-as-usual scenario (common approach), (ii) based on a counterfactual situation depicted by the most-likely alternative policy instrument(s), and (iii) based on a counterfactual scenario depicted by the existing portfolio of policy instruments targeting energy efficiency.

benefits into the evaluation exercise, as well as providing guidelines on how to address co-benefits. Due to the fact that energy efficiency can benefit both society and the environment, one can safely argue that co-benefits should become a significant decision building block in the public policy process related to energy efficiency.[134]

Consistent with the lesson elaborated on above, *energy efficiency policy evaluation should also embark on broad evaluation studies*. The traditional but narrow single-criterion evaluation approach based on cost-effectiveness seems to dominate the limited number of evaluation studies on energy efficiency (cf. Harmelink *et al.,* 2007; Vreuls *et al.,* 2005). This thesis suggests that the cost-effectiveness criterion is inappropriate to comprehensively addressing the attributes of energy (efficiency) policy instruments and the institutional and market conditions in which they work (cf. Greening and Bernow, 2004; Gupta *et al.,* 2007). The research shows that multiple attributes are related or can be attached to energy efficiency policy instruments. Besides the specific integration of co-benefits into evaluation studies, the case for a broad evaluation is further justified when policy instruments explicitly address multiple policy objectives (e.g. social, environmental, economical and technical). In public policy, we very often see that one policy objective can be maximised only at the expense of other(s). Then, conflicting policy objectives can arise in the interplay of energy and other public policy fields. Thus, a multi-criteria evaluation framework gives us the opportunity to better comprehend the complexity of the instruments' effects and to identify inevitable trade-offs. Furthermore, a multi-criteria evaluation policy framework can allow us to better understand the broad effects, attributes and complexities of energy efficiency policy instruments.

Broad policy evaluation studies underscore the *triangulation* research approach for both data collection and data analysis. Undoubtedly, like any other, a wide evaluation needs to define its purpose and research questions. Furthermore, it has to match a number of conditions, including the resources available and the dissemination and effective exploitation of the findings. Results from broad evaluation studies can provide an extensive foundation for balanced discussions and may contribute to improved

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[134] Note that the fourth IPCC assessment report explicitly acknowledges the need to integrate co-benefits in GHG mitigation studies, and into related policy decision-making processes (see Levine *et al.,* 2007). Furthermore, it has been noted that one of weaknesses of the *Integrated Impact Assessment* carried out for major EU policy proposals lies in the exclusion of long-term (environmental) benefits (see Pallemaerts *et al.,* 2006).

communication among stakeholders. A broad evaluation also gives policy makers stronger grounds on which to assess the performance of policy instruments and on which to justify these instruments to stakeholders. Based on the research findings, it can be said that the objective(s) and design of the policy, as well as an understanding of how the instrument should be implemented and function within a portfolio of instruments are also likely to frame the challenges encompassed by broad energy efficiency policy evaluations.

Another lesson arising from the research involves the need for *a far greater focus on outcome evaluation* to complement impact evaluation. As described in Chapter 1, an *outcome* is understood as the response to the policy instrument by subject participants (e.g. the adoption of new technologies and the development of new business plans). The research on transaction costs and flexibilities indicated several strategies deployed by obliged parties in meeting their mandatory energy saving targets. These evaluation efforts revealed corporate responses that are slowly mounting up and that stress the importance of outcome evaluation and the development of specific indicators.[135] Only a few energy suppliers are integrating energy efficiency into their core business although these are dominant players. In turn, such firms may be in a better position to help shape (future) energy efficiency policies. Another interesting outcome was that, although technical change seemed to be limited to the dissemination of mature efficient technologies, the involvement of multiple market agents showed a high level of activity in Great Britain. This is relevant because, in the long-term, it is argued that innovation does not take place solely within a firm, but occurs as a result of the interaction and collaboration between firms and other organisations (see Burtraw, 2000; Edquist, 2005). The identification of the drivers behind the to-trade-or-not-to-trade dilemma also suggested that the potential commercial benefits of non-trading encourage energy suppliers to take a front-line position and to act proactively on energy efficiency. It is unlikely that focusing solely on impact evaluation would have captured all of the aspects listed above.

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[135] See Neij and Åstrand (2006) for examples of *outcome indicators* applicable to new energy efficient technologies.

5.4 Policy recommendations

For those stakeholders interested in TWC schemes as a policy instrument for increased energy efficiency, this section briefly elaborates on several policy considerations related to its design and implementation.[136] As concluded previously, the performance of the TWC schemes is rather unique and highly case-specific. Therefore, whereas the set of policy recommendations given below attempts to cover many aspects, it must be stressed that generic policy considerations may not be suitable in all cases. The policy recommendations presented here address three main target groups: (i) policy makers (at the national and EU levels) in charge of the (evaluation and) design of TWC schemes, (ii) authorities responsible for the operation, administration and enforcement of TWC schemes, and (iii) eligible parties participating in TWC schemes.

Justify the implementation of a TWC scheme. On the one hand, the set of policy objectives embedded in TWC schemes is clear, well accepted and supports the implementation of TWC schemes (e.g. by reducing GHG emissions, increasing the security of energy supply and supporting the development of energy service markets). On the other hand, it has not been clear why and how a given TWC scheme was finally chosen and developed in a particular country rather than an alternative policy instrument. Policy makers need to develop their own evaluation frameworks in order to support the public policy process needed to justify whether a TWC scheme is a preferred policy choice. Since the proper introduction of a TWC scheme requires a careful setting of baselines and targets, it is essential to improve and complete the required data sets (e.g. energy efficiency potentials) in all EU member states interested in TWC schemes.

Perform ex-ante and ex-post assessments. Results indicate that the performance of TWC schemes is rather case and context-specific. For countries planning to implement TWC schemes, thorough evaluations should be performed. These studies will improve stakeholders' understanding of the effects of TWC schemes, help them judge their merit and justify the choice of instrument. A multi-criteria evaluation could ideally address the different design options for TWC schemes, and would also address the matter of

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[136] Note that under the EU SAVE EuroWhiteCert project, the researcher was the lead author for the work devoted to developing a package of policy recommendations related to TWC schemes. For a full description of these policy recommendations, see Mundaca and Neij (2007b).

additional and alternative policy instruments for increased energy efficiency. The choice of evaluation criteria is likely to depend on the specific circumstances that define the barriers and opportunities for increased energy efficiency, but also on other national policies (e.g. climate change and fuel poverty). Because TWC schemes operate as credit-based trading mechanisms, there is a strong need for the development of baseline(s). The use of a combination of quantitative and qualitative evaluation methods is recommended. Continuous assessments are recommended for the TWC schemes implemented, revealing the gap between ex-ante and ex-post evaluations. Ex-post studies also provide a basis on which to make the necessary corrections and enhance the performance of the TWC schemes.

Do not overestimate the theory-based rationale of TWC schemes. Although modelling studies do provide useful insights in many respects and should be used to support the policy decision-making process, they must be taken with due caution. In reality, market conditions that prevent energy efficiency technology investments—sometimes very difficult to replicate in modelling exercises—do influence the performance of TWC schemes. The theoretical rationale of cost-effectiveness depends on institutional and market conditions that need to be carefully analysed and managed. Certainly, multiple assumptions behind the theory may not hold in reality.

Provide and ensure flexibility with due consideration to trade-offs. The central argument for implementing TWC schemes relies on lowest-cost compliance by means of high flexibility. Five types of flexibility were identified: (i) eligible measures, (ii) eligible end-use sectors, (iii) banking provision, (iv) the market engagement of non-obliged parties and (v) the trading option. When dealing with these flexibilities, policy makers must be aware of the embedded multiple trade-offs. One of the key challenges is how to encourage cost-effectiveness without hampering distributional equity. Likewise, a proper balance should be found between cost-effectiveness and low administrative burden and transaction costs.

Facilitate trading and consider the to-trade-or-not-to-trade dilemma. Stakeholders need to consider that the trading component in a TWC scheme aims at facilitating lowest-cost compliance, thus enhancing the scheme's cost-effectiveness in meeting a mandatory energy savings target. Therefore, trading is certainly relevant, albeit not an objective per se of TWC schemes. The experience in Great Britain (and indications from France) suggests that increased branding and customer loyalty have been identified as a potential commercial benefit of non-trading for obliged parties. In all events, trading markets can work

when the design and implementation of policies encourage this. In the short term, eligible parties have little trading experience and lack business models to cope with this new policy instrument. Ambitious targets and thus a scarcity of TWCs is a critical pre-condition to trigger trading activity. The implementation of a clearinghouse to provide information about market (both spot and bilateral) prices, volumes and parties should be considered; thereby increasing transparency. A clearinghouse can keep market actors updated and well informed about the dynamics of the TWC market and its regulatory framework. Furthermore, an electronic trading platform can reduce transaction costs (e.g. search costs) by establishing a forum at which buyers and sellers can regularly meet, also allowing bidding and bilateral trading. The development of standardised contracts (or at least key contractual provisions) can reduce transaction costs related to legal services and perceived liability risks in trading. In Great Britain, the need for written approval for trading from the authority could be dismissed.

Set ambitious energy savings targets. A critical pre-condition for a TWC scheme to be effective is the establishment of mandatory energy saving/efficiency targets. Given the magnitude of the problem of climate change, and also the benefits that can be expected from increased energy efficiency, ambitious targets should bet set if TWC schemes are to play a relevant policy role. If highly ambitious targets are set, non-compliance rules and effective enforcement become increasingly important. Once the target is set, it automatically becomes the benchmark for evaluating how effective and relevant the scheme is in energy (and environmental) terms. TWC schemes require the careful setting of baselines and an estimation of energy efficiency potentials. As energy efficiency is a moving target, and addressed by multiple policy instruments, the reference scenario must be updated periodically.

Design functioning coverage for fuels and technologies. Current TWC schemes cover a wide range of fuels, in particular under the French TWC scheme. Nevertheless this is a complex issue that, depending on the scope of coverage, could also have distributional effects in the fuel market. TWC schemes with extensive coverage must be weighted against the administrative burden and transaction costs that the design imposes on authorities and eligible parties. In addition, it has to be kept in mind that oil products should be carefully considered in order to avoid negative environmental rebound effects (i.e. by encouraging electricity savings only, a shift from electricity to oil products could occur). When it comes to eligible measures, a broad portfolio is preferred in order to ensure more cost-effective options. However, careful consideration must be given to the

administrative burden and generation of transaction costs that this situation entails (e.g. M&V approaches).

Develop clear and enforceable non-compliance frameworks. Among other design elements, energy-saving effectiveness relies on non-compliance rules and effective enforcement. For instance penalties for non-compliance in the form of ceiling prices operate under the logic that they must be set high enough so that obliged parties prefer to avoid them and comply with their individual targets. Together with specific penalties for non-compliance—that need to be updated regularly—the achievement of energy saving targets relies on its enforcement mechanisms. This involves not only the ensuing penalties, but also legal regulations and effective M&V approaches. Altogether, this set of elements must send a clear signal to obliged parties that non-compliance does not pay.

Ensure synergies and avoid overlaps within the portfolio of policy instruments targeting energy efficiency. Policy instruments do no function in isolation, so it is necessary to analyse the interaction with other policy instruments in order to identify synergies and avoid overlaps. For instance ex-ante and ex-post results strongly indicated that a high level of effectiveness among supporting informative policy instruments is needed. It is also relevant to consider how the additionality of measures implemented under TWC schemes can be ensured if a variety of policy instruments exists. Overlaps can exist, but a constant review process would allow them to exist only temporarily.

Do not overestimate the political feasibility of TWC schemes. If a TWC scheme is a plausible policy choice for a given country, the key political challenge is to find ways of implementing TWC schemes in the most acceptable manner. Clear operational and regulatory frameworks must be developed. Policy makers should be prepared to discuss and negotiate design elements and the institutional framework with obliged parties. Continuous dialogue and debate should be encouraged.

If an EU-wide TWC is evaluated, do consider its potential distributional effects. If considering the potential implementation of a TWC scheme, it is crucial to consider how cost and co-benefits are to be distributed, particularly in a scenario with an EU-wide TWC scheme. While modelling work indicates that the cost-effective achievement of the indicative target of the EEE&ES Directive can be achieved by means of an EU-wide TWC scheme, opposition to this policy option can arise at the national level due to the potential transfer of welfare. Thus, countries could decide to adopt autarky

compliance strategies to secure co-benefits, thereby maximising their net present welfare without international trading.

Ensure long-term policy objectives to imbue confidence in emerging TWC markets. If justified, the creation of TWC schemes should be seen as a long-term policy goal and not as a single burst of policy-making effort. Strong political commitment is necessary to give confidence and certainty over regulatory issues so that stakeholders can effectively plan, develop and/or adjust their compliance strategies. Among other issues, a secure long-term policy horizon will help market players to factor the costs and benefits of TWC schemes into their investment and commercial plans (e.g. branding), develop adequate marketing strategies compatible with other informative policy instruments, and encourage technological change capable of meeting higher energy saving target ambition levels.

Facilitate dialogue between policy initiatives. With some TWC schemes already implemented, stakeholders have a unique opportunity to closely scrutinise the institutional and market conditions affecting the performance of such schemes. In addition, TWC schemes could be developed on the basis of existing policy initiatives, deriving advantages from on-going learning processes and human and institutional capacities. For instance, in Great Britain, the scheme was built upon the EESoP. This meant stakeholders were already familiar with operational and implementation aspects of the TWC scheme.

Develop a clear but simple institutional framework. In order to keep the level of administrative burden low, simple but clearly defined operational and regulatory frameworks are crucial when designing TWC schemes. Without hampering the environmental/energy integrity of the scheme, a simplified enforcement system can ease the burden for the authorities. Additionality must prevent eligible parties from free-riding, so only energy efficiency measures that would not have been implemented under the BAU scenario are encouraged. The development and enforcement of fair and transparent investment cost-recovery mechanisms is another crucial design element.

Develop an ex-ante M&V of energy savings approach whenever feasible. The utilisation of an ex-ante approach as a mechanism to reduce transaction costs related to M&V activities should be analysed accordingly. Because there is handful set of measures for which the technical performance is relatively well understood, the British scheme allows energy savings to be granted beforehand so there is no requirement for ex-post M&V as such.

This approach has reduced the administrative burden for the authority and eligible parties. Despite the uncertainties that can arise from it, it is argued that the robustness and reliability of an ex-ante M&V approach must be balanced with simplicity and cost-effectiveness. The suitability of this approach is heavily related to knowledge regarding baselines and the performance of particular measures. As energy efficiency is a moving target, the assumptions, baselines and methods included in this approach need to be carefully scrutinised and periodically reviewed/updated.

Aim for transaction cost accounting. It is certainly difficult to provide generalised recommendations for obliged parties on this subject, simply because they know their own organisations much better than anybody else. However, one can argue that a simple, but formal internal mechanism for keeping track of transaction costs (sources and related costs) can be useful for obliged parties in order to better manage the situation and reduce transaction costs under their control. After due evaluation of TWC schemes, policy makers could also give guidance to eligible parties by providing a list of the most common sources of transaction costs.

Allow bundling of eligible energy efficiency measures. Bundling or pooling of similar measures arises as a straightforward strategy to reduce transaction costs. This means that a project developer can group several projects and/or develop similar projects in order to reduce the financial burden that potentially fixed transaction costs can generate. For instance, the adoption of this strategy in the regulatory framework can reduce the burden of transaction costs related to contract negotiation, baseline development and M&V activities. This strategy can also reduce transaction costs for eligible parties like ESCOs. For instance the domestic sector may offer little attractiveness on an individual-measure basis. However if project bundling is allowed, the number of measures and larger volume of savings can trigger a more active participation (if allowed) of ESCOs or other eligible parties in the residential sector.

Adopt streamlined procedures. The development of the institutional framework of any TWC scheme has a direct impact on the administrative burden that both authorities and eligible actors face. Whenever possible, authorities should design streamlined procedures that can help obliged and eligible parties to reduce related transaction costs (e.g. a fast track or simplified modalities for small-scale measures). Streamlined procedures must counteract any lengthy approval procedure. These actions should help eligible parties to standardise internal courses of actions. Certainly, the

implementation of this strategy must not hamper the integrity of a TWC scheme.

5.5 Further research

This research has attempted to provide a comprehensive, detailed and insightful portrait of TWC schemes; however, many aspects still need to be investigated. Various theoretical and empirical issues for further research were identified throughout the development of this doctoral thesis. Although some of them were touched upon during the research, they need to be better understood.

Much more research needs to be done on *ex-ante evaluation studies* for countries that are interested in, or about to implement or experiment with TWC schemes. As already suggested, a multi-criteria evaluation should address different design options of TWC schemes, and also consider additional and alternative policy instruments for increased energy efficiency. As the research shows, some designs work better than others and a TWC scheme might not be the best policy choice to increase energy efficiency. Furthermore, no cases in which very ambitious energy saving targets have been set exist at the national level. If TWC schemes are to play a relevant role in energy and environmental terms, their relevance must be evaluated against the related challenges (e.g. climate change).

There is a need for *further studies on ex-post evaluation and the implications of TWC schemes for energy market competitiveness*. As noted previously, continuous assessments are recommended for implemented TWC schemes. These studies serve as an important basis on which to make the necessary corrections and/or enhance the performance of schemes. In other words, a lack of ex-post policy evaluation can result in the maintenance of, for instance, ineffective and inefficient TWC schemes, long after they should have been improved or removed. For schemes implemented in Italy and France, it was noted that there is a strong need to develop baseline(s) and investigate transaction costs and the administrative burden for public authorities. Furthermore, it remains to be seen whether or not commercial benefits of non-trading add to the overall economic efficiency of TWC schemes. In this particular regard, the British and French schemes may be particularly interesting cases with which to begin.

Another empirical issue involves the *de-linking of effects (impacts and outcomes) of different energy efficiency policy instruments*. It is recognised that disentangling the contributions made by different policy instruments is a complex and challenging task for the evaluator (see e.g. Chen, 1990; Pawson and Tilley, 1997; Rossi *et al.,* 2004). As noted during the course of the research, neglecting the interdependence of policy instruments can, however, lead to biased evaluation results. The development of credible baselines, causal-loop relationships and specific (impact and outcome) indicators can support the evaluation in distinguishing the specific contributions made by each policy instrument. Disentangling the effects of different energy efficiency policy instruments should also be relevant in asserting the added or net value of TWC schemes.

As noted several times throughout the research, *there is a strong need to perform a comparative evaluations between TWC schemes and alternative policy instruments.* The use of several evaluation criteria underscored the relative component of the results (e.g. cost-effectiveness, economic efficiency, administrative burden). One has to bear in mind that the debate on the added value of TWC schemes is also hampered by the lack of evaluation of (already implemented) policy instruments addressing energy efficiency. Certainly, the research on the disentangling of effects mentioned above can be highly necessary for comparative evaluations between TWC schemes and other competing policy instruments (e.g. whether instrument X can achieve a given energy saving target with more or less resources than TWC schemes).

From the theoretical point of view, research efforts need to be devoted to developing *choice-decision models for household energy (efficiency) technology investments.* The model of rational choice (i.e. unbounded rationality) seems to dominate much of the conventional energy-economy-environment modelling tools for policy analysis (cf. Greening and Bernow, 2004). These models are cost-driven and usually assume perfect information and individuals with well-defined preferences that make decisions to maximise them. Consequently, they can be criticised for offering an unrealistic portrait of investment decision-making processes (cf. Hourcade *et al.,* 2006). If limitations of these models are not overcome or explicitly mentioned, modelling results may send misleading messages to policy makers. Furthermore, investment and operational costs are only part of a great variety of variables (e.g. design, functionality, reliability, learning, environmental awareness) that frame and drive energy-related consumer investment decisions. Research initiatives should address the development of more comprehensive models that better capture choice-decision variables of energy (efficiency) technology

investments. Research outcomes would provide a better basis to support public policy addressing energy (efficiency) and environmental aspects at the household level.

Finally, another theoretical aspect refers to research on *energy sufficiency policy*. Calls for energy sufficiency, and thus absolute reductions in energy consumption in the richest parts of the world, are increasingly common (see e.g. Wilhite and Norgard, 2004). Considering unsustainable patterns of (energy) production and consumption, "sufficiency" has been already defined as a principle for sustainability (see Daly, 1996; Princen, 2003). With its strong normative character, is there any room for sufficiency' in the energy (efficiency) policy agenda? How can an energy "sufficiency" threshold be approached and/or determined? What kind of policy instruments could encourage energy sufficiency? Which policy areas could be targeted?

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Appendix A – Other author publications

The following is a list of other publications by the author and research colleagues, which are of relevance to the thesis work:

Mundaca, L. (2007). *Transaction costs of energy efficiency policy instruments.* Paper presented at the European Council for an Energy Efficiency Economy (ECEEE) - Summer Study: Saving Energy - Just do it!, La Colle sur Loup, France. June 4-9.

Mundaca, L., & McCormick, K. (2004). *Energy policy instruments and innovation: How can tradable permit schemes influence innovation processes?* Paper presented at the International Conference on Innovation, Sustainability and Policy, Kloster, Germany. May 23-25.

Mundaca, L., & Neij, L. (2006a). *Tradable white certificate schemes: What can we learn from early experiences in other countries? A Swedish national report in the context of the IEA-DSM Task XIV on markets mechanisms for 'White Certificates' trading*: International Institute for Industrial Environmental Economics at Lund University.

Mundaca, L., & Neij, L. (2006b). *Transaction costs of energy efficiency projects: A review of quantitative estimates. Task report work package 3. EuroWhiteCert Project*: International Institute for Industrial Environmental Economics at Lund University.

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Neij, L., & Mundaca, L. (2007). *Handbook for the design and evaluation of TWC schemes. Task report work package 5. EuroWhiteCert Project*: International Institute for Industrial Environmental Economics at Lund University.

Appendix B – List of interviewees

The following is a table with details about the professionals that were interviewed during the research:

In relation to TWC scheme in	Name	Organisation
Great Britain	Brian Samuel	Energy Saving Trust
	Carsten Rohr	Department for Environment, Food and Rural Affairs
	Charles Hargreaves	Office of Gas and Electricity Markets
	Elaine Waterson	Energy Saving Trust
	Gill Owen	Warwick Business School
	Iris Ronney	Department for Environment, Food and Rural Affairs
	Joanne Wade	Impetus Consulting
	John Costyn	Office of Gas and Electricity Markets
	Martin Devine	Department for Environment, Food and Rural Affairs
	Russell Hamblin	Energy Retail Association
	Russell Marsh	UK Green Alliance
Italy	Antonio Capozza	Centro Elettrotecnico Sperimentale Italiano
	Danielle Russolillo	Fondazione per l' Ambiente
	Marcella Pavan	Autorità per l'energia elettrica e il gas
	Nicola Labanca	end-use Efficiency Research Group at Politecnico di Milano
	Stefano Alaimo	Gestore del Mercato Elettrico Italiano
	Walter Grattieri	Centro Elettrotecnico Sperimentale Italiano
France	Emmanuel Branche	Électricité de France
	Luc Bodineau	Agence de l'Environnement et de la Maîtrise de l'Energie
	Magali Tarbé	Électricité de France
	Paul Baudry	Électricité de France
	Stéphanie Monjon	Agence de l'Environnement et de la Maîtrise de l'Energie

Appendix C – Interview protocols

I. General interview protocol[137]

General policy issues

1. Please describe the role of you organisation in relation to the TWC scheme implemented in your country.
2. According to you, what are the main drivers (problems and/or opportunities) to implement the TWC scheme in your country?
3. Now, what is official argumentation to implement the TWC scheme in your country? Do you agree?
4. In general, what are the main market conditions that hamper higher levels of energy efficiency in your country?
5. Would you say that these market conditions/aspects are also applicable to the context in which the TWC scheme implemented in your country operates? Why?
6. Are you familiar with the existing portfolio of policy instrument addressing energy efficiency? Please elaborate.
7. Within this context, what would you say is, or might be, the added value of the TWC scheme in your country?
8. Do you know any other policy instrument/initiative that could have been implemented as an alternative of the TWC scheme?

Issues related to policy formulation[138]

1. Please explain the policy development of the TWC scheme in your country.
2. Please describe the most important design elements of the TWC scheme. For instance:
    a. Who are the obliged parties?
    b. What is the mandatory energy saving target?
    c. What are the rules for non-compliance?
    d. What is the time period/horizon for the scheme?
    e. Are there any other parties that are allowed to participate but bear no obligation?
    f. What are the end-use sectors in which energy savings can be realised?

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[137] Note that this general interview protocol was firstly used to conduct semi-structured interviews. Then, specific issues related to policy formulation and policy implementation also included in this interview protocol were also used to conduct focused interviews.

[138] These aspects were covered more in detail when conducting focused interviews.

      g. Do you a list or specific information about eligible measures?
      h. Please describe the main aspects concerning trading of TWCs.
      i. Please describe the measurement and verification approach(es) to certify energy savings.

3. Please elaborate regarding the political discussions and consultation process (if any) regarding the aspects mentioned before.
4. Does the TWC scheme (or the design as such) create any conflicts with the beliefs, interest and/or ambitions of obliged parties?
5. What are/were the main actors participating in the formulation process of the TWC scheme?
6. Please indicate/describe the critical or more contentious design elements.
7. How do you evaluate the willingness of energy suppliers to become energy savers? Was there any resistance to have mandatory targets? Do you think that energy suppliers had preferred another type of instrument instead of the TWC scheme?
8. Are you familiar with the concept of additionality? If yes, please explain how this concept applies to the TWC scheme in your country? How critical has been the issue of additionality when defining eligible measures? What are the criteria used for determining additionality? Is additionality set before or after the measure is defined as eligible? Is there a market share threshold that determines whether an eligible measure is additional? Is it difficult to draw the line between additional and non-additional? What happens when there are other policy instruments also encouraging or promoting eligible measures?
9. Is there any investment cost-recovery mechanism for obliged parties in place? If yes, please explain its central features and the way it operates.

Issues related to ex-ante evaluation

1. How was the specific energy saving target level determined?
2. Was there any study about of the potential effects (impacts and outcomes) of the TWC scheme implemented in your country?
3. If yes, please summarise the main findings/conclusions. Do you agree with the findings of the study?
4. If there was no study at all, what do you think are the reasons behind this situation?
5. According to you, is there any tradition in your country to analyse before hand or ex-ante the potential effects of energy (efficiency) policy instruments? Please elaborate.

Issues related to policy implementation[139]

1. Looking at the lifecycle of energy savings, what have been the main barriers and opportunities that obliged parties have faced?
2. What are the most implemented eligible measures? Why? Would you characterise this level of activity as above or beyond business-as-usual trends?
3. An important issue when it comes to energy efficiency is the so-called rebound effect (i.e. meaning that people increase the utilisation of equipment because it cost less to operate) Is it possible to identify any rebound effect as a result of eligible measures implemented under the TWC scheme? Can you point out to any evidence?
4. What are the end-use sectors that show high levels of activity? Why?
5. What has been the activity level of obliged and non-obliged parties? Are there any major drivers behind these aspects? What are the main compliance strategies that obliged parties have implemented so far?
6. How would you characterise the involvement of ESCOs? High? Low? Why?
7. Do you have any information about the level of banking of TWCs?
8. Please describe the trading activity level? Is there any preference towards trading or non-trading so far? Why?
9. Do you have any information about the main market and institutional drivers (potentially) explaining the trading level?
10. Is there any official source of information where eligible parties can obtain updated market information?
11. Do you have information about the administrative burden for the public authorities to administer and enforce the TWC scheme? What is the order of magnitude in terms of human and financial resources devoted to run the scheme? Was there a need to create a new institution?

Issues related to ex-post evaluation

1. How would you consider the performance of the TWC scheme until now?
2. What are the main positive and negative results?
3. Would you identify any pitfall(s) in the design of the scheme?
4. What could be done to improve the performance of the scheme?
6. Would you say that the TWC scheme has increased or reduced the competitiveness of obliged parties? Why?
7. How is the investment cost-recovery mechanism working? How are obliged parties transferring investment costs to end-users?

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[139] These aspects were covered in detail when conducting focused interviews.

II. Specific interview protocol for investigating transaction costs

The purpose of this interview protocol was to identify the nature and scale of transactions costs that obliged parties face under the British TWC scheme (e.g. search for and assessment of information, search for trading partner, negotiation with partners, measurement and verification of energy savings, and legal costs). The structure of this interview protocol followed the lifecycle of TWCs, namely, planning and implementation of eligible measures, measurement and verification of energy savings, and issuance, trading and redemption of certificates.

Issues related to the planning of EE measures

1. During the planning phase of eligible measures, what are the main activities that obliged parties usually undertake?
2. Does the burden (e.g. in terms of time and effort) of all the activities differ according to the specific type of eligible measure? Please give an example.
3. Do obliged parties face high search costs in order to identify end-users willing to implement their schemes? Do you have any information/opinion on that? Is there any evidence?
4. The regulator mentions that there is a need to persuade end-users to implement eligible measures. Does this means that major efforts still need to done to raise awareness among end-users about energy efficiency? What are the implications for obliged parties and the scheme in particular?
5. Do you have any information about how energy suppliers assess risk of failed implemented investments?
6. Looking at the planning phase of eligible measures, what is the role of local authorities?

Issues related to the implementation of EE measures

1. During the implementation phase of eligible measures, what are the main activities that obliged parties usually undertake?
2. Does the burden (e.g. in terms of time and effort) of all the activities differ according to the specific type of eligible measure? Please give an example.
3. Are there any intermediaries between obliged parties and end-users? In this regard, it was found that middlemen are very active? How would you interpret this?

4. How would you consider the role of Social Housing Programmes (SHP), manufacturers, etc?
5. According to the regulator, partnership with SHP, manufacturers, retailers, etc. has been rather critical for the suppliers to meet their savings targets, why?
6. What would be the reasons behind this constellation of actors? Does this suggest that obliged parties face difficulties to reach end-users?
7. What would it be the result for the scheme without the support of these market actors? Are these partnerships considered to be an opportunity or necessity for obliged parties? Please explain.
8. Looking at the implementation phase of eligible measures, what is the role of local authorities?
9. It is argued that the majority of the implemented measures could be characterised as market push rather than end-user pull. At the same time, it is also argued that end-users are not interested in the information that is produced by obliged parties and Energywatch about the scheme. How much efforts need to be devoted to marketing the scheme?
10. How important is the "28-day" rule for the actual implementation of energy service actions? In fact, it has been mentioned that it is not clear that the scheme stimulates the promotion of energy services, why?
11. Despite the incentives in terms of uplift in savings for suppliers to deliver measures as an energy service action, only 3 suppliers have followed this compliance approach. Besides the "28-day" rule, are there any other barriers that prevent a higher share of energy service actions under the scheme? Could this entail that higher transaction costs for implementing energy service actions than individual eligible measures?
12. In May 2004, the regulator launched a 2-year pilot to test the removal of the "28-day" rule; which has been perceived as a barrier to energy services. What has been the outcome of this initiative?

Issues related to the measurement and verification of energy savings

1. During the M&V phase of energy efficiency measures, what are the main activities that obliged parties usually undertake?
2. Does the burden (e.g. in terms of time and effort) of all the activities differ according to the specific type of eligible measure? Please give an example.
3. Taking into the methodology for determining energy savings on an ex-ante basis, how would you describe the process (or negotiation) for setting the baselines and energy savings beforehand?
4. Based on your expertise, what are the pros and cons of this ex-ante approach? It is argued that this approach is "simple, manageable and verifiable". What is your opinion? What are the main trade-offs?

5. According to the regulatory framework, a proportion of beneficiaries have to be monitored to ensure consumer satisfaction and proper use of eligible measures. What kinds of activities do obliged parties undertake in this regard? Do obliged parties face any barrier to get feedback from end-users?
6. For the regulator: Two audits were conducted during the first phase, what were the costs of these audits? Are these costs included in the total costs for administering the scheme?

Issues related to trading activity

1. During the trading phase, what are the main activities that obliged parties usually undertake?
2. What are the main barriers that obliged parties face for trading savings/obligations?
3. Is the search for trading partner a significant source of transaction costs?
4. According to you, does the regulatory framework encourage trading activity?
5. How would you characterise the level of trading activity so far?
6. Overall, very little trading has been seen until now. What do you think are the reasons behind this trend? For instance, preliminary research findings reveal the following reasons:
   a. Obliged parties see the scheme as a rolling programme. As banking is permitted, obliged parties are keen to save the excess of savings for future commitment periods
   b. Obliged parties use the same and few contractors companies to undertake the work. This means that it is very likely that all obliged parties face similar costs
   c. Obliged parties face a lack of trading platform in which buyers and sellers can identify each other (also unable to use the experience they have gained with Tradable Green Certificates).

Issues related to the declaration (redemption) of energy savings

1. During the declaration phase of energy efficiency measures, what are the main activities that obliged parties usually undertake?
2. Does the burden (e.g. in terms of time and effort) of all these activities differ according to the specific type of measure that is under declaration? Why? Please give an example.
3. For the regulator: It is known that two companies did not comply with their obligation, what were the main reasons? It is also known that the authority did not impose any penalty, why?

4. What are the main reasons that allowed suppliers to exceed the target by ca. 40%?

5. Considering the entire lifecycle of savings under the scheme, i.e. "planning-implementation-monitoring&verification-trading-declaration", would you have an estimate (or any idea) about the costs to arrange an eligible measure prior to its implementation a monitoring it ex-post implementation (as opposed to direct investment and administrative costs)?

Appendix D – Questionnaire

The objective of this questionnaire was to identify the nature and scale of related transactions costs (e.g. search of information, feasibility studies, negotiation with partners, legal costs, administrative procedures) borne by obliged parties under Tradable 'White Certificate' schemes. Taking the "Energy Efficiency Commitment" (EEC) in Great Britain as case study (2002-2005), the purpose of this questionnaire is to get empirical data about transaction costs. This questionnaire was developed based on preliminary data collection and a series of interviews with key stakeholders carried out in London during September 2005.[140]

*

Questionnaire

1. Transaction costs are generally defined as any cost that is not directly involved in the production of goods or services but they are essential for realising the trade as such. In other words, transaction costs arise from initiating and completing transactions (buying or selling) of any product and service that is traded. Potential sources of transaction costs include searching for information, negotiation costs, search for trading partner, consulting with experts, monitoring agreements, etc.

Based on the above definition, please state your level of expertise about this topic:

Unfamiliar   X   X   X   X   Expert

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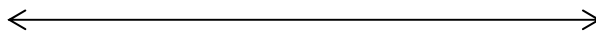
[140] Note that a similar questionnaire was used to approach transaction costs under the Free-of-Charge Energy Audit Programme (FCEA). The structure of the questionnaire followed the lifecycle of energy audits under the FCEA. Results were briefly reported in paper V. Full details are found in Mundaca and Neij (2007a).

2. Please indicate the energy saving target (in GWh) that your company faced for the EEC 2002-2005:

	Target (GWh)
For gas	
For electricity	

3. Please specify/estimate investment costs (in million £) per category of implemented measure during the EEC 2002-2005:

Measure	£M / Year 1	£M / Year 2	£M / Year 3
Lighting			
Heating			
Insulation			
Appliances			

4. Please specify the number of measures that your company installed during EEC 2002-2005, including total investment costs (in £) and their estimated lifetime energy savings (in GWh):

Type of eligible measure	Number of measures installed	Investments costs	Energy savings (GWh)
Cavity wall insulation			
Loft insulation (top up)			
Loft insulation (virgin)			
DIY loft insulation (m²)			
Draught stripping			
Tank insulation			
Radiator panels (m²)			
Solid wall insulation			
Other insulation			
CFLs			

5. In general, what were the most important barriers to implement any energy efficiency measure under the EEC 2002-2005? Please tick the most relevant boxes. Note: You may add additional barriers.

Type of barrier	
Lack of knowledge/information/ of end-users about energy efficiency	
Lack of developers/contractors	
Lack of awareness among end-users	
Uncertainties about the performance of energy efficiency technologies	
High costs of energy efficiency technologies	
Lack of adequate capital or financing possibilities	
Low market price for energy savings	
Projects not easily replicable	
Time consuming approval and registration process	
High approval costs requirements	
Poor development of Energy Service Companies	
The "28-day" rule for domestic energy service contracts	

6. During the <u>planning</u> phase of energy efficiency measures, please indicate the activities that your company undertook during the EEC 2002-2005. Please estimate their related costs on per lighting and insulation measures as a percentage of the investment costs. Note: You may add additional activities.

Activities during the <u>planning</u> phase	% of investment costs per	
	Lighting measures	Insulation measures
Search for information		
Persuasion of end-users		
Search for partners/contractors		
Negotiation with partners/contractors		
Agreement with partners/contractors		
Project documentation/internal management		
Brokerage fee		

7. During the <u>implementation</u> phase of energy efficiency measures, please indicate the activities that your company undertook during the EEC 2002-2005. Please estimate their related costs on per lighting and insulation measures as a percentage of the investment costs. Note: You may add additional activities.

Activities during the <u>implementation</u> phase	% of investment costs per	
	Lighting measures	Insulation measures
Approval procedures		
Persuasion of end-users		
Baseline setting		
Agreement with partners/contractors		
Project documentation/internal management		
Consultancy		
Brokerage fee		

8. During the <u>implementation</u> phase of energy efficiency measures, please indicate the level of importance that the following activities had when it comes to the implementation of the measures among end-users. Note: You may add additional activities. Please tick only <u>one</u> box for each activity.

Activities	Level of importance				
	Very High	High	Medium	Low	Very Low
Dealing directly with end-users					
Partnering with local authorities					
Links with Government programmes					
Partnering with retailers					
Partnering with manufacturers					

9. During the <u>measurement and verification</u> (M&V) phase of energy efficiency savings, please indicate the activities that your company undertook during the EEC 2002-2005. Please estimate their related costs on per lighting and insulation measures as a percentage of the investment costs. Note: You may add additional activities.

Activities during the <u>M&V</u> phase	% of investment costs per	
	Lighting measures	Insulation measures
Search for information		
Legal services		
Energy audit		
Measurement of end-use satisfaction		

10. Under the EEC, energy suppliers are accredited with energy savings on an <u>ex-ante basis</u>. How do you evaluate this approach?

    a) Very positive
    b) Positive
    c) Negative
    d) Very negative
    e) Don't know

10.a) Under the EEC, obliged parties have the <u>option of trading their obligation/savings</u> with other suppliers. Did your company trade any <u>energy obligation/savings</u> with other supplier(s) during the EEC 2002-2005?

_____ Yes

_____ No

10.b) If yes, kindly indicate the amount of energy obligation/savings traded, related costs of the trading and whether your company acted as a seller or buyer of an obligation/savings. Note: You may add additional trades.

	GWh	Costs (£)	Seller / Buyer?
Trade 1			
Trade 2			
Trade 3			
Trade 4			

10.c) If trading of an energy obligation/savings took place, please indicate the activities that your company undertook in order to trade. Estimate related costs on a trade-by-trade basis as a percentage of the total trading costs. Note: You may add additional activities.

Activities during the trading of energy obligation/target	% of total investment costs
Search for information	
Search for trading partner	
Negotiation / bargaining with partner / buyer	
Project documentation / internal management	
Legal services	

10.d) If your company did <u>not</u> trade any <u>energy obligation/target,</u> please indicate the causes of why this happened. Note: Please tick the most relevant boxes. You may add additional causes.

Causes of no trading of energy obligation/savings	
Importance of learning in how to meet the target	
There was no demand for energy savings (i.e. excess of supply)	
Low costs of energy savings	
Company preferred to save achieved energy savings for future commitment periods	
Company preferred until market price of energy savings are higher	
Corporate/business reasons	
Lack of trading platform	
High negotiation / bargaining costs with partner / buyer	
Little financial / commercial gain as all suppliers face similar compliance costs	
Shareholders could have interpreted trading as a level of inefficiency within company's business	
Need of approval from the authority	

11. During the <u>declaration</u> phase of energy efficiency savings, please indicate the activities that your company undertook during the EEC 2002-2005. Please estimate their related costs on per lighting and insulation measures as a percentage of the investment costs. Note: You may add additional activities.

Activities during the <u>declaration</u> phase	% of investment costs per	
	Lighting measures	Insulation measures
Project documentation/internal management		
Legal services		

12) By looking at the entire cycle of "planning-implementing-monitoring& verifying-trading-declaring" of energy savings, you would consider that the total burden of transaction costs was:

Measure	Burden of transaction costs was				
	Very High	High	Medium	Low	Very Low
Lighting					
Insulation					

Appendix E – Focus group discussions

The following is a table with details about the focus group discussions in which the author of this thesis participated:

Date	Location	Main participants	In the context of
2004/06/08	Milano, Italy	Policy makers, researchers	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2004/10/06	Stockholm, Sweden	Policy makers, researchers, consultants, energy companies	Swedish Chapter IEA-DSM Task on Market Mechanisms for White Certificates Trading
2004/11/08	London, UK	Policy makers, researchers, consultants	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/01/30	Stockholm, Sweden	Policy makers, researchers, consultants, energy companies	Swedish Chapter IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/04/05	Milano, Italy	Policy makers, researchers, consultants, energy companies	Intelligent Energy Europe – EuroWhiteCert Project
2005/04/14	Paris, France	Policy makers, researchers, consultants, energy companies	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/04/28	Stockholm, Sweden	Policy makers, researchers, consultants, energy companies	Swedish Chapter IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/06/16	Lund, Sweden	Policy makers, researchers, energy companies	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/09/22	Copenhagen, Denmark	Policy makers, researchers, consultants	Intelligent Energy Europe – EuroWhiteCert Project
2005/10/27	Groningen, The Netherlands	Policy makers, researchers, consultants, energy companies	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/11/09	Stockholm, Sweden	Policy makers, researchers, consultants, energy companies	Swedish Chapter IEA-DSM Task on Market Mechanisms for White Certificates Trading
2006/01/26	Budapest, Hungary	Policy makers, researchers, consultants	Intelligent Energy Europe – EuroWhiteCert Project

Date	Location	Main participants	In the context of
2006/03/23	Trondheim, Norway	Policy makers, researchers	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2006/05/03	Stockholm, Sweden	Policy makers, researchers, consultants, energy companies	Swedish Chapter IEA-DSM Task on Market Mechanisms for White Certificates Trading
2006/10/06	Stockholm, Sweden	Policy makers, researchers, consultants, energy companies	Swedish Chapter IEA-DSM Task on Market Mechanisms for White Certificates Trading
2007/06/03	La Colle sur Loup, France	Policy makers, researchers, consultants	Intelligent Energy Europe – EuroWhiteCert Project
2007/11/28	Stockholm, Sweden	Policy makers, researchers, consultants, energy companies	Swedish Chapter IEA-DSM Task on Market Mechanisms for White Certificates Trading

Appendix F – Research workshops

The following is a table with details about the research workshops fully dedicated to TWC schemes in which the author of this thesis participated:

Date	Location	Participating organisations	In the context of
2003/06/06	Utrecht, The Netherlands	Copernicus Institute, Italian Assoc. Energy Economics, Ecofys, IIIEE	EU SAVE White & Green project
2003/08/25-28	Rome, Italy	Italian Assoc. Energy Economics, IIIEE	EU SAVE White & Green project
2003/12/04	Rome, Italy	Copernicus Institute, Italian Assoc. Energy Economics, IIIEE	EU SAVE White & Green project
2004/08/25	Utrecht, The Netherlands	Copernicus Institute, Italian Assoc. Energy Economics, IIIEE	EU SAVE White & Green project
2004/10/13-14	Rome, Italy	Copernicus Institute, Italian Assoc. Energy Economics, IIIEE	EU SAVE White & Green project
2004/11/09	London, UK	ADEME, CESI, DEFRA, ENOVA, ELFORSK, IIIEE, SENTERNOVEM, SOM, STEM	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/04/05	Milano, Italy	ARMINES, eERG, Ecofys, ESD, ZSW, VATT, IIIEE, EnEFFECT, CRES, ISR-UC, EVA, APAT, ADEME, CEU	Intelligent Energy Europe – EuroWhiteCert Project
2005/04/15	Paris, France	CESI, DEFRA, ADEME, ENOVA, STEM, EDF, IIIEE, SOM, ELFORSK	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/06/17	Lund, Sweden	CESI, DEFRA, ADEME, ENOVA, STEM, EDF, IIIEE, SOM, ELFORSK	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/09/22	Copenhagen, Denmark	eERG ECOFYS, ESD, ZSW, VATT, IIIEE, ARMINES, EnEFFECT, CRES, ISR-UC, EVA, APAT, ADEME	Intelligent Energy Europe – EuroWhiteCert Project

Date	Location	Participating organisations	In the context of
2005/10/28	Groningen, The Netherlands	CESI, DEFRA, ADEME, ENOVA, STEM, EDF, IIIEE, SOM, ELFORSK, CEU	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2005/11/07	Paris, France	ARMINES, EVA, CRES, EnEFFECT, ISR-UC, IIIEE, eERG, VATT	Intelligent Energy Europe – EuroWhiteCert Project
2006/01/25-26	Budapest, Hungary	eERG ECOFYS, ESD, ZSW, VATT, IIIEE, ARMINES, EnEFFECT, CRES, ISR-UC, EVA, APAT, ADEME, CEU	Intelligent Energy Europe – EuroWhiteCert Project
2006/03/24	Trondheim, Norway	CESI, DEFRA, ADEME, ENOVA, STEM, EDF, IIIEE, SOM, ELFORSK,	IEA-DSM Task on Market Mechanisms for White Certificates Trading
2006/09/05	Milano, Italy	eERG ECOFYS, ESD, ZSW, VATT, IIIEE, ARMINES, EnEFFECT, CRES, ISR-UC, EVA, APAT, ADEME	Intelligent Energy Europe – EuroWhiteCert Project

Appended Papers

The following papers are included in the thesis:

Paper I: Farinelli, U., Johansson, T. B., McCormick, K., Mundaca, L., Oikonomou, V, Örtenvik, M., Patel, M., Santi, F. (2005). 'White and Green': Comparison of market-based instruments to promote energy efficiency. *Journal of Cleaner Production* 13 (10-11):1015-1026.

Paper II: Mundaca, L. (2008). Markets for energy efficiency: Exploring the implications of an EU-wide 'Tradable White Certificate' scheme. *Energy Economics* (forthcoming).*

(*)Best Nordic PhD Paper 2008 in social science. Prize awarded by the Energy Forum & Nordic Energy Research Council.

Paper III: Mundaca, L. (2007). Transaction costs of Tradable White Certificate schemes: The Energy Efficiency Commitment as case study. *Energy Policy* 35 (8):4340-4354.

Paper IV: Mundaca, L., Neij, L., Labanca, N., Duplessis, B., Pagliano, L. (2008). Market behaviour and the to-trade-or-not-to-trade dilemma in 'Tradable White Certificate' schemes. *Energy Efficiency* (forthcoming).

Paper V: Mundaca, L., Neij, L. (2008). A multi-criteria evaluation framework for 'Tradable White Certificate' schemes (submitted to *Energy Policy*).

Paper I

Farinelli, U., Johansson, T. B., McCormick, K., Mundaca, L., Oikonomou, V, Örtenvik, M., Patel, M., & Santi, F. (2005). 'White and Green': Comparison of market-based instruments to promote energy efficiency. *Journal of Cleaner Production* 13 (10-11):1015-1026.

"White and Green": Comparison of market-based instruments to promote energy efficiency

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Abstract

The "White and Green" Project completed under the EU SAVE Programme reviewed policies and measures to promote energy efficiency, which involved analysing the experience with instruments that are already implemented, and assessing innovative instruments that are proposed. In particular, the practicability of using "White Certificates" (energy efficiency) along the same lines as "Green Certificates" (renewable energy) was explored.

Several of the policies and measures were simulated using technical–economic models of the MARKAL family. The results show that by 2020 it is possible to increase energy efficiency by 15% at no cost without taking externalities into account. If externalities are considered, an increase of 30–35% with respect to the business-as-usual scenario is justified.

The wealth of information obtained through the models and analysis provides a set of recommendations for policy-makers, including: (1) the need for closer co-ordination between energy policies and environmental and climate policies; (2) the opportunity to establish more ambitious targets for energy efficiency; (3) the scope for increased EU co-ordination; (4) the extension of White Certificates to the medium and low energy-intensive industries; (5) the need to support White Certificates with accompanying actions, such as running information campaigns, promoting energy service companies, and providing dedicated credit lines; (6) the need to develop similar instruments for transport and (7) the continuing need for energy research and development.
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Keywords: Energy efficiency; White certificates; Green certificates; Renewable energy; Energy policies

1. Introduction

The move towards the liberalisation of the energy markets in the whole world and the general shift from command-and-control to market mechanisms bring forward new ways of stimulating initiatives to increase the efficiency in the final uses of energy and demand-side management. In the past, energy policies were implemented in most countries by direct action of the governments through state monopolies, prescriptive legislation and in some cases incentives. With the progressive advent of liberalisation of the energy market and privatisation of state companies, the emphasis has shifted toward a regulation of the market that introduces economic corrections to take into account collective interests (such as externalities) and long-term objectives, which are not spontaneously considered by market forces. Policies based on incentives have also

shown their limits. As they rarely use market forces effectively, the results obtained tend to have a higher cost than necessary and they may bring to a non-optimal development of new technology by prompting the adoption of presently available technology and not directly promoting improvements. Recently, the emergence of other problems – as shown by the blackouts in the USA, Italy, UK and Sweden – the insufficient attention given by the system to security of supply, some concerns about the quality of the service, the lower than expected decrease of prices to the final user have prompted a reconsideration of the regulation of energy markets. In this context, it is important to consider the ways in which the increase of the share of energy supplied by renewable sources and the increase in the efficiency of energy utilisation can be promoted. These two measures, together with improved and innovative ways of using traditional sources, are considered the mainframe of any sustainable energy strategy and necessary steps to contrast the threats of climate change.

While there is essential agreement on the technologies available to save energy, policies and measures to help the diffusion of these technologies differ, are evolving and in some cases are just now being tested and evaluated.

It was thus, considered important and timely to review and compare present and proposed policy instruments for energy efficiency in the European Union, with particular attention to the "White Certificates", and to analyse and predict their effects, their benefits and costs and the difficulties in their implementation.

The present article summarises the results of a study carried out in the frame of the EU SAVE project "White and Green" – comparison of market-based instruments to promote energy efficiency, co-ordinated by the International Institute for Industrial Environmental Economics of Lund University, Sweden, in partnership with the Copernicus Institute of the University of Utrecht (Netherlands), the Italian Association of Energy Economists and the Swedish utility Sydkraft.

The study consists of collecting and reviewing the policy instruments aimed at increasing energy efficiency, with emphasis on market-based mechanisms; in choosing three representative policy instruments for further analysis, and collecting information and results of their actual implementation; in simulating the effects of each instrument and of some combinations there by means of technical–economic computer models (of the "MAR-KAL" type[1]) for the European Union (EU-15) and for three EU countries: Italy, Germany and Estonia; in drawing some conclusions and recommendations from the results of the three previous phases, and discussing them among stakeholders in order to identify the most significant results, which can be used as a help in shaping future energy efficiency policies; and finally in diffusing the results as widely as possible.

The reader interested in learning more about the "White and Green" project is invited to visit its web-site at http://www.iiiee.lu.se/whiteandgreen.

2. Energy efficiency efforts in the European Union

Improving energy efficiency is an essential component of the energy policies of the European Union and of all EU member states, motivated by considerations of security of supply, economics, environmental and health protection and as a component of long-term stability of the global climate. The directive on CO_2 emission trading,[2] entering into effect from the beginning of 2005, will have an important effect on energy efficiency in energy-intensive industrial sectors. The proposed EU Directive on Energy End Use Efficiency and Energy Services[3] is another concrete step in this direction. This proposal expresses the saving goal as the amount of energy that should be saved as a consequence of energy efficiency measures for final consumers in the domestic and tertiary sectors, industry (except energy-intensive industries included in the Emissions Trading Directive), and transport (excluding aviation and foreign shipping). The annual amount of the targeted savings is an increment of 1% (cumulated each year, and relative to GDP) of the energy efficiency of these final users. This amount is fixed for a period of six years. Other initiatives by the commission with impact on energy efficiency are the Directive on Energy Performance in Buildings[4] and the one on combined heat and power production.[5] The European Parliament has also been interested in energy efficiency, as shown by its initiative on Intelligent Energy Europe.[6]

Technological solutions to improve energy efficiency at affordable costs are available for all sectors and end

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[1] The assistance of ETSAP – the Energy Technology Systems Analysis Programme – of the International Energy Agency, and in particular of its programme leader, GianCarlo Tosato, in setting up and utilising the MARKAL models is gratefully acknowledged.

[2] Directive 2003/87/CE of the European Parliament and of the Council of October 2003 establishing a Scheme for Greenhouse Gas Emission Allowance Trading within the Community and Amending Council Directive 96/61/EC.

[3] COM/2003/0739 def. of 10/12.2003 – COD 2003/0300.

[4] Directive 2002/91/CE of 12/12/2002 published on the OJ n. L001 of 04/01/2003, page 65.

[5] Directive 2004/8/CE of 11/2/2004 on the "Promotion of Co-generation based on a useful Heat Demand in the Internal Energy Market and Amending Directive 92/42/CEE, published on OJ n. L052 of 21/02/2004, page 50.

[6] Decision no. 1230/2003/EC of the European Parliament and of the Council of 26 June 2003 adopting a Multiannual Programme for Action in the field of Energy "Intelligent Energy Europe".

uses, and certainly for the residential and service sectors.[7] Many of these are economically motivated, especially if indirect costs and benefits (externalities[8]) are considered. However, the rate at which these innovative as well as established technologies diffuse spontaneously is insufficient with respect to the time horizon indicated by security of supply, climate change and health/environment considerations. Government policies and measures (P&M) are needed to facilitate, promote or require an accelerated introduction of energy saving features as concerns new investments, turnover of equipment and appliances, and retrofitting of buildings and industrial installations. Such P&M are necessary to correct price signals, now distorted by subsidies to supply side conventional energies, to reflect external costs (health, environment and climate change), as well as benefits (improved energy security, job creation, balance of payment, poverty alleviation) to help overcome institutional and other barriers (such as the landlord/tenant sharing of costs and benefits, the information barriers etc.).

3. Review of policy instruments

Many different instruments are or have been employed to increase energy efficiency. They include typically "positive" financial measures (*incentives*), such as subsidies, grants, low interest loans and tax exemption or reduction for energy efficiency interventions, or "negative" financial measures (*disincentives*) such as energy or CO_2 emission taxes, taxation on less efficient devices, user charges and product taxes; legal or *regulatory measures* ranging from energy consumption or emission standards for appliances, vehicles, buildings and specific technologies, labelling of appliances, equipment, and installations to codes for the management of land and other resources; *organisational measures*, including, in particular, negotiated or voluntary agreements; and finally to *market-based* "cap and trade" or "target and trade" measures. *Procurement policies* (such as purchases of high efficiency devices, systems and buildings) by public bodies may also play an important role in creating a leading market.

Among these various instruments, there is growing interest for and application of market-based instruments, because they use market forces to minimise the cost of saving energy, and accelerate the penetration of

efficiency improvement interventions when (as is often the case) they can be made at *negative* costs, i.e. with a profit, but can also be used to force the introduction of positive (conventional) cost measures, justified by the externalities.

In the course of this project, through a selection based on their perceived potential and present interest, three main types of market instruments for energy efficiency (or for the related objective of reducing greenhouse gas emissions) have been selected for detailed analysis and their application has been reviewed and simulated:

- *White certificates* (or WhC), partly implemented in the UK and in Italy, and on their way to application in France and possibly elsewhere. In this system, electricity and gas suppliers or distributors are obliged to undertake the promotion of energy efficiency among final uses, and to show that they implement, each year, interventions designed to save an amount of energy that is a given percentage of the energy they supply or distribute. This amount is certified through certificates (the "White Certificates") that are generated when the obligated parties themselves, or other actors, introduce energy saving measures. Such certificates can be exchanged and traded on the market. Obligated parties unable to submit their share of certificates are subject to pecuniary sanctions exceeding the estimated market value of the missing certificates.
- Carbon dioxide *emission trading* (which is now becoming mandatory in the EU and may be extended to other greenhouse gases after 2007). This scheme concerns energy-intensive industry (as specified by the EU directive), including the energy industry itself. Each installation pertaining to these industrial sectors is assigned a permit for the emission of a certain quantity of carbon dioxide, which will generally decrease with time according to the general targets of the EU. If the installation exceeds that limit, it will be able to buy allowances from other installations that have reduced their emissions below their assigned quota.
- The case of a (high) *carbon tax* has been considered for comparison, especially in order to be able to compare its effects and its costs with the effects of the instruments based on tradable certificates.
- *Green certificates* (for renewably-generated electricity) consist of obligations for the electricity suppliers or distributors or even for the final client to show that a certain percentage of the electricity they generate, distribute or use is produced by renewable energy sources. This is done by certifying all renewably-generated electricity by means of "green certificates", which can be bought and traded in the market. Green certificates have been considered and

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[7] See for instance the collection of successful applications of energy saving technologies promoted by the International Energy Agency under the name CADDET at http://www.caddet.org/technologies.

[8] Externalities are costs and benefits paid or received by other than the users of the service, or not in proportion to that use, and often borne by all society in equal or differentiated proportion. They may include effects on environment, health, climate stability, employment, energy security etc.

introduced in the simulations, not so much because they contribute to energy saving, but because they have been on the scene in several countries and for longer times and are much more diffused than white certificates. Given the similarity between the two systems, they can also shed light on problems likely to be met with a white certificate system. In addition, Tradable Green Certificates (TGC) overlap with emission trading certificates (however, their overlapping with White Certificates is negligible, at least for the time being). Both interactions have been studied with the models.

- What we called "*smart standards*" have also been reviewed and analysed but not simulated. Smart standards are physical regulations involving a high degree of flexibility with regard to the selection and combination of individual measures in order to reach a mandatory target (e.g. of energy use) for relatively complex systems or subsystems (e.g. for buildings, or for industrial plants or for passenger cars).

A description of all these instruments is available on the Web at http://www.iiiee.lu.se/whiteandgreen.

The coverage of the policy instruments considered in this study is quite large. White Certificates are estimated to cover potentially about half (or 6900 PJ) of the total natural gas use in the EU-15 countries and 70% (or 5700 PJ) of the total electricity use. Renewable electricity, being the target of Green Certificates, currently represents 14.5%[9] (or ca. 333 TWh) of the total electricity use (2240 TWh); the EU target for 2010 is a share of 22.4% (675 TWh). The amount of direct fossil fuel use covered by emission trading (15,700 PJ) represents about one-third of the total fossil fuel use which amounted to around 48,000 PJ in the total of all EU-15 member states by the year 2000.[10]

Smart Standards are primarily addressed to measures related to space heating, other measures related to buildings, appliances or so-called horizontal technologies such as motors and drives. For this reason the scope of smart standards is comparable to that of White Certificates. The values are summarized in Table 1, which also gives the primary energy equivalents for the total of fossil fuels and electricity. To put these values into perspective they can be compared to the total fossil fuel use (48,000 PJ) and to the total primary energy use (61,000 PJ[11]). Similarly, the emissions in Table 1 can be compared to the total CO_2 emissions from fuel combustion, amounting to around 3,150 million tonnes (EU-15, year 2000) [4]. These comparisons show that the

policy instruments discussed in this report cover a substantial amount of the total energy use and the related carbon dioxide emissions, thereby confirming the preselection made above.

4. The MARKAL methodology

Since many of the conclusions and recommendations in this project are based on the results of the simulation work, some explanations on the approach followed are in order.

The impact of the policies has been evaluated by means of different models built with ETSAP[12] tools, the MARKAL methodology. MARKAL is a generator of economic equilibrium programming models of energy systems and their time development. Supply/demand curves of commodities are specified by stepwise linearised functions. Each step refers to a different technology providing/consuming the commodity. The minimum and maximum length of each step (quantity) is imposed by the market potential of each input/output technology and fuel. The height of each step (cost) depends on the costs (investment, fixed operation and maintenance, or fixed and variable O&M) of each supply/utilisation technology and fuel. The actual equilibrium cost of each step is the sum of costs incurred in primary extraction, transformation, transmission, distribution, including taxes and subsidies, taking into account the efficiencies of all intermediate technologies. Since technologies and values are interlinked, the actual supply/demand curves are fully resolved only in the solution.

The construction of such supply/demand curves for each commodity is made possible through the Reference Energy System approach. The entire energy system is represented by a graph, where each branch is an energy or material flow and each knot is a technology. In fullscale models each fuel appearing in detailed energy balances is represented by a separate flow, sometimes more than one if different environmental characteristics have to be accounted for. Each supply/demand technology is characterized by technical–economic and environmental parameters, together with the graphical indication of the input commodities/output services.

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[9] This value refers to the year 1999 [1]. It has been applied to total electricity production in the year 2000.
[10] According to [3].
[11] Value for TPES (total primary energy supply) according to [3].

[12] MARKAL (MARKet ALlocation) has been developed by the Implementing Agreement of the International Energy Agency for a Programme of Energy Technology Systems Analysis (IEA/ETSAP). Two international teams based at Brookhaven National Laboratory (USA) and Kernforschungsanlage Juelich (Germany) implemented jointly the first version in the late seventies. The "*Second Assessment Report*" of IPCC [7] suggests using MARKAL models to evaluate possible impacts of mitigation policies. The source code is open, regularly maintained and documented. The most recent versions of the tool are considerably more powerful and rich of options; they are documented together with the users' interfaces at http://www.etsap.org and in several related web sites.

Table 1
Coverage of innovative policy measures in the European Union (EU-15) by the year 2000

	Fossil fuel (PJ)	Electricity (TWh)	Primary energy equivalents[a] (PJ)	CO_2 emissions[b] million tonnes CO_2
WhC, Smart	6900 (natural gas)	1583	21,150	940
GC	–	675[c]	6075	550
ET	15,700	–	15,700	1230

[a] Estimated adding up the fossil fuel use and the electricity demand in primary energy terms (assuming a conversion efficiency of 40% for the latter).
[b] Estimated by assuming CO_2 emission factors for fossil fuels according to [2]. For electricity, a value of 97 kg/GJ was estimated.
[c] Estimated by multiplying total electricity use in the EU in 2010 with the EU-15 target by 2010 (22.4%, see also [1]).

When the supply/demand curves are specified as linear stepwise functions, the equilibrium model is formulated as a mathematical programme. A linear/non-linear programme (LP/NLP) builds equilibrium models when the objective function specifies the total surplus (partial equilibrium) or the utility (general equilibrium) of the system. The equilibrium over time is maintained through a substitution mechanism of one energy source/technology with a cheaper one.

Formulating economic equilibrium models of the energy systems with the MARKAL methodology has several *advantages*.

The same MARKAL toolkit is used to create models of systems:

○ with few or thousands of energy commodities, materials, emissions and technologies,
○ including all energy sectors from primary reserves expressed in PJ to energy services, expressed in specific units, such as passenger km or in tonnes of steel,
○ extended to many regions interlinked together in multi-regional models with endogenous trade,
○ limited to the energy supply sector and/or selected sectors of final energy demand (partial equilibrium) or extended to the full economy (general equilibrium, MARKAL–MACRO versions),
○ at increasing level of equilibrium: from nearly simulation modes, to intra-temporal equilibria and myopic view, to inter-temporal perfect foresight allocation of capital investments and decisions, to endogenous learning.

Since each step of supply/demand curves represents a technology or a fuel source, further to equilibrium quantities and prices the solution of the model indicates the set of technologies or fuel source that makes the equilibrium feasible.

When all equations are linear, the solution of very large size models (approaching one million variables and equations) requires an hour or little more in normal PCs if recent powerful linear programming solvers are used. Till the number of non-linear functions remains low, the solution of the corresponding non-linear programming models does not require much more.

The same toolkit has maintained the original capacity of running the model in simpler optimisation models, where it minimizes in turn the total discounted system cost, the cumulative emissions, the total import of unsecure energy sources, or whatever combination of objective functions, in order to provide trade-offs among different policy objectives.

The methodology used has, of course, some *limitations*, which however, are well understood. In particular, MARKAL has limited capabilities to estimate the following economic issues:

• Effects of market imperfections;
• Number of participants (buyers and sellers);
• Price speculations;
• Participants' savings (difference between the marginal cost of domestic actions vs. the market price of the certificate or permit);
• Traders and risk takers.

Furthermore, the specific MARKAL-generated models used in this study do not include:

• Transaction costs;
• Volume of certificates banked.

Despite these limitations, the MARKAL models used in the present study are a powerful instrument for exploring the economic consequences of technological innovation and policies in the field of energy; their simulations yield realistic and consistent scenarios and shed light on several aspects of the application of different policy instruments, investigate their interactions, identify problem areas that may otherwise escape attention and at least in some cases show the effects of the instrument on the overall economic situation.

The modelling parameters of MARKAL were compared with those of the MURE[13] and the ICA-RUS[14] databases, which brought to two improvements. The MARKAL model does not explicitly include increased insulation in buildings (considered as a part

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[13] See the website http://www.MURE2.com.
[14] See, for instance, [5].

of the performance of the heating system), which, in the case of the White Certificates for the UK, has proven to be the single most important measure. Furthermore, MARKAL does not include organisational measures for companies and households, which can be expressed as adaptation behaviour to the policy and can increase the flexibility in achieving the set objectives.

It should be noted that in the MARKAL models, technologies are not "evolving" (e.g. as a consequence of following a learning curve): a more efficient technology is represented as a new technology, which will be available from a certain time on, subject to constraints for the rate of penetration, and which will replace totally or partially the older one according to market choices. Thus the technologies evolve by steps rather than continuously; but considering that the time step we use in our models is five years, this will not appreciably change the results.

5. Results of the modelling work

5.1. Introduction

Once the initial equilibrium conditions are established, and the input data are prepared, it is fairly easy and speedy to run many different cases corresponding to different policy measures, or to different values of various parameters (e.g. different level of ambition for the goals). The quantity of results that has been generated is thus, very impressive, and it has been possible to analyse only a relatively small part of them. Even so, only a small part of the results analysed can be presented in this article. We concentrate on the case of EU-15 (all the countries of the Union before the 2004 enlargement)[15] and on the instrument of White Certificates, and mention briefly the conclusions deriving from other parts of the analysis.

5.2. European Union: white certificates

For the EU-15+ market there is a financial potential of increasing energy efficiency by 15% until 2020 ("zero-cost target"); in other words, the average unit cost of the energy system, following the application of a WhC system for a reduction of 15% (-3 EJ) of the overall energy consumption of residential and service sectors with respect to the Business-As-Usual (BAU) scenario, is equal to the average unit cost of the energy system in the BAU case; *in other words, the increase of the energy efficiency is free of cost to society*.

For less ambitious targets, and in particular for the 1% per annum for six years target, defined by the EU directive proposal, the cost of the energy savings is negative and, by freeing resources, it involves a positive impact on GDP growth. If the target of energy saving in the residential and service sectors is greater than 1% per annum (cumulative) until 2020, the cost of the energy savings may become positive; for instance, a target of 1% until 2010, then of 2% from 2010 to 2020 ("medium target") implies for the year 2020 a reduction of consumption by 5 EJ (−27% of BAU) and an increase of the average unit cost of the energy system[16] of 1 €/GJ (+13%).

More ambitious targets have relatively high costs, but are technically possible; for instance, a target of 2% per annum until 2010 and of 4% per annum between 2010 and 2020 ("high target") brings to more than halving the energy consumption of the residential and service sectors with respect to BAU (−56%), with an increase of the average system unit cost of 38% (or 3 €/GJ).

However, these evaluations do not include externalities. If the environmental and other externalities were taken into account, one would evaluate an economic potential of energy saving much higher than the 15% indicated above, which is "zero-cost" only in strictly financial terms.

With reference to the trade-off curve shown in Fig. 1, if instead of the conventional zero-cost axis one introduces an external cost of energy of about 1.5 €/GJ (a reasonable assumption according to several studies on externalities[17]) the trade-off value rises to a value of about 35%.

The model also allows predicting where and how these energy savings would be obtained. For instance, if the cap in consumption is posed on the sum of gas plus electricity and not on each of them separately, the market (choosing by economic optimisation) will lead to a nearly 50–50 share of gas and electricity in terms of primary energy, while the reduction will be stronger for gas than electricity if expressed in terms of final energy. As concerns the subdivision by sector, the reduction is stronger in the service sector until 2010, while the residential sector takes a slight prevalence in the following decade. The estimated market price of White Certificates (based on marginal cost of energy savings) should grow from about 5 €/GJ/y in 2005 to a little more than 25 €/GJ/y in 2020. The reduction of CO_2 emissions resulting from the application of the White

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[15] Actually, the configuration we refer to includes, in addition to the 15 EU member states before the enlargement, also Norway, Switzerland, Malta, Iceland, Gibraltar and Greenland and will therefore be called EU-15+.

[16] The average unit cost of the energy system (expressed in €/GJ) is defined as the sum of all the costs of the energy system, including fuel, operation and maintenance, and investments both on the supply and on the demand side, divided by the total consumption of primary sources of energy (total primary energy supply).

[17] See "ExternE – Externalities of Energy", a series of volumes issued by the European Commission, DG-XII, Brussels – Luxembourg starting from 1996 (EUR 16520 EN).

**WEU Markal model - White Certificates Scenarios
Residential and Commercial Sector**

Trade-off curve:
total (R&C) final energy saved in 2020 (% of b.a.u. scenario) vs.
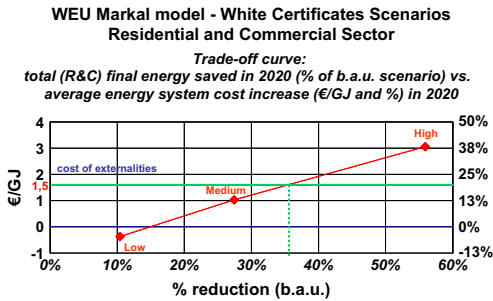*average energy system cost increase (€/GJ and %) in 2020*

Fig. 1. WEU MARKAL model – White Certificates scenarios residential and commercial Sector. Trade-off curve: total (R&C) final energy saved in 2020 (% of BAU scenario) vs. average energy system cost increase (€/GJ and %) in 2020.

Certificate system is of 1.5% in 2020 ("low target") vs. the base case.

The application of the mechanism of WhC involves in any case an increase of the investments in new technologies for energy utilisation. The low target scenario implies for the year 2020 an increase of 7% in investments in energy demand technologies for the residential and service sectors relative to BAU, while the average unit cost of the energy system is decreased (more technology, less fuel!). For the more ambitious medium and high scenarios, investments in technology grow much more: for the year 2020 by 30% and 80% respectively. Therefore, even when there is a trade-off between cost of saving and value of the energy saved, there will be a displacement from expenditure for fuels to investment in new technology, which in itself is likely to have a positive effect on the economy as a whole.

The reduction of CO_2 emissions associated to the "zero-cost" scenario identified above is of the order of 5% with respect to BAU, or about 190 Mtonnes CO_2. In case externalities are taken into account and the target becomes -35%, the corresponding reduction of CO_2 emission becomes 270 Mtonnes if accomplished by 2020 and 340 Mtonnes if enforced by 2015.

As concern the technologies induced by the WhC system, for natural gas the largest improvements of energy efficiency are in the segment of space heating, while for electricity the major opportunities are in the field of lighting. The White Certificate system promotes innovative technologies, which have been considered in some detail: examples are hot water production by heat pumps, conditioners based on centrifugal chillers, natural gas heat pumps, solar water heaters etc.

The definition of the base case for WhC proved in itself to be at the same time difficult and enlightening. The MARKAL approach is an equilibrium approach seeking an economic optimisation, and assuming that market forces will automatically bring the system to this (dynamic) equilibrium. The actual situation is different,

and does not correspond to an optimal solution, insofar as economically (and financially) convenient technological solutions do not diffuse as much as the optimisation would require. This points to the fact that there are imperfections in the market, especially when one considers the level of single households. This brought to an approach that takes into account the market imperfections and financial aspects (difficulties of access to credit and information, scarcity of capital available for investments etc.) not through constraint equations, but by introducing an apparent discount rate applied to the investments in new energy technologies in the residential and service sectors.

By comparing the results of the simulation with reality, we found that a discount rate of about 30% per year has to be assumed in order to explain the limited diffusion of "convenient" energy saving technologies. Such apparent discount rate (much higher than the system's "social" discount rate), has proved to simulate well the displacement of the system from the economic optimum in the business-as-usual scenarios. The application of the White Certificate system, coupled to well-targeted and diffused information campaigns, and to simplified and publicly guaranteed access to credit, should cause the apparent discount rate to decrease, tending to the value of the social discount rate. This approach can be considered as one of the relevant accomplishments of the project.

5.3. European Union: tradable emission rights

As stated earlier, the limited length of this article only allows us to report briefly about some results obtained in the modelling work.

When simulating the tradable Emission Rights instrument, the model results in a containment of emissions obtained mostly on the supply side, i.e. in the energy sector and in the generation of energy (electricity, heat or CHP) in the eight high energy-intensive industrial activities considered by the EU directive. The reason for this is that the energy consumption in the energy-intensive activities considered is rather rigid, having gone through a long process of optimisation, unless radical changes of process are introduced: this is likely to happen only when entirely new plants are built, which seldom occurs today in Europe for the energy-intensive sectors. The substantial reduction of CO_2 emissions that are required have the effect of radically changing the structure of the energy production park. For the lower-ambition target, there is a strong increase of the natural gas combined cycle plants, which is sufficient to comply with the emission cap. In the other two cases, there is also a strong increase of RES plants, especially wind and biomass. The case with the highest reduction of emissions also contemplates the development of an advanced technology such as Hot Dry Rocks (HDR),

since the potential of conventional geothermal energy is too limited.

The average overall cost of the reduction of CO_2 emissions, calculated as the ratio of the increase of the total 30 year overall cost of the energy system with respect to the base case to the total reduction obtained for the emissions is about 30 €/tonne of CO_2 for the slower scenario, about 35 €/tonne of CO_2 for the intermediate and over 50 €/tonne of CO_2 for the more demanding one. The CO_2 emission cap is realistically simulated with a system of allocation and trading of emission permits. The price of the "Black certificates" is calculated by the model and is roughly in line with the cost of emission reduction: about 30 €/tonne of CO_2 for the first scenario, 40 €/tonne of CO_2 for the second and, for the most demanding scenario, decreasing from 90 €/tonne of CO_2 in 2005 to 50 €/tonne of CO_2 in 2030, in relation with the dynamics applied to the emission cap. The resulting electricity price increases 30% in the first scenario, a little more in the second and about 60% in the third. These relatively high price increases are partly due to the fact that, as we mentioned, all the reduction in CO_2 emissions is obtained on the supply side; also, on the 2030 horizon the technology of CO_2 sequestration may well have evolved to present smaller costs than those picked up by the model. It should also be considered that these costs implicitly include the costs of the incentives for the installation of RES plants, not considered elsewhere in the ETS scenarios.

Results concerning Green Certificates will not be reported here. Results concerning the simultaneous application of different policies and measures show essentially the additivity of costs and benefits.

In addition to the whole of the EU, model calculations were performed for Italy, Estonia and Germany.

5.4. The case of Italy[18]

The modelling work for the case of *Italy* used the MARKAL–MACRO model.[19] The conclusions found include the following:

- The Green Certificates have a potential which is too low to influence the CO_2 emissions appreciably.
- The White Certificates free up economic resources which can be allocated more effectively, giving rise to a positive effect on the growth of GDP of some tenths of 1%.
- The high carbon tax does reduce CO_2 emissions, but with a severe impact on the growth of GDP (several percent less every year) and in any case without reaching targets of reduction in absolute terms.

5.5. The case of Estonia[20]

The *Estonian* simulation work, carried out with MARKAL, had to take into account the fact that Estonia is in some respect a unique case, due to the high share of oil shales in the energy budget (60%), the highest in the world. The Estonian energy system presents low energy efficiency and produces high quantities of pollution. The economic collapse in 1990–1995 decreased the economic output by more than a factor 2; therefore, there is no special challenge in meeting the Kyoto objectives, even in the event of a sustained economic re-growth. On the Kyoto horizon, Estonia is likely to have 5 Mtonne CO_2 emission rights to sell in Joint Implementation projects. Much of the attention is centred on the technologies for the use of oil shales in order to increase the efficiency of energy transformation and improve its environmental impact. Pressurised Fluid Bed Combustion (PFBC) is regarded in Estonia as the favourite future technology to replace pulverised oil shale combustion. Somewhat surprisingly, oil shale gasification is not being considered, at least for the time being.

5.6. The case of Germany[21]

The case of *Germany* was studied using the TIMES[22] model. White and Green Certificates were simulated. In the WhC case, for the residential sector, most of the improvements of energy efficiency take place in space heating. According to the figures, the other energy services (e.g. cooking, lighting, etc.) represent minor opportunities of increasing energy efficiency. When it comes to the commercial sector, water heating represents

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[18] The modelling work for Italy was carried out by Francesco Gracceva (ENEA) and Mario Contaldi (APAT); see also [6].

[19] MARKAL–MACRO is a non-linear, dynamic optimisation model that links MARKAL, the bottom–up specification of a country's energy system, to a top–down macroeconomic growth model to provide a dynamical, neoclassical, applied general equilibrium model. The difference with the standard MARKAL is the determination of demand for energy services. In MARKAL–MACRO, once MARKAL finds the least-cost way to meet the demand, energy costs are passed back to MACRO, which compares energy costs to activity in the remainder of the economy. If a decrease in energy costs causes an increase in consumer utility, a new higher level of demand for energy services is estimated and returned to MARKAL, and so on until the process finds the highest level of consumer utility.

[20] The modelling work for Estonia was performed by Olev Liik and Mart Landsberg, in the Dept. of Electrical Power Engineering, at the Tallin Technical University.

[21] The modelling work for Germany was performed by Markus Blesl et al. at the Institute of Energy Economics and the Rational Use of Energy, in the University of Stuttgart.

[22] TIMES (The Integrated MARKAL–EFOM System) is an evolutionary development of MARKAL, which introduces a much higher degree of flexibility in the description of the energy system and allows for investigating a wider range of problems.

the main area of energy efficiency improvements. It is worth mentioning that there is a shift in the fuel usage for district heating and electricity, although in a modest degree, in both sectors, as biomass displaces natural gas and electricity. Regarding the estimated value of White Certificates, this goes from approximately six to nine, and back to 6 €/MWh in 2005, 2020 and 2030, respectively. The peak price is heavily influenced by the phase-out of nuclear power.

6. Opportunities and barriers for white certificates

There is a nearly unlimited range of opportunities to increase energy efficiency. Many of these opportunities are highly cost-effective, with payback times of one or two years (e.g. most of the thermal insulation projects, compact fluorescent lamps and avoidance of stand-by losses) and are profitable in their own right. The fact they do not diffuse rapidly points to important market imperfections. The most important is lack of information: most people and organisations do not know what options they have for saving energy, or get incomplete or distorted information. With the exception of energy-intensive industry, energy costs are not high enough for actors to bother about saving energy. Another important barrier is organisational and financial: it is much more difficult and more costly to find funding for a high number of small interventions than for one large intervention of the same total amount. The sharing of costs and benefits among owners and renters is also a problem. Further, in many cases, it may be difficult to find a reliable operator to contact in order to make this intervention. Finally, there may be other kind of barriers such as inadequate building codes, obsolete norms etc.

The findings reported are based on an analysis of the practical experience so far gained in the UK and in Italy, and are confirmed by the difficulties of accounting for the actual situation in the modelling work, as mentioned above.

As a consequence, policy action is required. The WhC system cannot be implemented in isolation it must be accompanied:

- By information campaigns and other means to promote opportunities of energy saving;
- By facilitating the setting up of subjects that are able, qualified and certified to implement certain types of intervention, typically the Energy Service Companies, or ESCOs, which may also aggregate a large number of similar interventions both to make use of economies of scale and to present the aggregation as a lump for financing;
- Finally making efforts to remove non-technical, non-financial barriers that impede the diffusion of economically sound solutions.

One of the main difficulties for the WhC scheme is its transaction cost with regard to evaluation, monitoring and certification: it may be expensive and not always easy to estimate and verify the energy saving that can be obtained by a certain intervention with respect to a base-line (which in turn evolves with time). This obstacle is overcome in the UK by considering only standard types of interventions, with simple procedures to calculate the expected improvements in energy efficiency.

The Italian system is more flexible and much more extended; but it pays for this with increased costs and with the technical and political difficulties that have delayed its entering into force until recently. Such difficulties include:

- The need of considering a wide range of possible interventions and establishing rules for the valuation of "open" project options (not listed beforehand);
- The uncertain role of regional governments in the scheme, and their contention with the central government on the decentralisation of energy issues;
- The negative or at best sceptical attitude of electricity and gas distributors, who do not seem anxious to extend their activities to demand-side management (distributors, although formally "unbundled" from producers and suppliers, often share the same property structure, and prefer selling electricity and/or gas rather than energy services);
- The still unsolved question whether distributors should be allowed to perform post-meter interventions, which is challenged by anti-monopoly authorities;
- The evaluation of the results of information campaigns, which, at least in the initial scheme, were listed as one of the possible categories of admissible interventions.

7. Rebound effects

The result of a WhC system may be lower than expected because of the "rebound effect": more energy efficiency brings less cost for the energy service, leading to more demand for services and thus less energy is saved.

Actually, the rebound effect may come from two sources:

1. Direct: since the cost for a given service is lower, the demand for that service will increase (elasticity);
2. Indirect: the lower cost frees up some money, which is spent for something else, which will have other consequences upon the energy demand.

The direct effect may reduce the expected savings by a maximum of 40%, but many services are rather inelastic (e.g. "white goods", or home appliances). Twenty% seems a reasonable assumption on the average. The indirect effect is more difficult to evaluate, but it is unlikely to be higher than 10%. A MARKAL−MACRO calculation for Italy has shown a 27% total rebound effect for a specific case.

8. The emission trading system (ETS): opportunities and barriers

The ETS is very clearly defined in the EC directive, and the implementation may be very effective, in the sense that it sets a cap (decreasing with time) to emissions (in the sectors concerned) and by imposing adequate penalties ensures that the policy goal is met.

However, the initial phase of implementation is the allocation of emission permits to each plant involved, which is proving to be a non-trivial endeavour. The practical experience gained so far is quite different from the theoretical optimum, which is the one assumed in the model. Transaction costs should be relatively low. However, the financial cost of this instrument may be high, and in particular it becomes very high if the emission cap is lowered significantly, as apparent in the simulation results.

Opportunities for adopting new technologies and processes with higher energy efficiency do exist in some energy-intensive activities (such as steel production) but this "leapfrogging" is generally justified only when new plants are being built, which is quite uncommon in the EU for such industrial sectors. In the medium to long-term, however, this situation is likely to change, with an expected increase in the number of replacement investments in energy-intensive industries as present plants approach the end of their useful life, or major overhauls are needed, and as highly efficient new technologies are increasingly available on the market at lower costs.

The mechanisms in the Kyoto Protocol (especially Joint Implementation and Clean Development Mechanisms) offer other opportunities in countries that have only recently introduced a market economy, and where little attention was given to energy efficiency in the past, even for energy-intensive industry.

9. Differences between emission trading and white certificates

There are important differences between the emission trading and the White Certificate instruments:

1. *By goal*: ET is an instrument of environmental (or, more strictly, of global climate) policy and its stated objective is reducing greenhouse gas (GHG) emissions. WhC is an instrument of energy policy, and its purpose is increasing the efficiency of final energy use as a means of pursuing several objectives: increasing energy security, shielding the economy from oil (or gas) price volatility, protecting environment and climate stability and, last not least, providing energy services at affordable prices which allow economic growth and competitiveness. The two instruments are closely linked, as they concur in reducing GHG (or at least CO_2) emissions, but there are also relevant differences; for instance, ET includes fuel substitution even if the primary energy consumption remains the same, while this would not be the case for WhC; the same applies to carbon sequestration (see Table 2). Policy setting in the presence of multiple objectives has been identified as one of the important problem areas for the future.

2. *By sector*: the ET system only concerns (at least for the time being) energy-intensive industries, including energy producers, while WhC could cover in principle all sectors, but for the time being are applied to the building sector (residential and service sectors), which account for about one third of the final energy consumption in the EU. In the future, the ET and WhC systems may be in competition as instruments to extend the efficiency/emission policies to new sectors, like the medium-energy-intensive industries and transport.

3. *By responsible parties*: in the ET case, the responsibility (obligation) is clearly on the industrial activities and it is set at installation level, including power companies and industries. In the case of the WhC, there are several options: the energy suppliers, the distributors, the final clients etc. Each of these gives rise to particular problems and/or opportunities. For instance in Italy, where the liberalisation of the energy market is still limited, the final users, at least in the domestic sector, have no choice as to the original supplier of the electricity or gas, and the choice of distributors as responsible parties for the WhCS is justified by the fact that they are more

Table 2

Comparison of (fossil) energy saving vs. CO_2 emission reductions for different policy instruments − year 2020, EU-15+, intermediate scenarios

	Total CO_2 emission reduction (Mtonne CO_2)	Total fossil energy saved (Mtoe)[a]	Total CO_2 saved per toe saved (t CO_2/toe)[a]
Black certificates	−245	−57	4.3
Green certificates	−188	−67	2.8
White certificates	−216	−91	2.4

[a] toe, tonne of oil equivalent.

closely in contact with the final user; in the UK, where the market is fully liberalised, energy suppliers (rather than distributors) may use the demand-side management as a further marketing aspect in their relation with clients. The responsibility to the final energy user, although in principle the most logical, collides with the difficulties inherent in a very large number of actors and with the information barrier.

4. *By evaluation and verification methods*: in some cases these are straight-forward, in others they require complicated procedures, which may weigh heavily on the transaction costs. An effort to reduce these costs in the case of a generalised application of the White Certificate system could increase their applicability.

5. *By political responsibility*: in most countries, ET systems are promoted and managed by Ministries of Environment, while energy efficiency is more often the responsibility of Ministries of Energy or Industry or Economic Affairs; the same is the case for the European Commission.

10. Recommendations

The analysis and the modelling work sketched above brought us to formulate the results in form of the following recommendations directed to policy-makers in the field of energy at the level of EU institutions, of the member states and at the (sub-national) regional level.

1. There is ample opportunities for increasing energy efficiency in all sectors of final energy utilisation as well as in energy production and transformation, so as to contribute to all energy and environmental goals while promoting rather than hindering economic development. These opportunities should be used!

2. Environmental, climate and energy policy should be more strictly co-ordinated than in the past; all impacts of an energy-related policy on climate, economy, environment, health, security of supply, competitiveness, employment etc. should be considered at the same time with appropriate weights, which are the result of general political decisions.

3. In particular, action in the domain of energy should be carried out jointly by Ministries responsible for Energy and those responsible for Environment at all levels (member states, Commission, Regional and local governments).

4. Guidelines on the design and implementation of energy efficiency measures, and in particular of the White Certificate systems, should be issued at the EU level, and the performance of the different systems at country and regional level monitored and benchmarked, so as to help in their further development and diffusion. If this system is to diffuse throughout the EU member states, it is important to ensure that they develop in a compatible manner, allowing for an EU market, and avoiding the difficulties inherent in the GC situations where many non-compatible schemes have been adopted.

5. The quantification of energy saving objectives should be more ambitious than has been the case so far, both at the EU and at the Member state levels and related to the overriding objectives of energy security, health and environment, and climate change mitigation.

6. An energy efficiency policy (and more generally a sustainable energy policy) requires a number of different policy instruments and not just one. Norms, regulations and incentives are necessary and have their role; however, market-based instruments, properly designed and implemented, should be used as widely as possible.

7. Specific instruments should be employed for heat and power generation (in particular district heating), for biofuels and for energy valorisation of wastes.

8. While the ET system appears adequate to cover the energy-intensive industrial sectors, the White Certificate system now considered for the residential and commercial buildings seems more adequate for reaching new sectors, in particular the industrial sectors with medium and low energy intensity; it is suggested that this system should progressively be extended from the domestic and the service sectors to industry.

9. The transport sector is still waiting for market-oriented mechanisms to improve energy efficiency; although great progress has been obtained in terms of the energy efficiency of single vehicles, this has been more than compensated by the increase in the demand for private transport, larger average size of cars and in many cases worse traffic congestion, and little or nothing has been achieved in terms of transport systems and modal shifts. Inventive thought is required in this direction; new ideas and experimentation should be encouraged; an eventual extension of a WhC-like system to transport should be evaluated.

10. The evaluation of projects should be standardised as much as possible and be based on simple and agreed criteria to calculate the base-line, as done in the UK and proposed for most technologies in Italy so as to simplify procedures and reduce transaction costs. Due to the importance of transaction costs for the success of WhC schemes, R&D in this direction is recommended. Progressive implementation of the WhC scheme, gradually introducing new technologies and new sectors, may be considered.

11. In order to have an effective implementation of a White Certificate system, a parallel or preliminary action is needed to eliminate or at least reduce market imperfections: this is a task for national and regional governments. The first step should be through effective and objective information campaigns, starting from the residential sector, where the largest potentialities are present.

12. There is generally a lack of effective and objective structures to carry out the field work required for demand-side management. Such Energy Service Companies (or ESCO) should be the backbone of a WhC system, which creates a market for their services. However, this market has been slow in stimulating the birth of such companies, or the expansion of those, which are already present. Public support in the start-up and in the first phases of ESCOs is recommended, as is a system of qualification of ESCOs that can guarantee the client of their competence and ability to deliver. Investing in ESCOs also brings benefits in terms of job creation.

13. Financial barriers have been recognised as one of the main obstacles to the introduction of energy saving measures, even when they are cost-effective. Provisions to facilitate financing of such measures by bundling similar projects or by guarantees through a rotating fund should be introduced by the banking system with public support.

14. Legislative and normative constraints slowing down the penetration of effective energy saving measures should be identified and removed whenever possible; such barriers may be present for instance in (outdated) building codes, in unnecessary safety regulations or in competition-protecting rules.

15. Energy efficiency can not only be the right solution for the long-term energy system (e.g. by reducing import dependence and hence increasing security of supply) but also provide the quickest and most effective response to unbalances between energy supply and demand (e.g. in order to avoid black-outs). Schemes to remunerate energy efficiency, as a "power credit" should be explored.

16. Technological development is a pre-condition for a sustained improvement in the efficiency of energy use. Long-term energy scenarios as those considered in the present work show that the gradual improvement of the technologies available or being studied today will not be sufficient to feed the efficiency improvements needed beyond 2015 or 2020. Fundamental research on many aspects of energy utilisation and innovative approaches are needed and should be supported.

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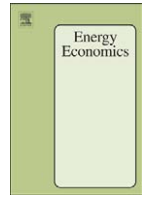
Paper II

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Markets for energy efficiency: Exploring the implications of an EU-wide 'Tradable White Certificate' scheme

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ABSTRACT

Recent developments in European energy policy reveal an increasing interest in implementing the so-called 'Tradable White Certificate' (TWC) schemes to improve energy efficiency. Based on three evaluation criteria (cost-effectiveness, environmental effectiveness and distributional equity) this paper analyses the implications of implementing a European-wide TWC scheme targeting the household and commercial sectors. Using a bottom-up model, quantitative results show significant cost-effective potentials for improvements (ca. 1400 TWh in cumulative energy savings by 2020), with the household sector, gas and space heating representing most of the TWC supply in terms of eligible sector, fuel and energy service demand, respectively. If a single market price of negative externalities is considered, a societal cost-effective potential of energy savings above 30% (compared to the baseline) is observed. In environmental terms, the resulting greenhouse gas emission reductions are around 200 Mt CO_{2-eq} by 2010, representing nearly 60% of the EU-Kyoto-target. From the qualitative perspective, several embedded ancillary benefits are identified (e.g. employment generation, improved comfort level, reduced 'fuel poverty', security of energy supply). Whereas an EU-wide TWC increases liquidity and reduces the risks of market power, autarky compliance strategies may be expected in order to capture co-benefits nationally. Cross subsidies could occur due to investment recovery mechanisms and there is a risk that effects may be regressive for low-income households. Assumptions undertaken by the modelling approach strongly indicate that high effectiveness of other policy instruments is needed for an EU-wide TWC scheme to be cost-effective.

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1. Introduction

Increased energy efficiency continues to be considered a crucial policy strategy to support a sustainable energy future (UNDP et al., 2000). With energy consumption soaring, energy-related environmental problems becoming apparent (e.g. climate change), oil prices highly volatile, and security of energy supply turning into a significant socio-economic issue, achieving greater energy efficiency is becoming increasingly vital to our society (UNDP et al., 2000, 2002). For this reason, policy instruments targeting energy efficiency are often more emphasized and the focus of policymakers and researchers is to analyse what improvements need to be made to the existing mix of policy instruments. Some have pointed out that the creation of an energy efficiency market is one approach that needs to be considered in the portfolio of policy instruments (e.g. Capozza et al., 2006; European Commission, 2006a; Rader and Norgaard, 1996). To many, such a market would realize savings at least-possible cost.

Recent developments in European energy policy reveal a growing interest in creating markets aiming to boost energy efficiency cost-effectively. In the past few years, France, Italy and Great Britain have embarked on implementing tradable certificate schemes to improve energy efficiency, so-called 'Tradable White Certificate' (TWC) schemes — described in more detail in Section 2. Other EU Member States (e.g. The Netherlands, Denmark, and Poland) are analysing potential design options and/or implementing a TWC scheme. While considerable policy efforts and attention have been devoted to encouraging national TWC schemes, the design and implementation of existing schemes have not been subject to *ex ante* evaluations. In fact, the creation of national TWC schemes has shown a policy dichotomy. From the macro policy perspective, countries have had plenty of policy arguments for implementing TWC schemes, with issues such as climate change, reduction of local pollutants, security of energy supply, political acceptability and cost-effective option are often mentioned as key drivers (cf. Bertoldi and Rezessy, 2006; Capozza et al., 2006). However, all countries with a TWC scheme – except Great Britain (see DEFRA, 2004) – have failed to quantitatively justify why and how a given design was chosen. From the micro policy perspective a lack of ex-ante evaluation regarding the potential effects of TWC schemes is identified. For instance the implementation of the Italian and French TWC schemes was mostly supported by the general policy issues rather than specific and/or independent assessments (Capozza et al., 2006; Mundaca and Neij, 2006).

Apart from these country-specific trends, there are several policy documents at the EU level that may lay the framework for more national European TWC schemes; or even the base for a future EU-wide TWC scheme, which is the focus of this paper. First, the recently adopted 'Energy End-use Efficiency and Energy Services (EEE&ES) Directive', which sets an indicative cumulative energy saving target of 1% (compared to the baseline) per year over the 9 years between 2008 and 2017 (i.e. 9%), aims to enhance cost-effective improvements in all end-use sectors (European Commission, 2006a:69). Encouraging several policy instruments to achieve this goal, the Directive further mentions that Member States are allowed to implement TWC schemes and that after due revision of how schemes are executed, the EU Commission will study the suitability of proposing a Directive to develop TWC schemes. Second, addressing the 'European Action Plan for Energy Efficiency' – which indicates policies and measures for realizing a 20% estimated saving potential by 2020 – the European Commission highlights that the EEE&ES Directive enables the assessment of an EU-wide TWC scheme in 2008 (European Commission, 2006b). Third, the adopted 'Green Paper Doing More with Less' identifies numerous barriers to and options for increased energy efficiency. Calling for concrete policy measures, it poses the question about how an EU-wide TWC scheme could be implemented with the least bureaucratic burden (European Commission, 2005:10). Furthermore, it is mentioned that the European Commission is already preparing for a possible EU-wide TWC scheme to allow trading of energy saving among the EU Member States (European Commission, 2005:28).

Bearing in mind the lack of evaluation at national levels and the growing policy interest at the EU level in TWC schemes, this study aims to enhance the understanding of the implications of creating an EU-wide TWC scheme targeting the household and commercial sectors.[1] European policy makers and scholars working on TWC schemes compose the main target groups of this paper. The study focuses on analyzing the potential effects of implementing an EU-wide TWC scheme by performing an ex ante assessment that

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[1] This study is an extension of the work done by the author under the "EU SAVE White and Green" project No 4.1031/Z/02-005. The work presented here deepens and complements previous research efforts by expanding the research framework and its energy–environment–economy (E3) analytical coverage.

considers three evaluation criteria: cost-effectiveness, environmental effectiveness and distributional equity. In this study, the following research questions are addressed:

- *Cost*-effectiveness[2]: How much cost-effective energy savings could be expected? To what extent can the inclusion of negative external costs resulting from electricity savings increase cost-effective potentials of energy savings?[3]
- *Environmental effectiveness*: What would be the potential contribution of an EU TWC scheme to reducing greenhouse gas (GHG) emissions? (e.g. with respect to the 'EU Bubble' Kyoto-target)
- *Distributional equity*: How could the financial burden of compliance be distributed? What type of ancillary effects could be expected?

The first two evaluation criteria are approached using the MARket ALlocation (MARKAL) modelling tool. The modelling exercise allows for analysing in more detail the 'Energy Service Demands' that yields the most cost-effective life cycle saving potentials; which have received very little attention so far even though this is a crucial technical aspect; often mentioned in the above-listed policy documents, and targeted by TWC schemes.[4] The third evaluation criterion complements the quantitative part of this study, with the costs and potential benefits embedded in a TWC being identified and key aspects that can influence their distribution discussed. Until now, very little consideration has been paid to equity aspects under TWC schemes, and the limited literature is largely confined to the distribution of energy saving targets or narrowed to energy saving costs and carbon emissions (cf. Bertoldi and Rezessy, 2006; Quirion, 2006) — the only exception is found in NERA (2005). For the analysis, experiences from current TWC schemes were also considered and key stakeholders were interviewed. In all, it is believed that this paper can provide broader insights to policy makers and scholars regarding potential impacts of an EU-wide TWC scheme — stressing some underlying policy conditions affecting the obtained results.

The structure of this paper is as follows. Section 2 gives an overview of existing European TWC schemes as background information for the study. Section 3 presents the main features of the methodological approach undertaken, with particular focus on the modelling approach. The main findings of this study are presented in Section 4, including qualitative aspects in relation to distributional effects. Section 5 discusses some underlying policy issues related to the findings of this study. Finally, conclusions are drawn in Section 6.

2. An overview of 'Tradable White Certificate' schemes

The theoretical efforts of Coase (1960) and Dales (1968) first shed light on the application of tradable permits[5] to efficiently address environmental problems, as opposed to direct regulatory control. Since then, the theoretical foundations of this economic instrument have been further demonstrated by Baumol and Oates (1971), Montgomery (1972), and Tietenberg (1974), among others. With the development of more robust concepts and frameworks, we have witnessed how the application of this form of regulation has been expanded to many issues during the last decades, becoming a cornerstone of many environmental/energy policy programmes (OECD, 2002). Also called 'cap-and-trade' or 'target-and-trade' schemes, the tradable certificate schemes already implemented have addressed, for instance, atmospheric pollutants, fishing stocks, renewable energy, municipal solid waste, and wastewater. Lately, they have been materialised in the field of energy efficiency. The idea can be attributed to Rader and Norgaard (1996:45).

A 'Tradable White Certificate' (TWC) scheme is a credit-based trading mechanism for increasing improvements in energy efficiency. The central argument for implementing a TWC scheme relies on

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[2] As evaluation criterion, *cost-effectiveness* is defined as whether a policy instrument (i.e. an EU-wide TWC scheme in this paper) minimizes the costs of meeting the imposed (energy saving) policy target (i.e. achieve target at lowest possible costs). On the other hand, *cost-effectiveness of energy savings* is defined herein as the lowest marginal life cycle costs per unit of energy saved (i.e. Euros per extra unit of final energy saved). In other words, high marginal life cycle costs per unit of final energy saved mean that an EU-wide TWC scheme is *less* cost-effective.

[3] Externalities – either positive or negative – are understood as the costs or benefits that arise from any activity but are not taken into account (i.e. not reflected in market prices) by the person/organization carrying out such an activity (e.g. consumption or production of a good). In the case of negative externalities, the level of welfare of one individual is adversely affected by another and no compensation takes place (e.g. pollution).

[4] The term energy service is used to describe the delivered benefits of useful energy consumption such as heating, refrigeration, lightning, cooking, transportation, etc., instead of providing units of energy as such (e.g. kWh).

[5] Please note that in this paper the words "permit" and "certificate" are used interchangeably.

meeting given energy-saving target at least possible costs. According to the growing literature, the following aspects characterize a TWC scheme. It involves the achievement of a mandatory energy-saving target set by a public authority (e.g. energy agency) during a given time period. Authorities are usually responsible for setting the overall policy design, implementation, administration and enforcement of the scheme. *Obliged parties* – usually energy suppliers or distributors – then bear this obligation in terms of being required to meet individual energy-saving targets, which are generally apportioned among them according to their market share. Obliged parties are required to implement energy efficiency measures in *eligible end-use sectors* (e.g. household, commercial) in which *eligible technologies* (i.e. energy efficient technologies) can be implemented. The authorities approve these technologies as qualifying for inclusion in a TWC scheme and certificates are then issued as evidence of realized energy savings. Obliged parties are allowed to trade these certificates; represented as a trading commodity with associated physical energy saved units. Like any application, the trading component is not an objective per se but merely a way of enhancing the scheme's efficiency in order to meet a mandatory saving target. The main argument for trading is an economic one: equalization of marginal compliance costs among obliged parties. On the one hand, parties that achieve significant energy savings are those that can do it inexpensively so they are likely to supply the market with TWCs. These parties can also save or *bank* TWCs for future commitments periods or to speculate on market prices going higher. On the other hand, parties that find it costly to meet their targets buy TWCs. To increase the liquidity of the market, authorities also allow other *market agents* (e.g. Energy Service Companies [ESCOs]), that do not bear any obligation but are entitled to implement measures, to earn and trade TWCs. Independent organizations perform activities related to the measurement and verification (M&V) of energy savings and the organization of trading platforms. The authorities issue TWCs, and parties that are unable to reach their target pay a penalty for non-compliance (cf. Bertoldi and Rezessy, 2006; Capozza et al., 2006; Langniss and Praetorius, 2006; Mundaca, 2007a; Mundaca and Neij, 2006; Oikonomou et al., 2007). In all, five types of 'flexibility' for meeting a saving target cost-effectively are identified in TWC schemes (Mundaca et al., in press):

- the range of eligible measures that eligible parties can implement to achieve their target;
- the number of eligible sectors in which eligible measures can be implemented;
- the banking provision;
- the engagement of non-obliged parties to generate and trade TWCs; and
- the trading option as such.

It is worth noticing that TWC schemes are credit-based and not an allowance trading oriented mechanism. This means that a TWC scheme allows energy savings above and beyond legal requirements (elaborated below when describing additionality) to be certified as tradable certificates. Unlike an allowance trading mechanism, in which a number of pre-defined number of allowances are not necessarily allocated among polluters based on historical regulatory standards, the baseline for certificate trading is determined by technology-based standards (Tietenberg, 2006). In other words, whereas allowance trading does not rely on pre-determined regulatory standards (i.e. once amount of allowances is determined they can be allocated in several ways), a TWC scheme does. Therefore, a TWC scheme needs to provide more incentives to achieve an energy savings target than the ones provided by the historical or current technological standards. Table 1 shows the main design elements of European TWC schemes. At present, there are three TWC schemes implemented in Europe: in France, Great Britain (hereafter GB) and Italy. The scheme in GB is not a certificate-based system, however it is often regarded as a TWC scheme because it allows bilateral trading of obligations and energy savings. More in-depth descriptions of these schemes are provided in Bertoldi and Rezessy (2006), Capozza et al. (2006), Langniss and Praetorius (2006), Monjon (2006), Mundaca and Neij (2006), NERA (2005); Oikonomou et al. (2007); Pagliano et al. (2003) and Pavan (2002).

As shown in Table 1, the design of the TWC schemes that are already implemented varies from one country to another. Although the nature of any tradable certificate scheme is the same (i.e. equalization of marginal compliance costs), a scheme's coverage is driven by many design elements that are often subject to national policy programmes (Capozza et al., 2006). Indeed, a variety of challenging design issues need to be resolved to ensure the theoretical performance that, ultimately, justifies the implementation of TWC schemes. For instance: What policy goals are to be achieved? How can an energy-saving target be set? Who should be obliged to comply with a mandatory target? Who can buy and sell certificates? Who can trade certificates and what rules are needed? How should the baseline be defined? What approaches can be used

Table 1
Main design characteristics of current national European TWC schemes

	Great Britain[a]	Italy	France
Energy saving target	468 PJ (130 TWh)[b]	243 PJ (67 TWh)	194 PJ (54 TWh)[c]
Time frame	2005–2008	2005–2009	2006–2008
Obliged parties (actors that bear the obligation)	Suppliers of gas and electricity with more than 15000 customers	Distributors of gas and electricity with more than 100000 customers served	Suppliers of gas, electricity, cooling and/or heating with annual sales equal or higher than 0.4 TWh. Suppliers of LPG with annual sales equal or higher than 0.1 TWh
Eligible actors (parties that can participate in trading)	Only obliged actors, but sub-contracting is allowed	Obliged parties, non-obliged parties and ESCOs	Obliged parties, ESCOs and any economic actor able to achieve or bundle more than 1GWh in savings
Market size	8 suppliers that cover 99% of the energy supply markets	Around 24 distributors of natural gas, 10 distributors of electricity (obliged parties). Another 570 non-obliged distributors, and more than 550 ESCOs	ca. 2400 energy suppliers. 23 obliged parties capture more than 90% of the total energy saving target obligation.
Eligible sectors (end-use sectors in which eligible measures can be implemented)	Only household	All energy end-use sectors. At least 50% of the target has to be achieved through electricity and gas savings	All energy end-use sectors, including transportation but excluding installations covered by EU emission trading scheme
Eligible technologies (measures that are subject to yield TWC)	An open list. Examples: Cavity wall insulation, loft insulation, fridge saver-type programme, condensing boilers, appliance replacement, (A+, A++), CFL, tank insulation	An open list with 14 categories. Examples: CFL, cavity wall insulation, micro CHP, solar heaters, high efficiency boilers, small PV applications, double glazing, appliances, A+, A++, low-flow water taps, etc.	An open list with ca. 100 methodologies related to measures for the household and commercial sectors, ca. 20 for the Industrial sector, and 5 for the transport sector
Certificate-based scheme	No, but trading of savings and obligations is allowed	Yes	Yes
Penalty for non-compliance	A fine up to 10% of the supplier's turnover	Not explicitly defined but a fee that is proportional and in any case greater than investments needed to compensate for non-compliance	2 €cents per kWh

[a] Scheme implemented in England, Wales, and Scotland.
[b] Fuel standardized lifetime discounted (3.5%) energy savings.
[c] Lifetime discounted (4%) energy savings.

to measure, verify and certify energy savings? Should one consider lifetime energy savings to be granted all at once, or should TWCs be issued for a certain period? How can the time horizon of the scheme be made compatible with the lifetime of the measures and the certificates? In what way does a TWC scheme encourage measures that are additional to the business-as-usual scenario?

Among these design elements, the issue of 'additionality' is quite significant because TWC schemes encourage energy efficiency measures that would not have occurred under the business-as-usual scenario (i.e. as depicted by the baseline). The key question is how the additional component of energy efficiency measures is determined. This is still a debatable and country-specific issue, but some criteria used to determine additionality include measures that exceed what current law and building regulations require as well as spontaneous market trends and/or legislative requirements, and also measures that have a long payback time and do not result in increased turnover (cf. Capozza et al., 2006). Additionality also aims to prevent responsible parties from 'free-riding'. If the measures implemented are not considered as additional, they are not eligible and obliged parties cannot claim certificates for the achieved energy savings.[6] Finally, in TWC schemes – as in any energy efficiency related policy programme – the so-called 'rebound effect' can hamper their performance.[7] In order to lessen the rebound effect of implemented eligible measures, the British TWC scheme has taken some precautions despite inherent uncertainties. The so-called 'comfort taking' effect (i.e. energy savings that are taken because of improved household comfort) was introduced when estimating and granting ex-ante savings generated by insulation measures-between 15 to 45% (DEFRA, 2004:22–24).

3. Method and model

The MARKAL modelling tool is used to develop an energy–environment–economy (E^3) analysis. Developed by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA), MARKAL is a bottom-up dynamic (mostly) linear programming optimisation tool with perfect foresight (see Seebregts et al., 2001, for an overview of MARKAL models). In MARKAL a user-defined reference energy system depicts a network of energy sources, fuel systems and supply and demand technology options (including transmission). With all parameters specified, the model finds the combination of fuels and technologies that minimises total discounted energy system costs while keeping exogenously determined energy demands satisfied over a given time period. MARKAL allows studying the response from an energy system to specific constraints that are useful for policy and planning analysis (e.g. increase deployment of renewable energy technologies, cap on atmospheric emissions, etc.).[8]

Stressing that there is no such a thing as 'the single-best' method for evaluating policy instruments, the use of MARKAL – to be taken as part of a mix of complementary research approaches – arises from the system analysis standpoint and the specific research questions posed by this study. The emphasis is on the potential impacts for the entire EU15+ energy system.[9] Although not being the focus of this paper, notice that MARKAL falls short in capturing, for instance, market size (buyers and sellers), transaction costs, market power (e.g. monopolistic or monopsonistic conditions set by obliged parties) or realistic representation of economic decision-making by consumers/firms.[10] However, implications of some of these aspects are discussed in Section 5.

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[6] The British TWC scheme attempts to counteract the free-riding effect by using 'deadweight factors'. In this case, deadweight means the level of investment activity carried out under business-as-usual, which is considered when both energy and cost savings from eligible measures are estimated (DEFRA, 2004:22). The free-riding effect has been also discussed in the French TWC scheme because some eligible measures under the TWC scheme are already encouraged by tax-credits. The legal framework of the scheme does not prohibit the overlapping of these two instruments so the measures being implemented due to tax credits are also considered to be additional under the TWC scheme.

[7] The term refers to the increased energy demand as a result of efficiency improvements that reduce the costs for end-users (Khazzoom, 1980).

[8] For further information about MARKAL and its different applications visit http://www.etsap.org/Tools/MARKAL.htm.

[9] For country-specific *demand side* quantitative analyses of TWC schemes see Oikonomou et al. (2007) and Perrels and Tuovinen (2007).

[10] Addressing other tradable certificate mechanisms (e.g. 'green' certificates, carbon allowances), similar limitations are also found in other MARKAL modeling exercises (cf. Zongxin et al., 2001; Chen, 2005; Unger and Ahlgen, 2005).

Table 2
Key drivers to determine energy service demands in EU15+ MARKAL model

Driver	No	2005	2010	2015	2020	2025
GDP (1997 billions US$)	1	10378	11694	13125	14724	16395
Population (millions)	2	391	391	389	387	385
GDP/population	3	27	30	34	38	43
Housing stock total (millions)	4	152	155	158	161	164

Data source: EIA-DOE (2003, Vol. II:101).

Table 3
Exogenous energy service demands for the household and commercial sector in the EU15+ MARKAL model (in PJ)

Sector/Segments	2005	2010	2015	2020	Driver
Commercial sector					
Cooling	1287	1368	1452	1540	1
Cooking	128	133	137	141	3
Space-heating	1427	1478	1523	1560	1
Hot water	593	614	632	648	1
Lighting	4311	4585	4865	5162	1
Office equipment	489	613	763	949	1
Other	132	134	136	137	1
Refrigeration	194	200	207	212	3
Household sector					
Cooling	41	42	43	43	4
Clothes drying	12	13	13	13	4
Clothes washing	2	2	2	2	4
Dishwashing	2	2	2	2	4
Other electronics	79	97	114	133	3
Space-heating	5152	5271	5366	5462	4
Hot water	720	737	750	764	4
Cooking	272	278	283	288	4
Lighting	25	26	27	27	4
Others	0	0	0	0	4
Refrigeration	29	29	30	30	4

The last column indicates the key driver used to forecast energy service demands (as shown in Table 2).
Data source: EIA-DOE (2003, Vol. II:99).

3.1. The EU15+ MARKAL_model

MARKAL is applied to a database that depicts the reference energy system of Western Europe-hereafter EU15+.[11] The Energy Information Administration (EIA) of the US Department of Energy (DOE) developed the database, which is fully described in EIA-DOE (2003).[12] The EU15+ database includes energy commodities that are extracted/imported and processed by technologies. Energy carriers are used by end-use technologies to satisfy a given demand for energy services. With regard to the structure of the model, the demands for energy services are grouped into five end-use sectors: household, commercial, agriculture, industry and transportation. The model contains input data from the year 2000 up to a time horizon of 2050. The model is averaged over 5-year increments (i.e. 5-year steps).

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[11] The EIA-DOE developed the System for Analysis of Global Energy markets (SAGE) to examine a wide range of global energy issues; it integrates a set of regional models for the development of the International Energy Outlook, 2003. In SAGE, 15 regions are identified based upon political, geographical and environmental factors: Africa, Australia–New Zealand, Canada, Central and South America, China, Eastern Europe and Former Soviet Union, India, Japan, Mexico, Middle-East, Rest of Asia, South Korea, United States, and Western Europe. For each region, input information regarding energy service demands are developed using economic and demographic projections.

[12] The entire documentation of the model and a detailed data implementation guide can be found at http://tonto.eia.doe.gov/ftproot/modeldoc/m072(2003)1.pdf and http://tonto.eia.doe.gov/ftproot/modeldoc/m072(2003)2.pdf.

Table 4
Key data for baseline scenario or counterfactual situation in EU15+ MARKAL model

Indicator	Unit	2005	2010	2015	2020
Total primary energy	PJ	68 509	73 250	77 579	83 175
Total energy system costs	Billion €	583.2	675.8	757.1	698.2
Electricity fuel selection					
Gas	TWh	388.8	602.6	689.2	877.1
Oil	TWh	163.6	132.9	119.6	116.3
Coal	TWh	468.9	489.9	528.3	554.1
Nuclear	TWh	855.8	855.8	855.8	855.8
Hydro	TWh	550.1	568.7	587.4	605.9
Other renewables	TWh	66.5	69.3	75.2	80.1
Total GHG emissions	Mt $CO_{2\text{-}eq}$	2762	2972	3139	3311
Household fuel consumption					
Gas	PJ	3932	4042	4239	4437
Electricity	PJ	3006	3294	3546	3822
Oil products	PJ	2697	2733	2748	2759
Other fuels	PJ	1532	1668	1683	1697
Commercial fuel consumption					
Gas	PJ	1070	1149	1250	1328
Electricity	PJ	2430	2693	2978	3316
Oil products	PJ	949	964	971	972
Other fuels	PJ	219	251	258	285

In the model, the EU15+ is treated as a single geographic region rather than as a group of countries.[13] Thus, data are aggregated so figures represent average estimates for this geographical coverage. It has to be acknowledged though that heterogeneity plays a significant role because consumer behaviour and regional differences are relevant. Needless to say, ancillary benefits and negative externalities are very site-specific and include related uncertainty levels. However while greater geographic details are desirable, notice that a multi-regional EU15+ MARKAL model does not yet exist.[14]

In the EU15+ MARKAL database energy service demands are exogenously determined. Projections of energy consumption were estimated by the EIA-DOE (2003) from information on energy-use patterns, existing and available new technologies, and potential sources of primary energy supply for the EU15+.

Input information was also supported using economic and demographic projections (see Table 2). Population and GDP projections were based on official data from the United Nations and EIA-DOE. Table 3 shows the estimated energy service demands for the sectors relevant to this study: household and commercial. With regard to GHG emissions, these are directly linked at the technology level and end-use sectors. In the model, sectoral emissions are converted into carbon dioxide (CO_2) equivalents using global warming potentials. Key E^3 indicators describing the baseline scenario are shown in Table 4. See Appendix A for details about pre-modelling steps undertaken in this study.

3.2. Modelled EU-wide TWC scheme

The EU-wide TWC scheme is modelled as a credit-based scheme applied to the household and commercial sector. The design of the modelled scheme attempts to capture the most common and key design features of current TWC schemes (see Table 5). In this study, quantitative economic and environmental effects are the result of how the energy system of the EU15+ MARKAL model reacts to the modelled TWC scheme. As a central part of the modelling approach, three different energy-saving targets – a crucial element in TWC schemes – were investigated.[15] By forcing the EU15+ energy system to meet a user-defined saving target (i.e. setting a

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[13] The model includes the following countries/regions: Austria, Belgium, Denmark, Finland, France (including Monaco), Germany, Gibraltar, Greece, Greenland, Iceland, Ireland, Italy (including San Marino and the Vatican), Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland (including Liechtenstein) and the United Kingdom.

[14] A pan-European MARKAL–TIMES model will be available in 2008. Models for 29 European countries are being developed under the project "New Energy Externalities Development for Sustainability" (NEEDS). For further information, visit http://www.needs-project.org.

[15] In this study, energy efficiency is simply defined as decreased energy consumption while always keeping energy service demands satisfied.

Table 5
Assumed design features of the modelled EU-wide TWC scheme

Design element	Description/value
Energy saving targets	Different cumulative annual saving targets relative to the base case (final energy consumption): a) Target-A: Low ambitious target, with 1% per year from 2005 to 2010; and 0.3%/year from 2010 to 2020. This leads to cumulative energy savings of 10% by 2020. In absolute terms, this account for 1938 PJ (or 538 TWh) b) Target-B: Relatively more ambitious target, with 1% per year from 2005 to 2010; and 2% per year from 2010 to 2020. This leads to cumulative energy savings of 27% by 2020. In absolute terms, this cumulative target accounts for 5108 PJ (or 1419 TWh) c) Target-C: Ambitious target, with 2% per year from 2005 to 2010; and 4% per year from 2010 to 2020. This leads to cumulative energy savings of 56% by 2020. In absolute terms, this cumulative saving level represents 10 404 PJ (or 2890 TWh)
Time frame	2005–2020
Obliged parties	Energy suppliers
Eligible technologies	All advanced energy efficiency measures that yield savings above the base case. Standard technologies are not eligible
Eligible fuels	All energy carriers (i.e. electricity, gas, oil products, etc.)
Eligible sectors	Household and commercial

maximum amount of final energy consumption compared to the baseline scenario), the analysis attempts to explore cost-effective potentials of cumulative energy savings capable of meeting different levels of mandatory policy ambitions when a TWC scheme is implemented (see Fig. 1). Thus, it is assumed full compliance, i.e. 100% 'energy-saving effectiveness'.[16] To be taken also as a sensitivity analysis – and related E^3 outcomes – different mandatory policy targets are analysed: target-A means that an EU-wide supports the achievement of the indicative cumulative saving target of 1% per year (over 9 years) as set by the EEE&ES Directive. Target-B means that an EU-wide aims at realizing already identified energy saving potentials (ca. 30%) for the household and commercial sectors (see European Commission, 2006b:5–6) — the achievement of target-A is then implicit. Finally, target-C aims at exploring a rather ambitious energy saving target (>50%) going beyond the ones identified in the literature — the achievement of target-A and -B is then also implicit.

Due to the aggregated nature of the EU15+ MARKAL model, it is assumed that a common EU mandatory energy saving target is determined through a top-down policy process; then apportioned nationally and in absolute terms according to the market share of obliged parties. TWC can then be traded on EU market.[17] All energy savings obtained beyond the counterfactual situation (i.e. as depicted by the baseline or business-as-usual scenario) are eligible to gain TWCs.[18] As far as fuels are concerned, despite that all savings from any fuel are eligible in the modelled TWC scheme, the study focuses mostly on electricity and gas, mainly because these two fuels are the dominant energy carriers in the eligible sectors under analysis. Unless specifically stated, all monetary figures are presented in Euros (2000). Finally, it is assumed that fewer market barriers and imperfections facilitate the penetration of eligible energy efficiency technologies due to the high effectiveness of complementary economic and informative policy instruments.[19] Regarding the

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[16] This evaluation criterion is defined herewith as whether obliged parties meet or not a mandatory energy saving target, i.e. effectiveness towards compliance level.

[17] Alternatively, and assuming the existence of a pan-European model, one could model national TWC schemes with separate national targets that are linked by means of an EU-TWC market.

[18] Unger and Ahlgren (2005) use a similar approach when modelling tradable green certificate schemes using the 'Nordic MARKAL_model'.

[19] In the energy/environmental policy arena, 'informative policy instruments' can be broadly defined as policy measures aimed at enhancing the understanding and awareness of how to increase energy efficiency and its related benefits. Types of informative policy instruments are, for instance, information campaigns, eco-labelling schemes, customer advice, information centres and certification programmes.
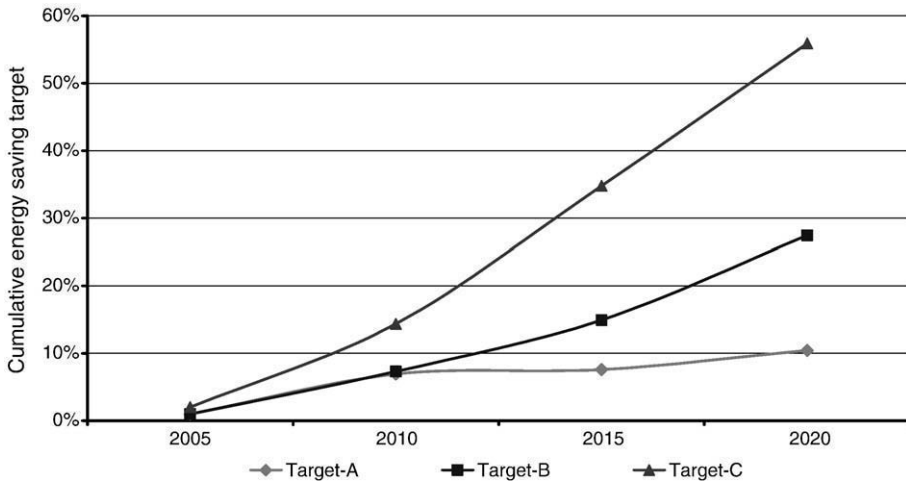
Fig. 1. Time dependence of different cumulative energy saving targets for the modelled EU-wide TWC scheme.

former, capital market imperfections are reduced so financial resources are available to make the necessary investments. Concerning the latter, three critical assumptions are embedded in this study:

- Technical and financial performance of measures for end-users is known because of the information provided by relevant stakeholders (e.g. obliged parties, equipment manufacturers, public authorities);
- Low or zero transaction costs for end-users exist when it comes to the search for information because other key stakeholders organize and provide reliable information about the functioning of eligible technologies as well as the TWC scheme as such;
- High awareness among end-users about the benefits of increased energy efficiency; which in turn reduces transaction costs for obliged parties as far as the search and persuasion of end-users willing to implement measures is concerned.

Some policy implications of the above-listed aspects are discussed in Section 5. For further details about the model, assumptions and data sources see Appendix A.

4. Results

Bearing in mind the assumptions and limitations of the research framework, the following sections describe the analysis of the key outcomes of this study. The results are presented according to the evaluation criteria that guide this work: cost-effectiveness, environmental effectiveness and distributional equity.

4.1. Cost-effectiveness

From the evaluation standpoint, the cost-effectiveness criterion is central to the economic rationale behind TWC schemes, i.e. whether a TWC scheme minimizes the costs of meeting mandatory energy saving targets. To tackle this, a delimited approach is used under this study. First, the focus is on estimating the financial cost-effectiveness of energy savings (externalities excluded) and related potentials. Second, energy service demands are analysed and used to identify cost-effective supplies of TWCs. Third, and to complement this cost-effectiveness approach, the reduction of negative externalities derived from power generation is used to ascertain the societal value of increased energy efficiency and to estimate the social cost-effective potential of energy savings. Aspects concerning broader welfare effects are beyond the scope of the quantitative part of this study.

4.1.1. Life cycle energy saving costs

Estimates of marginal life cycle energy saving costs were calculated from the absolute changes in energy system costs (i.e. fuel, operation, maintenance, and investments) when adding extra units of energy saved
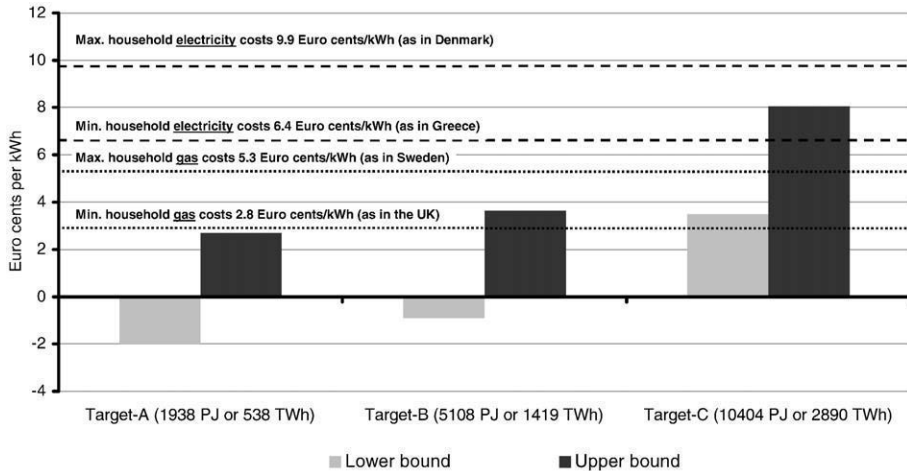
Fig. 2. Lowest and highest marginal life cycle energy saving costs under different cumulative energy saving targets (2005–2020). Household fuel costs (maximum and minimum values for electricity and gas in EU15+) are used as benchmarks to identify financial cost-effective potentials of energy savings under the modelled EU-wide TWC scheme.

under each time step as a result of pre-defined energy saving targets.[20] For simplification, lower and upper bounds of marginal costs for each target applied are shown in Fig. 2. Figures range from −2 to 8 Euro cents/ kWh. To ascertain the financial cost-effective potentials (i.e. end-user perspective), current minimum and maximum household energy fuel costs (excluding taxes and value-added tax [VAT]) of countries included in the model were used as benchmarks for comparison. Depending on the fuel saved, different cost-effective potentials are identified.

In Fig. 2, one can observe minimum and maximum nominal electricity costs corresponding to Greece (lowest) and Denmark (highest), respectively (see Eurostat, 2006a:3). Based on these values, both target-A and -B are met cost-effectively, i.e. even if the lowest electricity costs (as in Greece) are used as a benchmark, there is up to 27% (ca. 5100 PJ or 1400 TWh) of technical potential of energy savings (compared to the baseline) by 2020 that generates net financial benefits. Minimum and maximum nominal costs for household gas consumption are also shown in Fig. 2, corresponding to the UK (lowest) and Sweden (highest), respectively (see Eurostat, 2006b:4).

One can also observe a minimum gas price alone can ensure financially cost-effective savings for the whole target-A (10%) and most of target-B (ca. 20% target). The results show that financial cost-effective compliance under the modelled TWC scheme ranges from 10% up to 27% (i.e. from target-A to -B), depending on what fuel is saved to create TWCs. These figures are consistent with estimated technical and financial cost-effective potentials of 27% and 30% for the household and commercial sector respectively (cf. European Commission, 2006b:5–6).[21]

4.1.2. Cost-effective supply of TWCs

When exploring the supply the TWC, the study looks deep into three different levels: eligible sector, eligible fuels and energy service demands. Based on the results, cost-effective supply of TWCs is predominant in the household sector for all energy-saving targets applied. In terms of fuels, gas dominates the supply of TWCs (see Table 6). Electricity savings are also significant in the household sector, however savings related to oil products are found to have a similar share under target-B and -C by 2020. In the commercial sector, while electricity savings are slightly higher than gas savings, savings related to both fuels are equally relevant throughout the whole analysed period. In any case, electricity and gas represent

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[20] Note that calculations do not take into account the fact that the costs of energy efficiency technologies will eventually decrease and the costs of energy carriers (i.e. operating costs) might increase.

[21] The results also seem to be consistent with previous studies that show technical and economic cost-effective energy efficiency potentials of around 20% for the EU15 as a whole (see European Commission, 2005:4).

Table 6
Supply of TWCs based on cumulative energy savings per eligible sector and fuel (in PJ)

	2005	2010	2015	2020
Under target-A				
Household sector				
Gas	168	323	561	843
Electricity	113	169	141	180
Oil products	109	155	70	64
Other fuels	59	109	146	209
Total	450	756	919	1296
Commercial sector				
Gas	93	202	246	296
Electricity	117	171	179	338
Oil products	32	22	26	44
Other fuels	19	13	-29	-36
Total	261	409	422	642
Under target-B				
Household sector				
Gas	178	339	1067	2031
Electricity	120	178	299	583
Oil products	101	100	186	520
Other fuels	75	126	105	76
Total	473	743	1657	3211
Commercial sector				
Gas	98	211	461	701
Electricity	123	180	360	895
Oil products	45	70	145	267
Other fuels	10	18	17	35
Total	277	480	983	1897
Under target-C				
Household sector				
Gas	144	663	2249	3487
Electricity	97	361	821	1560
Oil products	48	160	558	1175
Other fuels	85	333	496	753
Total	374	1516	4123	6975
Commercial sector				
Gas	80	398	925	1158
Electricity	100	358	884	1835
Oil products	46	101	164	315
Other fuels	8	42	50	121
Total	234	900	2023	3429

the main sources of savings, yielding 85%, 82% and 77% of cumulative energy savings by 2020 under target-A, -B and -C respectively.

Regarding the sources of TWCs as regards energy service demand, results are shown in Figs. 3, 4 and 5. Overall, whereas space heating represents the dominant source of savings within the household sector; lighting and space heating are equally relevant within the commercial sector. As observed, trends are consistent in all scenarios — for both sectors and main fuels (electricity and gas). For instance, cumulative gas savings realized in the household space heating segment dominate all the savings under any analysed target. A similar remark can be given for cumulative gas savings in the commercial space-heating segment. When it comes to electricity savings realized in the commercial sector, the lighting segment clearly dominates.

4.1.3. Estimated societal cost-effective potential

Data generated from the EU ExternE Project[22] were used to approach the potential benefits for the EU15+ society of reducing atmospheric pollutants resulting from the modelled EU-wide TWC (see Appendix A for further details). The resulting negative external costs range from 0.8 to 4.6 Euro cents/kWh of electricity

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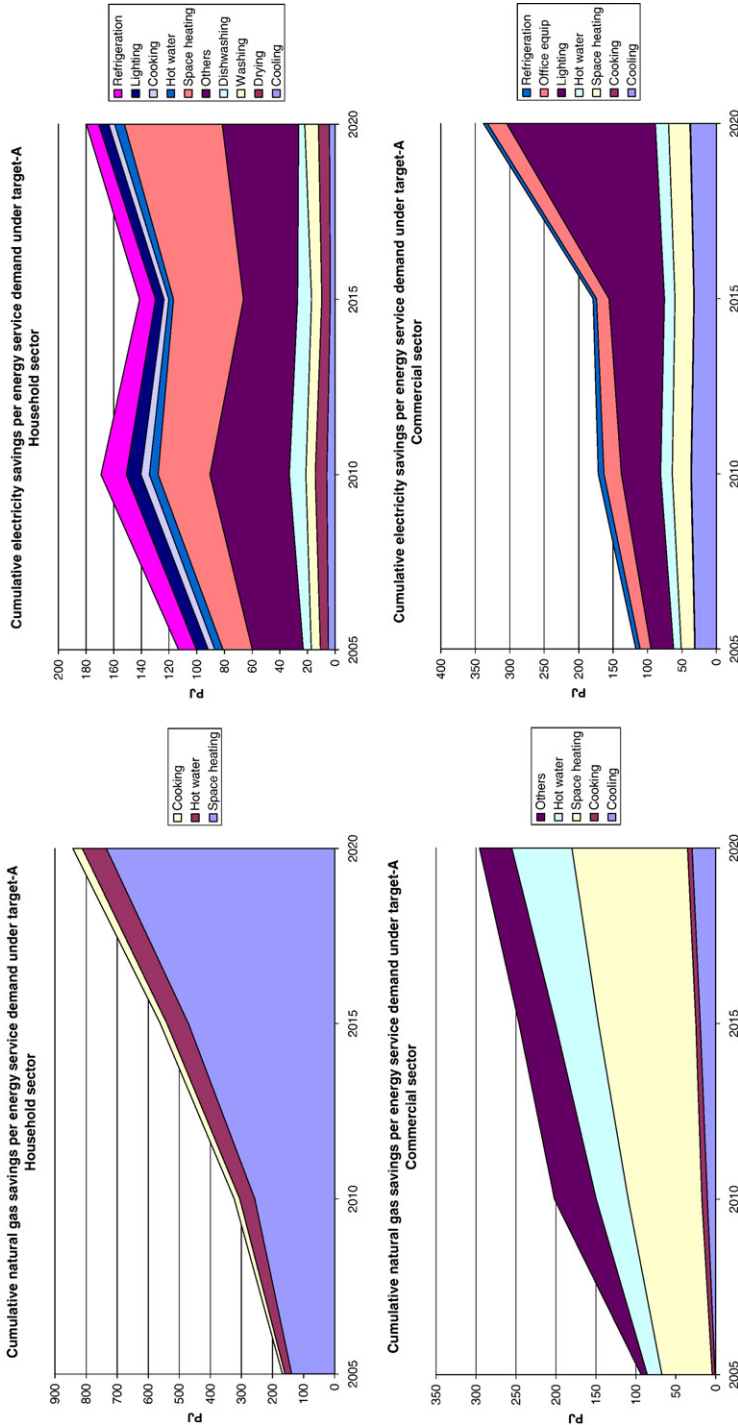[22] For further information visit http://externe.jrc.es/.

Fig. 3. Supply of TWCs — sources per eligible sector, fuel and energy saving demand under target-A.
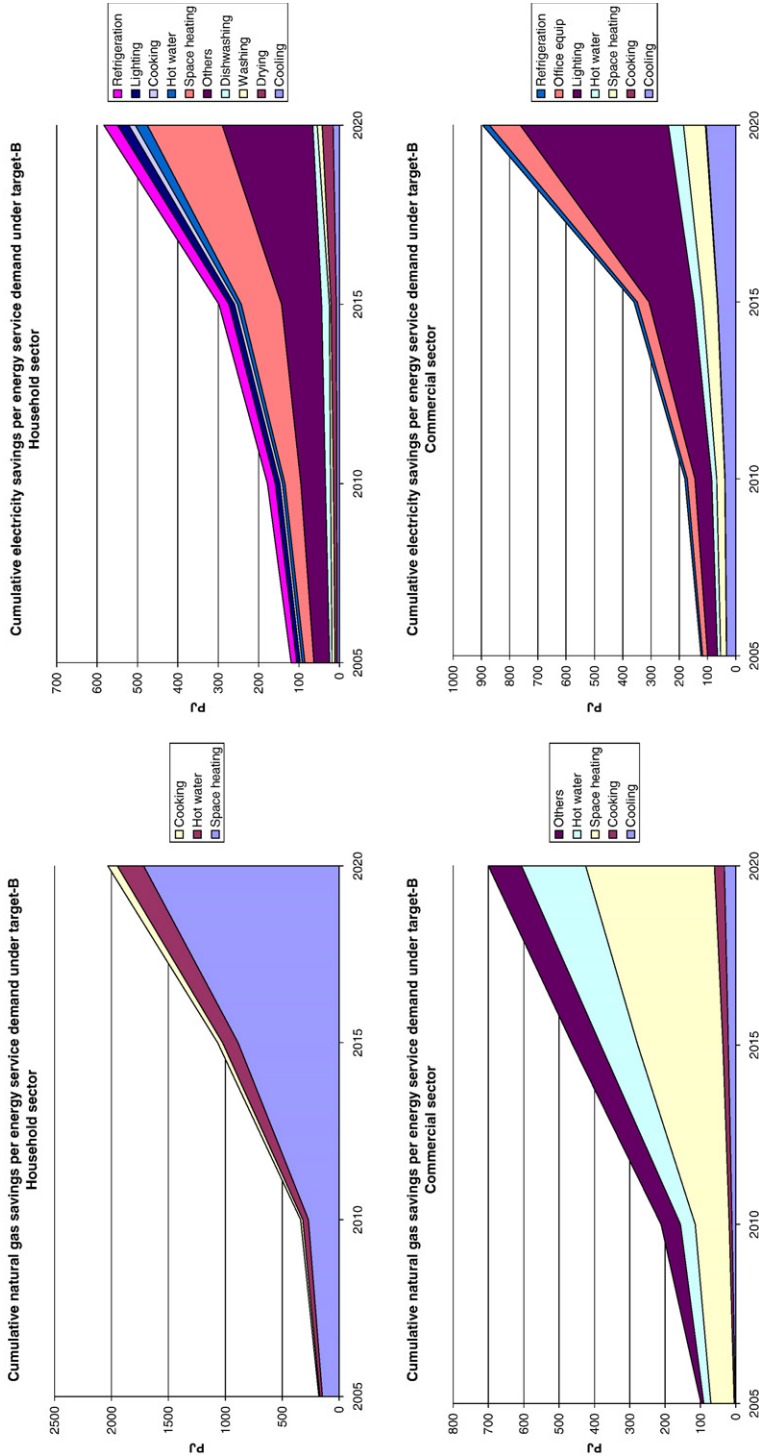
Fig. 4. Supply of TWCs – sources per eligible sector, fuel and energy saving demand under target-B.
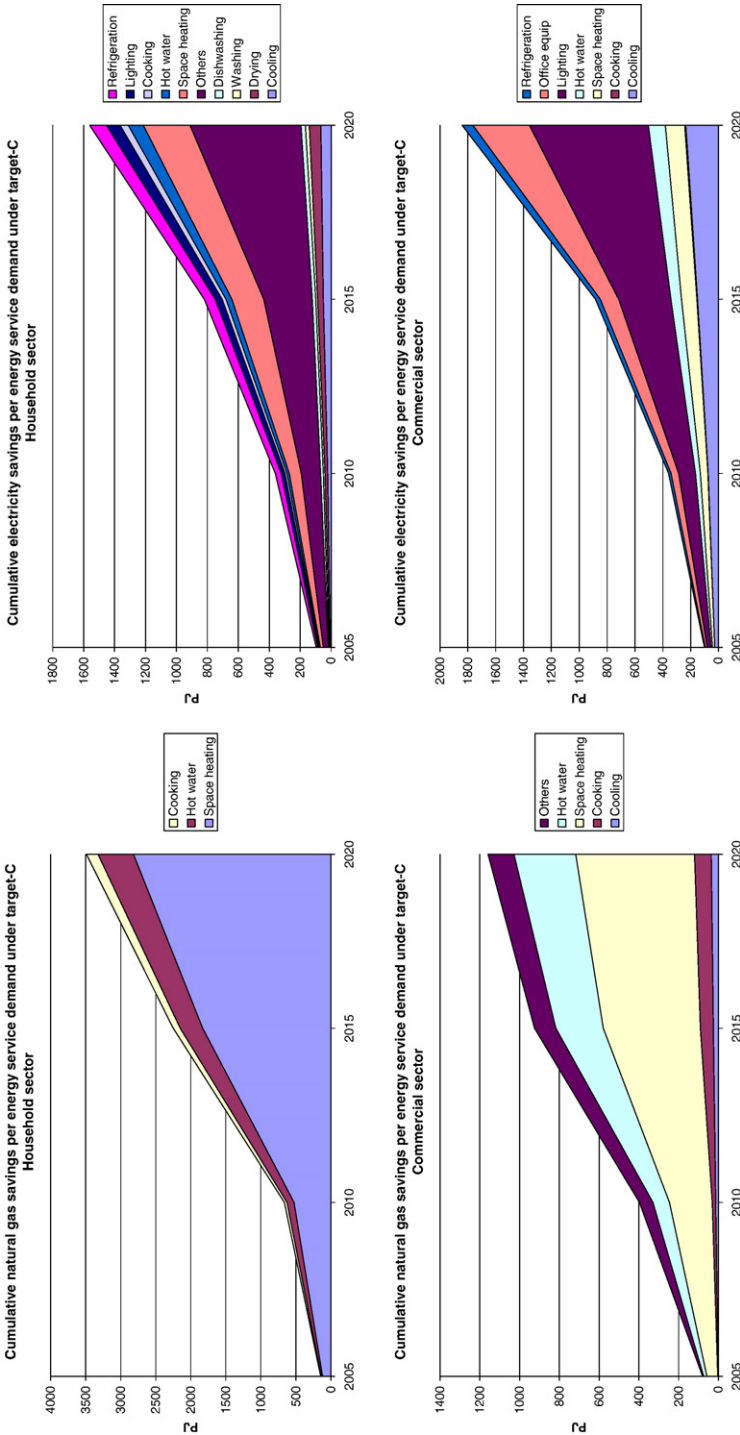
Fig. 5. Supply of TWCs — sources per eligible sector, fuel and energy saving demand under target-C.
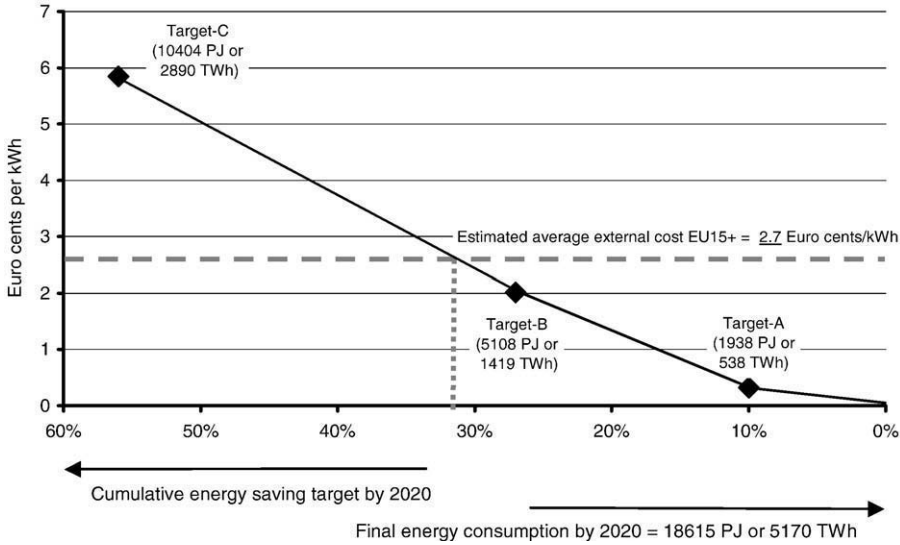
Fig. 6. Societal cost-effective potential by 2020. An average damage external costs value is used to identify societal cost-effective potential of energy savings. Considering average marginal life cycle energy saving costs at different target levels, an estimated societal cost-effective potential above 30% is observed.

saved, i.e. lower and upper bounds that represent the economic benefits, or avoided external costs when electricity is saved. Based on these figures, it is estimated that the social and environmental benefits of decreased energy consumption induced by the modelled TWC scheme add around 40% to 57% to the value of energy savings, i.e. for every Euro saved in electricity costs, the TWC scheme also saves another 40 to 57 Euro cents by avoiding the negative external costs of electricity generation.

Based on the above-mentioned estimates of negative external costs, a societal cost-effective potential of energy savings is estimated. Taking into account an average external cost of 2.7 Euro cents/kWh as well as average marginal energy saving costs for the different analysed energy saving targets, a cost-effective potential from the societal point of view is estimated (see Fig. 6). Using a single market price of social and environmental damage costs of energy production (even though marginal external costs are not constant), it is economically worth it for the society to save energy up to a level of approximately 32%, in which marginal energy saving costs are equal to the damage costs of energy consumption. The societal perspective increases the already estimated financial cost-effective potential (27%) to an economic cost-effective potential of 32% — which surpasses the level of ambition represented by target-B, for instance. If the already mentioned lowest and highest damage costs (0.8–4.6 Euro cents/kWh) are used instead of an average value, the societal cost-effective potential ranges roughly from 16% to 47%.

4.2. Environmental effectiveness

Although TWC schemes are not meant to solve environmental problems per se, the reduction of atmospheric pollutants is usually stated as an important policy goal (cf. Bertoldi and Rezessy, 2006; Capozza et al., 2006; DEFRA, 2004). This largely explains why this study also looks at GHG emission reductions resulting

Table 7
GHG emissions under different energy-saving target levels

GHG emissions (Mt $CO_{2\text{-eq}}$)	2005	2010	2015
Base case	2762	2972	3139
Under target-A	2651	2775	2979
Under target-B	2646	2775	2905
Under target-C	2636	2770	2796

from the modelled EU-wide TWC scheme. As any of the exogenously applied targets trigger higher penetration of more end-use efficient technologies and lower energy consumption, the modelled TWC scheme logically reduces GHG emissions. The question is to what extent and at what pace. Overall, GHG emission reductions range from 4 to 13% relative to the base case. By 2010 both target-A and -B achieved GHG emission reductions of 197 Mt CO_{2-eq}, representing an approximate 6% decrease compared to the base case (see Table 7). For target-A, GHG reductions slow down after 2010 because of the target's lower level of ambition. Although target-C is more ambitious, emission reductions by 2010 are marginally higher than those under targets-A and -B, reaching 202 Mt CO_{2-eq}. On the other hand, emission reductions are substantially higher by 2015, reaching 343 Mt CO_{2-eq}. The explanation for this particular trend is found in the perfect foresight that MARKAL entails. When running the model with the applied energy-saving target-C, the model increases the utilization values of less-efficient technologies during 2005 and 2010 because of the certainty that this set of technologies will not be used when the target is much higher by 2015 and 2020. This causes lower reductions than one would expect for 2005 and 2010 under target-C compared to targets-A and -B. In all cases, GHG emission reductions from electricity savings were reduced mostly upstream in the energy system (i.e. generation side).

From the evaluation standpoint, the environmental-effectiveness criterion also looks at whether the modelled TWC scheme achieves a given environmental target. In the absence of such an explicit policy target, it is assumed that the EU-wide TWC scheme aims to support attainment of the EU Bubble's Kyoto target, ca. 340 Mt CO_{2-eq}, by 2008–2012 compared to 1990 emission levels. This target is thus taken as a benchmark for comparison, with the modelling exercise focusing on 2010, as this year is taken as the "centre of gravity" relative to the first Kyoto commitment period (2008–2012). As shown in Table 7, the contribution of the modelled TWC scheme at any target level by 2010 ranges from 57 to 60% of the EU Bubble Kyoto target.[23] One can also observe that resulting GHG emission reductions from target-C cover the totality of the EU Kyoto-target year 2015.

4.3. Distributional equity

To complement the modelling results in this study, equity aspects were explored. From the evaluation standpoint, the study looks at the identification and distribution of potential costs and benefits across society. Two relevant distributional aspects are looked at from the qualitative perspective: burden of compliance and ancillary benefits.

In terms of costs, equity aspects are relevant because it would be unfair if some end-users are able to get the financial benefits of improved energy efficiency (e.g. direct benefits from energy efficiency investments; lower energy bills resulting from lower energy consumption demand) while passing on the costs of such investments to others (cf. NERA, 2005). While obliged parties are responsible for meeting the target from the operational standpoint end-users are, in principle, responsible from the financial viewpoint. Thus, investment recovery systems play a key role to legitimate a TWC scheme because obliged parties are entitled to recover their compliance costs through energy tariffs.[24] However, this approach may involve negative potential effects. For instance, while it is estimated that the net financial benefits for British end-users were around 1.5 and 7 Euro cents/kWh for gas and electricity savings, respectively (see Lees, 2006:27; Mundaca, 2007a:4349), these benefits are obtained only by end-users who have implemented energy efficiency measures. Whereas low-income households have benefited substantially in GB (e.g. because some eligible measures are heavily subsidized) it remains to be seen how British obliged parties are actually passing compliance costs on to customers through energy bills. Prima facie, one could argue that investment costs could be equally distributed across all end-users. Therefore, cross subsidies may be occurring and low-income households that have *not* implemented measures could be facing an unfair – albeit marginal – financial burden.[25] This would be paradoxical, as TWC schemes are also implemented to reduce 'fuel

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[23] This estimation is performed setting aside projected GHG emissions by 2010 from those countries contained in the model but that are not part of the EU15 Kyoto target, in particular Switzerland (49.8 Mt CO_{2-eq}), Norway (67.4 Mt CO_{2-eq}), and Iceland (4.5 Mt CO_{2-eq}).

[24] The burden of compliance costs is related to many design elements, in particular, how the target is apportioned; the type of responsibility held by obliged parties; the mechanism(s) to recover investment costs; and the eligible sectors in which eligible measures can be implemented. When the author interviewed obliged parties in GB, he found that the financial responsibility on end-users was a key driver for parties to legitimate or accept the scheme.

[25] In general, end-users under TWC schemes can lose because of higher energy prices and corresponding lower energy demand that result from the cost recovery mechanism (NERA, 2005).

poverty' (see below). In general, it could be thus argued that distributional effects of TWC schemes may be regressive if the net benefits represent a larger share of the income of the rich than of the poor. Therefore, for TWC schemes to have progressive effects, low-income households should be properly targeted or safe-guarded as far as a cost recovery mechanism is concerned.

In terms of co-benefits, attention must be given to the potential ancillary effects that TWC schemes can bring/trigger at the local/national level because of increased energy efficiency. When the early experience of current TWC schemes is analysed, the following potential co-benefits are identified:

a) *Scheme boosts competitiveness and employment generation*: According to the European Commission (2006b), increased energy efficiency is one of the most effective ways to foster competitiveness of the EU industry. A number of studies show that increased energy efficiency has direct or indirect positive effects on employment generation (cf. Levine et al., 2007). It is estimated that by saving 20% of its energy consumption by 2020, 1 million of high-quality new jobs can be created in Europe (European Commission, 2005:5). ESCOs and related businesses; which are argued to be highly labour-intensive can be, in principle, encouraged by TWC schemes (cf. Bertoldi and Rezessy, 2006; Capozza et al., 2006). The emerging market for ESCOs in Europe is estimated to be worth 5–10 billion Euros per year (European Commission, 2005:4.).[26]

b) *Scheme reduces 'fuel poverty'*. Due to the fact that household energy consumption is income inelastic, the poor shoulders a heavy burden. To confront this situation, the British scheme supports the 'Fuel Poverty Strategy', which aims to reduce the number of households that spend more than 10% of their income to satisfy energy needs (DEFRA & DTI, 2005).[27] This means that obliged parties must achieve at least 50% of their energy savings in the so-called 'Priority Group'; defined as households that receive certain income-related benefits and tax credits (OFGEM, 2005:4). During the EEC1, parties met this requirement by achieving 42 TWh of savings in the priority group — against 32 TWh required (OFGEM, 2005, 2005:9). During the first phase of British scheme, mostly low-income households were benefited (OFGEM, 2005).

c) *Scheme encourages technological market transformation.* Early evidence from GB shows that a TWC scheme – acting within a portfolio of policy instruments – can stimulate a higher diffusion of matured efficient technologies.[28] Obliged parties have worked with manufacturers and retailers of energy efficiency products to meet their obligation by setting commercial strategies to increase the market share of more efficient technologies (Mundaca, 2007a; NERA, 2006). While not boosting technological innovation, higher competition on energy efficiency technologies has driven a reduction of production costs and thus market prices for some eligible measures in real terms (Lees, 2006); giving indications of learning curve effects.[29]

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[26] Despite these theoretical claims, the specific market development of ESCOs under current TWC schemes remains uncertain so far, in particular in the household sector. On the one hand, ESCOs are allowed to create and trade TWCs under the Italian scheme and the Authority had already accredited more than 550 ESCOs by May 2006. However, due to the fact that the Italian scheme has a broad and less stringent definition of ESCOs, most of these actors can actually be considered mostly as providers of energy efficient equipments rather than ESCOs as such — generating free-riding effects. According to the Authority, only a small fraction (ca.<2%) can be considered 'real' ESCOs if a more stringent definition is used. On the other hand, the British scheme promotes 'energy service actions' (i.e. where an energy audit for the whole house is carried out and at least two measures are installed) instead of ESCOs as such. To promote energy service actions, the regulatory framework grants obliged parties an extra credit of 50% from the total savings realized. ESCOs – albeit not defined – are in principle eligible to realize savings but the regulatory framework does not allow them to trade realized savings. ESCOs that want to participate in the British scheme are dependent on the demand of the few obliged parties and are restricted to projects in the household sector; which is likely to be less attractive than the industrial and offer higher transaction costs. Thus, the ESCO activity in GB has shown little dynamism until now. It has also been claimed that some legal aspects (e.g. the rule that allows end-users to switch suppliers with a 28 days' notice) hamper the provision of energy services under the British scheme (DEFRA, 2004:11).

[27] It was estimated that by 1996, approximately 20% of all households in the UK were living in fuel poverty (Levine et al., 2007). The *Family Expenditure Survey* in the UK (2000/2001) showed that whereas the top quintile of income distribution spends 1.9% of its total expenditure in gas and electricity consumption, the bottom quintile spends 6.1%.

[28] For instance as a result of the British scheme, the insulation industry has faced an enormous demand that led to a shortage of material for loft insulation by the end of first phase (DEFRA, 2007:12). In fact, depending on the saving target imposed during the third phase, fears that the insulation industry might not be able to meet the demand exist so much more investment in capacity is needed (e.g. by a factor of 2 if>3 million cavity wall insulation installations are demanded as a result of the imposed saving target). For further details see DEFRA (2007).

[29] Notice that the British scheme was built upon the Energy Efficiency Standards of Performance programme (EESoP) that ran from 1994 until 2002.
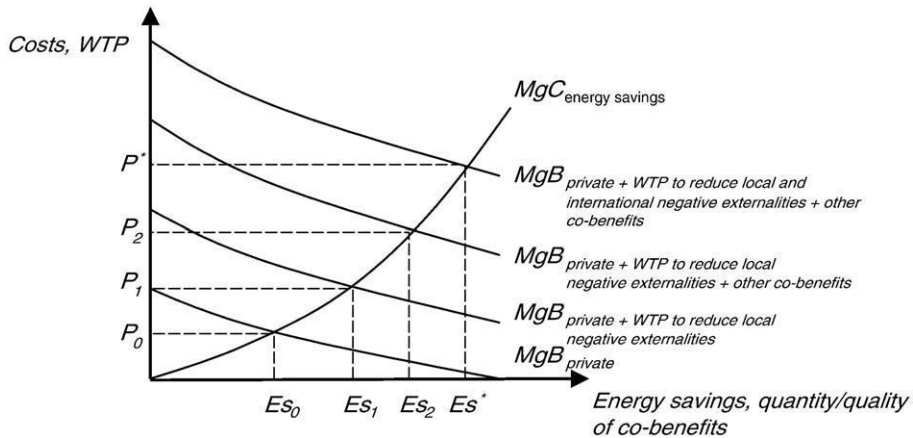

Fig. 7. Different levels of energy saved if private benefits and social co-benefits of increased energy saving are considered when an EU-wide TWC scheme operates. MgB = marginal benefits; MgC = marginal costs; and WTP = willingness to pay. From the private perspective (households), the market is able to deliver a relative low energy saving level, Es_0. If WTP for local environmental benefits (e.g. reduced local air pollution) is considered, a higher level is observed, Es_1. Then, if other local co-benefits are taken into account (e.g. improved comfort level, increased energy security), the level increased up to Es_2. Adding up international environmental benefits (e.g. reduced impacts of climate change), a global societal optimum level of energy saving is observed, Es^*.

d) *Scheme reduces atmospheric pollution.* Perhaps one of the most re-called ancillary benefits of TWC schemes is the avoidance of negative environmental externalities. Public health and the environment greatly benefit from reduced air pollution. The British scheme determined that its primary objective is to reduce carbon emissions from the household sector. Emissions reductions resulting from eligible measures under the first phase of the British scheme equated 0.4 MtC/year (DEFRA, 2006:1). Considering total UK CO_2 emissions to be ca. 150 MtC/year; of which household emissions contribute 40 MtC/year, the achieved emission reductions represent ca. 1%. As show in section 4.1.3, realized energy savings allows substantial reductions of atmospheric pollution upstream in the EU15+ energy system.

e) *Scheme improves the housing stock and comfort level.* TWC schemes can stimulate retrofitting of the existing housing stock and/or the construction of new buildings to standards superior than required under current regulations; which can also increase their commercial value. Furthermore, energy efficiency buildings can generate better comfort levels (e.g. though improved thermal conditions, reduced noise levels, etc.) that can lead to improved health and productivity (Leaman and Bordass, 1999; Jacob, 2006; Levine et al., 2007).

f) *Scheme increases security of energy supply.* This is another of the multiple policy objectives that TWC schemes attempt to support (cf. Bertoldi and Rezessy, 2006; Capozza et al., 2006; Langniss and Praetorius, 2006; Oikonomou et al., 2007). It is forecast that the EU25 will be 90% reliant on oil imports by 2030 (European Commission, 2005:5). Bearing in mind how critical security of supply is for securing ever-increasing energy demands, increased energy efficiency – triggered by a TWC scheme – can reduce imports of fossil fuels and improve the balance of payments. In this study, modelling results show a reduction in fossil fuel imports from 1% to 3% (or 15–41 Mtoe) by 2020 compared to the baseline.[30]

The findings listed above clearly suggest that if co-benefits are taken into account, a higher level of energy saving is encouraged and the economic attractiveness of an EU-wide TWC scheme increases (see Fig. 7). While ancillary benefits might be realized anyway, the key issue is how they may be distributed. In very simple terms, let us assume that two countries, A and B, implement TWC schemes that allow obliged parties to trade

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[30] In relation to energy security, realizing energy efficiency potentials can also reduce financial investments in new energy supply systems. It could be argued that TWC schemes can free up financial resources designated to replace or generate new energy capacity (cf. Capozza et al., 2006; Farinelli et al., 2005). For instance, the French TWC scheme aims to reduce investment in grid connection. As certain regions (e.g. Corsica) show high distribution losses, energy savings are greatly encouraged to reduce future investments in grid capacity (Monjon, 2006). In regions like this, energy savings are granted with a default multiple factor of two.

certificates internationally to meet their targets. Let us also assume that country B yields energy savings with lower marginal costs than country A. The latter thus purchases TWCs from country B and eventually meets its national target. Here, one can easily infer that local ancillary benefits cannot be obtained in country A when international trading operates, simply because energy savings, and thus the supply of cost-effective TWCs is concentrated in country B. Among many factors, the demand for and supply of TWCs are very likely to differ because countries have different cost- effective potentials; level of market barriers and imperfections; performance of the portfolio of policy instruments; and accessibility, variety and costs of measures capable of yielding those potentials.

5. Discussion

The order of magnitude of the economic and energy outcomes depended heavily on the level of ambition expressed by the applied energy saving targets. Basically, this confirms policy aspects regarding the timing and speed of the market transformation required to cope with different levels of mandatory energy saving targets. In all cases, the energy saving targets applied are technically met, with the household sector, gas and space heating representing the main supply of TWCs per eligible sector, fuel, and energy service demand, respectively. The results were consistent for each case analysed (i.e. per end-use sector/fuel/energy service demand/time-step) regardless of the variations in energy saving targets. If externalities are considered, the results also indicate that a TWC scheme could support the realization of techno-economic cost-effective potentials up to 30%; which are consistent with figures for household and commercial sectors included in the 'European Action Plan for Energy Efficiency' (see European Commission, 2006b:5–6). These aspects seem to point out the robustness of the model. Taking the figures with caution, the results suggest that the cumulative energy saving target of 9% proposed by the EEE&ES Directive could be achieved cost-effectively by means of an EU-wide TWC scheme. In turn, this means that EU policy makers could aim for a more ambitious saving target.

In environmental terms, the results confirms that increased energy efficiency, in this case achieved by a TWC scheme, is a sound policy option for reducing GHG emissions at zero or negative costs — the savings alone can cover the costs. Unlike the energy-related results, reductions of GHG emissions appeared to be less sensitive to the energy saving targets imposed until 2010. As most reductions occur upstream in the energy system, the results confirm some aspects as far as potential linkages between a TWC scheme and the EU Emission Trading Scheme (EU-ETS) are concerned. On one hand, CO_2 emissions from power production are already covered under the EU-ETS. On the other hand, electricity savings resulting from a TWC scheme frees up allowances on the supply side creating, in principle, certificates in two different markets.[31] For instance, this can trigger free-riding effects in the EU-ETS if electricity related emission reductions due to a TWC scheme are not taken into account in GHG national allocation plans. Likewise, the result confirms the issue of 'double counting' that electricity savings create if both a TWC scheme and the EU-ETS are formally pulled together for environmental purposes; which can hamper the environmental integrity of the EU-ETS scheme, and may distort the actual performance of the two markets (cf. Bertoldi and Rezessy, 2006; Capozza et al., 2006; NERA, 2005). In all, claims about GHG emission reductions from electricity savings under a TWC scheme become technically complex in the presence of the EU-ETS.[32]

Regarding equity, some key policy aspects need to be considered when discussing an EU-wide TWC scheme. If the key policy goal is to increase energy savings at least-possible cost, cost-effectiveness can be taken as the key criterion and international trading is much more advantageous. A European TWC market increases substantially the number of eligible parties – a key condition for high market liquidity – and reduces the risks of market power because a high concentration of the obligation in only one party is less likely.[33] In turn, this reduces the risks of creating monopolistic or monopsonistic market conditions. On the other hand, one can assume that EU Member countries that, inter alia, offer high cost-effective potentials, fewer market barriers and imperfections can probably benefit most from the distribution of ancillary benefits that a TWC scheme can trigger. Thus, the location of TWC supply – and thus local ancillary benefits –

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[31] An offset value can be attached to a TWC; which can be estimated by a carbon emission conversion factor given by the electricity mix.

[32] See Bertoldi and Rezessy (2006) and NERA (2005) for more on interactions between TWC schemes and the EU-ETS.

[33] Looking at national TWC schemes, market power is likely to arise in Italy and France. In the former, ENEL holds 90% of the apportioned electricity saving obligation during the first compliance year. For the latter, EDF holds 55% of the total obligation (30 out of 54 TWh) for the entire compliance period.

is likely to be concentrated in countries that have been less committed historically to increased energy efficiency. Thus, this would imply a disadvantage for 'efficient' EU countries, raising a variety of policy questions; for instance, would end-users from country-A be willing to afford, via higher energy tariffs, energy efficiency improvements in country-B? Can financial gains from an EU-wide TWC scheme be higher than the reduction in local/national welfare? How can ancillary benefits embedded in national TWC schemes be secured when an EU-wide TWC scheme operates? Would there be any interest in supporting national implementation of energy efficiency measures that are not necessarily cost-effective but yield attractive co-benefits? Recent studies have given indications that a 'national autarky' approach may be adopted to guarantee that co-benefits of increased energy efficiency are captured nationally (see Adnot et al., 2007; Mundaca et al., in press). In addition, experience in GB shows that obliged parties pay great attention to commercial co-benefits of non-trading (e.g. increased competitiveness); which also reinforces an autarky compliance approach (Mundaca 2007a; Mundaca et al., in press). Whereas it still remains to be seen whether this approach is an optimal choice for obliged parties, these aspects seem to support the hypothesis that the policy choice gets complex because of the trade-off between cost- effectiveness and equity. One could also argue though that an EU-wide TWC scheme could help reduce the gap between the most- and less-developed EU Member countries. Given transparent and fair cost- recovery mechanisms, welfare gains could take place where they are most needed. Furthermore, equity should be a relevant evaluation criterion if income disparities increase within the EU due to its enlargement.

As far as the implications of the results to the assumptions of this study are concerned, some key policy aspects and conditions need to be mentioned. First, the theoretical benefits presented in this study should not underestimate the challenges associated with getting a TWC scheme to work effectively. While this work indicates that an EU-wide TWC scheme is a plausible policy instrument from the economic and environmental standpoint – although challenged by distributional equity – implementing it successfully can be a demanding task. Experience shows that the whole process of designing, negotiating, and operating a TWC scheme is not trouble-free (cf. Capozza et al., 2006). Target compliance depends on many factors, among them, a functioning and enforceable regulatory framework. Furthermore, a crucial assumption is the harmonization of current national frameworks that would allow the operation of an EU- wide TWC scheme. However, one could expect that this task is likely to be cumbersome for policy makers before the scheme is put in place. Examples could relate to agreements on target level; eligible parties, sectors and measures; non-compliance systems; additionality; and M&V approaches.[34]

Second, the successful performance of any TWC scheme also depends on the actual range of eligible measures, transaction costs (TCs), and the rebound effect. Whereas the modelling exercise assumes that all relevant technologies are in fact eligible, in practice the definition and due enforcement of additionality may have a significant impact on the portfolio of measures, and thus the extension of the estimated cost-effective potentials. The broader the set of eligible measures, the more flexibility is given to parties to yield energy saving potentials. However, a larger set could in practice trigger free-riding effects and higher TCs resulting from M&V activities. As previously mentioned, this study assumes low or zero TCs; unlikely to hold in practice. Analysing the first phase of the British TWC schemes, it was found that the scale of TCs borne by obliged parties ranged from 8–12% to 24–36% of total investment costs for lighting and insulation measures respectively (Mundaca, 2007a:4348). Interestingly, to the surprise of many, while the scale of TCs can be heavy for obliged parties, the scheme still generated net financial and economic benefits for the British society. However, the experience in GB should not be extrapolated to the case of an EU-wide TWC scheme because the nature and scale of TCs are very case- and context-specific (Mundaca, 2007a,b). For instance, the design coverage of the modelled EU-wide TWC scheme is much larger that the coverage of the British scheme; which covers only one eligible sector, a handful of eligible technologies, an ex-ante M&V approach, and only 8 obliged parties. To support this modelling work, the experience in GB stresses the importance of several policy measures for reducing TCs; in particular by increasing awareness among end-users, encouraging project bundling, standardizing trading contracts, and developing ex-ante M&V approaches whenever possible, among others.[35]

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[34] For instance, comparing ex-ante M&V approaches used in current TWC schemes, one can observe substantial differences even if well understood technical eligible technologies are considered. For instance, lifetime savings attributed to a CFL can range from 100 to 330 kWh. Assumptions driving this wide rage of estimates are, for instance: different discount rates (from 3.5 to 6%), different lifetimes (from 6 to 14 years), and usage (or not) of 'comfort taking' factors (cf. Capozza et al., 2006:140).

[35] For detailed policy measures for reducing transaction costs, see Mundaca and Neij (2007).

When it comes to the so-called rebound effect, the modelled EU-wide TWC scheme shows no sign of it. However, this is due to the nature of the modelling approach rather than an outcome accredited to the modelled TWC scheme as such, i.e. because the mandatory energy saving targets were imposed as a 'cap' or 'constraints' in terms of maximum allowed final energy consumption. For the household sector, the direct rebound effect is likely to be around 30% and may be lower in the future due to saturated energy demand (see Greening et al., 2000:398; Sorrell, 2007:36-39). Whereas concerns about the rebound effect are valid for any instrument targeting energy efficiency, it is worth noticing that empirical evidence shows that the rebound effect is likely to be small — in the range of 0 to 15% (Berkhout et al., 2000:425).[36] In any case, both the rebound effect and TCs indicate that the estimated cost-effective potentials under this study are overestimated (e.g. societal cost-effective potential is reduced up to level of ca. 22% by 2020).

Third, this study assumes that fewer market barriers and imperfections facilitate the penetration of eligible energy efficiency technologies because the modelled TWC scheme is supported by high effectiveness of economic and informative policy measures. To support this set of assumptions (including different discount rates), it is relevant to stress that complementary policy measures that support TWC schemes to restructure consumer market decisions, can help solving irrational consumer choice that may explain high implicit discount rates. Although not explicitly included in the design of TWC schemes, a variety of policy measures should be implemented/encouraged to reduce or eliminate market barriers and imperfections that hamper a more rational behaviour of end-users towards the implementation of efficient technologies. Analysing the early experience of national TWC schemes, the following complementary policy measures also appear to be critical for their successful performance:

- Uncertainties and risks about technical and financial performance are reduced for end-users because of information provided by equipment manufacturers/dealers, obliged parties, ESCOs, and public authorities;[37]
- Transaction costs for obtaining reliable information are reduced for end-users due to fact that information gathering and the learning process about the functioning of new technologies is organized and facilitated by obliged parties (also contractors working on their behalf), retailers, ESCOs, and information centres providing specific and practical information about new technologies;
- More and cheaper energy efficiency equipment is available in retail stores because obliged parties and retailers work together to target end-users, leading to an eventual aggressive marketing campaign and thus increased awareness among end-users;
- Low-income households have more access to capital because of supportive financial mechanisms set by obliged parties and public authorities for eligible measures in which incremental costs are high;
- End-users are keen to implement new technologies because some of them are entirely or partly subsidized by obliged parties or governmental programmes;
- Increased awareness amongst end-users exists because of large information campaign launched by public authorities about the individual and societal benefits of increased energy efficiency as well the functioning of a TWC in particular. In turn, this reduces transaction costs for obliged parties in relation to their search for customers willing to implement measures.

One can observe that informative instruments form a substantial part of this identified mix of complementary policy measures. Therefore, the assumptions related to the high effectiveness of informative policy instruments (as presented in Section 3.2) seem to be crucial policy conditions for an EU-wide to deliver the estimated cost-effective potentials under this study. Then, the uncertainty and performance concerning these policy measures should be a relevant element in the policy formulation leading to an EU-wide TWC scheme.[38]

6. Concluding remarks

The objective of this paper was to analyse the potential implications of implementing an EU-wide TWC scheme based on three evaluation criteria: cost-effectiveness, environmental effectiveness and distributional equity. It is concluded that an EU-wide TWC scheme appears to meet the criteria for cost- effectiveness and

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[36] The experience in GB indicates that approaches such as 'comfort taking' factors can be used to counteract the direct rebound effect.

[37] However uncertainties about the exact the financial benefits continue existing because of some inherent degree of uncertainty related to future energy prices (i.e. operating costs of eligible energy efficiency measures).

[38] For a detailed package of policy recommendations to assess, implement and operate TWC schemes, see Mundaca and Neij (2007).

environmental effectiveness and assuming full compliance with energy saving targets. Quantitative results suggest that acting in portfolio of instruments, an EU-wide TWC scheme can largely contribute to realize cost-effective energy saving potentials in the household and commercial sector. Adding social and environmental benefits of energy saved, the choice for a TWC scheme is strengthened and the level of energy saving increases. To be equitable, the costs of energy savings should be borne by those who benefit from increased energy efficiency. As there are many potential co-benefits countries may oppose to an EU-wide TWC scheme in order to capture these benefits nationally, i.e. a national autarky strategy that attempt to maximize net present welfare without international trading.

The assumptions undertaken by the modelling approach strongly indicate that high effectiveness of complementary policy instruments is needed for an EU-wide TWC scheme to deliver cost-effective energy savings. On one hand, informative policy instruments are required to reduce uncertainties and transaction costs and support related technological learning processes. On the other hand, economic policy instruments that provide adequate capital are critical to support the needed investments in new efficient demand technologies. From the evaluation standpoint some limitations of the modelling approach stress the challenging task of developing a credible baseline, especially if an explicit and wider representation of co-benefits is desired. However this should be considered part of the evaluation problem, not a deficiency of the modelling tool. Thus, further research is needed and variety of research methods (e.g. multi-criteria assessment combined with triangulation approach) should be used to yield a more definite answer about whether an EU-wide TWC scheme is the right policy choice.

This study leads us to some further research and policy questions: how to build a realistic counterfactual situation that reflects the current portfolio of policy instruments in the absence of a TWC scheme? Then, under which market and policy conditions can an EU-wide TWC scheme achieve a given energy saving target with lower or higher costs than other policy instruments? Is it realistic to think about an optimal and dynamic portfolio of energy efficiency policy instruments under different levels of uncertainty and heterogeneity for the EU context?

Acknowledgements

Appendix A. Further modelling aspects and data sources

A.1. Pre-modelling steps

The PRIMES[39] energy system model was used as a benchmark to evaluate the robustness of key modelling outcome parameters such as primary energy supply, energy intensity, CO_2 emissions, final energy consumption, etc. As a result of this exercise, only marginal differences in absolute values were found and both models generated similar trends for the analysed period (2000–2020).[40] Differences in absolute values were largely explained by the fact that both models have slightly different geographical coverages.

To assess the consistency and completeness of the technological database of the EU15+ MARKAL model, two databases were used as benchmarks: MURE[41] and ICARUS[42]. These databases are mostly devoted to

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[39] More details about PRIMES can be found at http://www.e3mlab.ntua.gr/manuals/PRIMsd.pdf.
[40] Notice that the PRIMES model was successfully peer-reviewed by the European Commission in 1997–1998.
[41] MURE contains ca. 50 detailed measures types for the household. These measures are grouped into larger categories and subcategories. For further information visit http://www.isis-it.com/mure/.
[42] For further details see Alsema (2000).

energy saving measures. This important pre-modelling step resulted in two relevant aspects: a) for technologies included horizontally in all the databases, basically marginal differences were found in the following parameters: lifespan, technical efficiency, investment costs, and operation and maintenance costs, and b) despite the fact that MURE and ICARUS are databases extensively developed to depict energy saving measures, around 30 (out of a couple of hundred) were not identified in the MARKAL EU15+. Certainly, the inclusion of these measures could alter the results and should be taken into consideration.[43]

A.2. Other modelling assumptions

Building a plausible counterfactual situation is always a challenging task for the evaluator — an intrinsic evaluation difficulty (cf. Frondel and Schmidt, 2001; Ellerman, 2003; Tietenberg, 2006). In addition to the assumptions described in Section 3, different discount rates were used to calculate life cycle costs of energy savings resulting in the household and commercial sectors. Compelling evidence shows that households use implicitly high discount rates (e.g. up to 90% and even much higher) that hinder the adoption of efficient technologies; thus, setting greater hurdles than for conventional technologies (see Hausman, 1979; Gately, 1980; Train, 1985; Rudermand et al., 1987; Lutzenhiser, 1992; Jaffe and Stavins, 1994a,b; Metcalf, 1994; Howarth and Sanstad, 1995). Depending on the income class[44] and for the specific case of the household market behaviour, implicit discount rates have been analysed and estimated in a number of studies:

- Train (1985) found that average implicit discount rates in household purchase decisions for efficient equipments range between: a) 10 to 32% for insulation; b) 4 to 36% for space heating, b) 3 to 29% for air conditioning, and d) 18 to 67% for other appliances (e.g. water heating, cooking).
- Hausmann (1979) found average implicit discount rate of 25% for air conditioners (range between 9 to 39%).
- Gately (1980) estimated rather high implicit discount rates for efficient refrigerators, ranging from 45% up to 300%.
- Dubin and McFaden (1984) estimated an average discount rate of 20% for water- and space-heating measures.
- Sutherland (1991) notes that energy efficiency appliances appear to entail very high discount rates, say 50% or higher.

Taking into account the above-mentioned studies/figures, a relatively high but conservative discount rate (30%) is used as proxy for capturing, ceteris paribus, the inadequate diffusion of energy efficiency technologies applicable to the household and commercial sectors when running the model to determine to overall counterfactual situation. In fact, it is argued that high discount rates can be taken as an indication of the presence of market failures (e.g. Sanstad and Howarth, 1994; Howarth and Sanstad, 1995), with transaction costs also playing a significant role in explaining the divergence (e.g. Jaffe and Stavins, 1994a,b; Howarth and Sanstad, 1995; Mundaca, 2007a). The use of different discount rates in this modelling exercise attempts then to capture the so-called 'energy paradox' of slow diffusion of cost-effective energy efficiency measures (Jaffe and Stavins, 1994a,b; Johnson, 1994; Metcalf and Hasset, 1999).[45] While not exhaustive, according to a number of authors potential causes of high discount rates used by households can be: a lack of information about cost and

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[43] For further details see Mundaca and Santi (2004).

[44] Hausmann (1979) and Train (1985) also argue that implicit discount rates vary inversely with income class. In fact, Train (1985) argues that the relationship between low-income class and high implicit discount rates can be explained partly because low-income households have less access to capital markets and less liquid capital to invest than higher income class households. Thus, even in the presence of good information about investment returns, lower incomes households will still be unable to invest in efficient technologies if complementary economic instruments are not in place.

[45] In this regard, notice that it has long been debated whether the difference between social and private discount rates can be attributed to market imperfections (see, for instance, Reddy, 1991; Jaffe and Stavins, 1994a,b; Sanstad and Howarth, 1994; Scheraga, 1994; Howarth and Sanstad, 1995; Anderson and Newell, 2002). For instance, it is argued that the difference exists not just because of market imperfections but also because consumer behaviour is hampered by institutional and regulatory structures (Scheraga, 1994). In fact, Sutherland (1991) argues that household investments in energy efficiency appliances might correctly imply high discount rates because these investments are illiquid, risky and face high transaction costs. However, Morgenstern and Al-Jurf (1999) conclude that information programmes positively affect the diffusion of efficient technologies. Despite the fact that high implicit discount rates have been the most common and mentioned evidence for inefficient consumer behaviour (Huntington, 1994), the debate still continues (see Anderson and Newell, 2002). This surely indicates that much more research is needed on behavioural aspects driving choices about energy efficiency technologies.

benefits of efficiency improvements; lack of knowledge about how to use available information; uncertainties about technical performance of investments; lack of sufficient capital to purchase efficient products (or capital market imperfections); income level; high transaction costs for obtaining reliable information; risks associated to investments; etc. (e.g. Rudermand et al., 1981; Train, 1985; Suttherland, 1991; Gates, 1983).[46] With due caution, this discount rate is reduced (10%) when running the model for the different energy saving targets that are analysed. A lower discount rate is thus used as a proxy to represent consumer behaviour in the event of market barriers and imperfections being reduced or eliminated (cf. Train, 1985; Johnson, 1994; Metcalf, 1994) because of the implementation of an EU-wide TWC scheme and complementary economic and informative policy instruments (see discussion section). In all, the larger the difference between the upper and lower bound of discount rates, the larger the saving costs (e.g. if one decides to use an upper rate as high as 50–60% as found in the literature and a lower bound of 6% as used during the first phase of the British scheme). Thus, the chosen and narrowed range of discount rates is meant to yield conservative estimates of energy saving costs.[47] To support this specific assumption of the modelling exercise, notice that Farinelli et al. (2005) and Oikonomou et al. (2007) also introduce different discount rates for modelling TWC schemes.

A.3. Estimated negative externalities

For the specific case of external costs, data generated from the EU ExternE Project were used to approach the potential benefits for the EU15+ society of reducing atmospheric pollutants resulting from the modelled EU-wide TWC. Only the minimum and maximum European values of external costs per different fuel cycles were used (see Table A 1). These figures represent the costs for society resulting, for instance, from negative impacts on human health (mortality, morbidity), loss of amenities, and the impacts of global warming (European Commission, 2003). These values were applied to the electricity mix generated during each time step in the base case to estimate lower and upper bounds of negative external costs.

Table A1
Estimated external costs

Electricity fuel selection	External costs by source[a]		Electricity mix by source– baseline EU15+				External costs by source according to electricity mix							
	Lower bound	Upper bound					Lower bound				Upper bound			
			2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020
	€cents/kWh		%				€cents/kWh				€cents/kWh			
Gas	1	4	16%	22%	24%	28%	0.16	0.22	0.24	0.28	0.62	0.89	0.97	1.14
Oil	3	11	7%	5%	4%	4%	0.20	0.15	0.13	0.11	0.72	0.54	0.46	0.41
Coal	2	15	19%	18%	19%	18%	0.38	0.36	0.37	0.36	2.82	2.70	2.78	2.69
Nuclear	0.2	0.7	34%	31%	30%	28%	0.07	0.06	0.06	0.06	0.24	0.22	0.21	0.19
Hydro	0	1	22%	21%	21%	20%	0.00	0.00	0.00	0.00	0.22	0.21	0.21	0.20
Wind	0	0.2	1%	1%	1%	1%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar	0	0.6	1%	1%	1%	1%	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Biomass	0	3	0.2%	0.2%	0.2%	0.2%	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Total			100%	100%	100%	100%	0.80	0.79	0.80	0.81	4.64	4.57	4.63	4.64

[a]Data source: European Commission (2003:13).

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[46] In terms of some socio-economic explanations for high implicit discount rates, the ownership status is regarded as a relevant cause (Train, 1985). In this specific case, it is worth noticing that the cause related to ownership status has been found to be a significant barrier in the British TWC scheme. Indeed, the so-called *split-incentive problem* was identified because tenants were reluctant to implement measures because they might move out before realizing the financial saving (Mundaca, 2007a).

[47] Notice that there is not yet empirical information as regards the reduced level of implicit discount rates of householders resulting from a TWC scheme and complementary policy measures.

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Paper III

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Transaction costs of Tradable White Certificate schemes: The Energy Efficiency Commitment as case study

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Abstract

This paper analyses the nature and scale of transaction costs (TCs) borne by obliged parties under a "Tradable White Certificate" (TWC) scheme. Taking the first phase of the Energy Efficiency Commitment (EEC1) in Great Britain as a case study, several sources of TCs were considered, such as search for information, persuasion of customers, negotiation with business partners, and measurement and verification activities. Information was obtained through interviews and a questionnaire distributed to obliged parties. Results show that the most significant sources of TCs were related to search for information, persuading customers and negotiating with managing agents/contractors to implement energy efficiency measures. Perceived high TCs related to contract negotiation and liability risks slightly reduced the low trading level. The scale of TCs was estimated to be around 10% and 30% of total investments costs for the lighting and insulation segments, respectively. The results indicate that, despite the presence and scale of TCs, the EEC1 scheme generated energy savings that yielded net societal benefits. Estimated financial benefits range from 0.6 to 6 p/kWh for insulation and lighting savings, respectively. When avoided external costs due to electricity savings are included, estimated economic benefits range from 3 to 8 p/kWh. Several lessons from the EEC1 can be drawn for TWC schemes. Among others, it is found that informative policy instruments to raise awareness among end-users are critical if a TWC scheme is to deliver cost-effective energy savings. In all, the nature and scale of TCs under TWC schemes will differ because of a number of endogenous and exogenous determinants.
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Keywords: Energy efficiency; Tradable White Certificates; Transaction costs

1. Introduction

Greater energy efficiency plays a fundamental role in achieving a sustainable energy future. The continuous oil price escalation, increased awareness of the need for energy security, and energy-related environmental problems—including the threat of human-induced climate change—are all contributing to a reassessment of rational energy use. As the policy debate focuses more on achieving greater energy efficiency across all end-use sectors, the key challenge for policy makers is to choose the right portfolio of instruments to address institutional and market barriers and imperfections.

Recently, much more attention has been given to the role of marketable certificates for achieving higher energy

efficiency. Some European Union (EU) member states (France, Italy, the United Kingdom [UK][1]) have implemented tradable certificate[2] schemes to improve energy efficiency in end-use sectors (so-called "Tradable White Certificates" [TWC]), and other countries (e.g., The Netherlands) are exploring possible design options. A TWC scheme involves achieving a mandatory energy-saving target against the "business-as-usual" scenario. Obliged parties (e.g., energy distributors or suppliers) are required to meet individual targets set by the government; one option is to trade certified energy savings, which encourages parties to seek market strategies for least-cost compliance. At EU level, the proposed Directive on "Energy End-use Efficiency and Energy Services"

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[1]With the exception of Northern Ireland: in other words, Great Britain.
[2]Note that in this paper the words "permit" and "certificate" are used interchangeably.

(EEE&ES), which includes an overall energy-saving target of 1% per year over 9 years, may trigger further implementation of TWC schemes and even prepare the ground for a future EU-wide TWC scheme (EC, 2006a). Addressing the European "Action Plan for Energy Efficiency", which indicates policies and measures for realizing a 20% estimated saving potential in EU by 2020, the European Commission highlights that the EEE&ES Directive enables the assessment of an EU-wide TWC scheme in 2008 (EC, 2006b).

Despite these developments, there has been little research regarding the performance of these new markets. Some general *ex ante* evaluations have been carried out (see Farinelli et al., 2005; Mundaca, 2006; Mundaca and Santi, 2004; Oikonomou et al., 2007; Oikonomou and van der Gaast, forthcoming), however transaction costs (e.g., search for information, due diligence, negotiation of contracts, measurement, etc.) have not being addressed in such studies so the cost savings involved must be taken with caution. The successful implementation and performance of any TWC scheme will undoubtedly depend, inter alia, on the effects of transaction costs (TCs).

There is empirical evidence from emission trading schemes that TCs can be significant and hamper the performance of these markets (e.g., Hahn and Hester, 1989; Atkinson and Tietenberg, 1991). According to Stavins (1995), TCs can make trading schemes less cost-effective. Montero (1997) argues that transaction costs and uncertainties reduce the level of welfare, making the post-trading outcome different from the least-cost equilibrium. Analysing the US lead permit programme, Kerr and Maré (1998) found that TCs can reduce between 10% and 20% of the potential gains from trade. Stressing the need for *ex post* evaluations, OECD (2002) suggests that much more research should be focused on the various forms of TCs affecting tradable permit schemes in general. In the case of TWC schemes, very little attention has been given to TCs. Their impacts are unknown and can negatively affect: (a) the planning and implementation of eligible energy efficiency projects (e.g., profitable eligible small-scale projects may appear unfeasible) and thus the creation of TWCs; (b) the efficient functioning of the TWC market; and (c) the overall performance of the portfolio of policy instruments aimed at increasing energy efficiency. The information gap is due to a lack of experience (except in Great Britain), which this paper attempts to fill.

Taking the first phase (2002–2005) of the Energy Efficiency Commitment (EEC1) in Great Britain as a case study, this paper analyses the nature and scale of TCs borne by obliged parties (i.e., energy suppliers) under a system comparable to a TWC. Although the EEC1 is not a certificate-based scheme as such, it gives energy suppliers the option to trade their obligations and achieved energy savings, making it fairly similar to a TWC scheme. The present study identifies and obtains data for the estimation of TCs, focusing on TCs borne by energy suppliers. TCs borne by beneficiaries of energy efficiency measures were not considered.

The focus of this study is to identify the nature of TCs during the EEC1. When possible, the scale of TCs was estimated. Taking into account these results, cost-effectiveness of energy savings was calculated, including financial and economic benefits. The study discusses whether TCs hampered the trading of energy savings during the EEC1. Based on these results, it draws some lessons for TWC schemes in general.

The methodology of the study is based on interviews and a questionnaire, supported by the review of official documentation and related studies. Key stakeholders involved in the EEC1 were interviewed in September and October 2005. This included the Department for Environment Food and Rural Affairs (DEFRA), the Energy Retail Association (ERA),[3] the Energy Saving Trust (EST), the Green Alliance, the Office of Gas and Electricity Markets (OFGEM), energy researchers, involved consultants, and energy suppliers that participated in the scheme. The main objective of the interviews was to identify the *nature* of TCs (i.e., sources of TCs). Interviews were complemented with a questionnaire distributed to energy suppliers addressing both the *nature* and *scale* of TCs. The level of response to our questionnaire achieved 25% of energy suppliers (2 out of 8) currently involved in the scheme and willing to participate. In turn, this sample represents 16.5 TWh or 27.2% of the delivered energy savings (ca. 60.6 TWh) compared to the target of 62 TWh. Considering a confidence level of 95%, the margin of error of the reported data for estimating the scale of TCs is 20%. Finally, telephone interviews with energy suppliers were carried out in March 2006 in order to supplement and deepen all the gathered information.

The structure of this paper is as follows. Section 2 gives a short overview of current TWC schemes, presenting key design elements and describing the EEC and the outcomes achieved during the first phase. Section 3 elaborates on the theoretical elements guiding this research in relation to TCs, energy efficiency, and TWC schemes. Sections 4 and 5 present the main findings. Taking into account the life cycle of TWCs, Section 4 discusses the nature of TCs and Section 5 shows the estimated scale of TCs of energy savings. Section 6 discusses the underlying issues related to the nature and scale of TCs under EEC1, drawing some general lessons learnt for TWC schemes. Conclusions are presented in Section 7.

2. TWC schemes

2.1. An overview

White Certificates are tradable certificates used in the field of energy efficiency. Under TWC schemes, the government sets an overall energy saving target to be met by obliged parties within a given time frame. To reduce compliance costs, obliged parties have the option to trade

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[3] ERA represents 75% of the obliged parties under the EEC.

certified energy savings. Obliged parties able to meet their target inexpensively become potential suppliers of TWCs on the open market; parties finding it expensive to meet their target can buy TWCs from other parties. The main argument for implementing TWC schemes is to equalize compliance costs among responsible parties. By imposing a mandatory energy savings target, a TWC scheme attempts to provide incentives to market agents to modify their behaviour (e.g., to use more efficient technologies to increase efficient energy use).

In general terms, the TWC life cycle involves *planning*, *implementation*, *measurement and verification* (M&V), *issuance*, *trading* (if needed), and *redemption* (see Fig. 1). As shown, the first three phases of TWC are rather inherent in the development of energy efficiency projects. To create or generate a TWC, an obliged and/or eligible actor has to plan, implement, and eventually measure and verify (M&V) energy savings. Once energy savings have been certified, TWCs are issued; parties can trade these to fulfil individual targets, banking them for future periods and/or directly redeeming certificates to prove compliance with their commitments. Once certificates are redeemed, they are no longer available on the market. While much of the attention related to TCs of TWC schemes is given to the *trading* phase, Fig. 1 attempts to stress the wider analytical framework that one must have as TCs can negatively affect the early stages of energy saving generation and so the creation of TWC.

There are currently three TWC schemes in place: in France, Italy, and Great Britain. The British scheme is not certificate-based but allows bilateral trade of savings and/or obligations. Other European countries have declared their interest in implementing TWCs. For instance, The Netherlands has started to design a scheme and has undertaken an *ex ante* evaluation (Oikonomou et al., 2007). TWC schemes are described in more detail, for instance, in Oikonomou (2004), Capozza et al. (2006) and Mundaca and Neij (2006). Key features of these schemes are presented in Table 1.

Table 1 clearly shows that TWC schemes vary in design among countries. Although the essence of any tradable
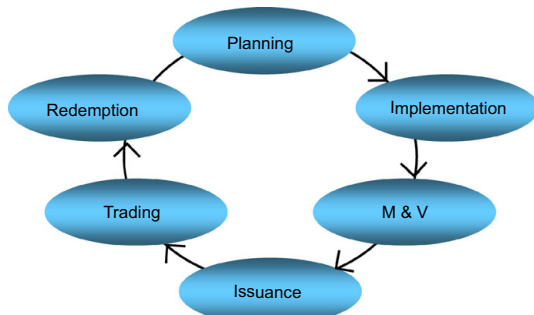

Fig. 1. Life cycle of TWC.

certificate scheme is the same (i.e., equalization of compliance costs), there are many variations in terms of, for example, obliged parties, eligible technologies, eligible energy carriers, and eligible technologies. The design features determine the coverage so careful design is one of the critical elements determining the successful implementation and performance of any TWC scheme.

2.2. Case study: first phase of EEC

The EEC1 imposes an obligation on gas and electricity suppliers to achieve mandatory energy savings targets for higher energy efficiency in the residential sector. The first phase, announced in March 2000, applies to Great Britain (GB) (i.e., England, Scotland, and Wales). The "Electricity and Gas (Energy Efficiency Obligations) Order 2001 No. 4011" is the legal basis for the EEC. The Act came into force on 15 December 2001. OFGEM is the authority responsible for administering and enforcing the EEC.

The EEC1 (April 2002–March 2005), which was aimed at electricity and gas suppliers with at least 15,000 domestic customers, involved achieving an energy saving target of 62 TWh. At that time, 12 energy suppliers were subject to the obligation: Atlantic Electric and Gas, British Gas, Cambridge Gas, Dee Valley, EDF Energy, npower, Opus Energy, Powergen, Scottish and Southern Energy, Scottish Power, Telecom Plus, and TXU Energi. Only obliged parties were allowed to participate in the trading of savings and/or obligations. The EEC1 did not allow third parties—other than governmental programmes—to be involved. While under the EEC1 trading was permitted, there was no "issuance" or "redemption" of certificates as such, as presented in Fig. 1. Instead, a "declaration" phase of energy efficiency measures was applicable. Registration, measurement, and verification apply to "qualified actions" that lead to energy savings. A penalty of up to 10% of turnover is imposed on suppliers failing to meet their individual target.

The EEC1 also had social goal. As household energy consumption is income-inelastic, the scheme supports the "Fuel Poverty Strategy".[4] In the UK, *fuel poverty* broadly occurs when a household spends more than 10% of its income to satisfy energy needs (OFGEM, 2005b). The strong social focus of the EEC means that at least 50% of the energy savings must occur in the so-called priority group, defined as "households that receive certain income-related benefits or tax credits" (OFGEM, 2005a, p.4).

DEFRA developed the "target-setting model" to determine energy savings attributed to eligible measures (OFGEM, 2005a). In this model, energy savings are expressed in fuel-standardized lifetime-discounted energy units. Some of the model parameters used to set the target are: assumed number of electricity and gas customers; domestic fuel mix; fuel prices; estimated number of

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[4]For more information about the Fuel Poverty Strategy, see DEFRA DTI (2005).

Table 1
Key design elements of existing European TWC schemes

	Great Britain[a]	Italy	France
Energy savings target	223 PJ (62 TWh)[b]	243 PJ (67 TWh)	194 PJ (54 TWh)[c]
Time frame	2002–2005	2005–2009	2006–2008
Obliged parties (actors that bear the obligation)	Suppliers of gas and electricity with more than 15,000 customers	Distributors of gas and electricity with more than 100,000 customers served	Suppliers of gas, electricity, LPG, heating, cooling, domestic fuels (not for transportation)
Eligible actors for trading (parties that can participate in TWC trading)	Only obliged actors and government related programmes. Sub-contracting is allowed	Obliged actors, ESCOs	Obliged actors, ESCOs and any economic actor able to achieve or bundle more than 1GWh in savings
Market size	12 suppliers covering 99% of the market	Around 24 distributors of natural gas, 10 distributors of electricity and more than 500 ESCOs	n/a
Eligible sectors (end-use sectors in which eligible measures can be implemented)	Only residential	All energy end-use sectors. At least 50% of the target has to be achieved through electricity and gas savings	All energy end-use sectors including transportation but excluding installations covered by EU emission trading scheme
Eligible technologies (measures that are subject to gain TWC)	An open list. Examples: Cavity wall insulation, loft insulation, fridge saver-type programme, condensing boilers, appliance replacement, CFL, tank insulation, etc.	An open list with ca. 14 categories. Examples: CFL, cavity wall insulation, micro CHP, solar heaters, high efficiency boilers, small PV applications, double glazing, appliances Low-flow water taps, etc.	An open list, with ca. 30 options for residential & commercial sectors, 10 for Industrial sector and 5 for transportation
Certificate-based scheme	No, but trading of savings and obligations is allowed	Yes	Yes
Penalty for non-compliance	A fine up to 10% of the supplier's turnover	Not explicitly defined but a fee that is proportional and in any case greater than investments needed to compensate the non-compliance	2 Euro cents per kWh

Source: Mundaca (2006).
[a]Features of the first phase of the scheme.
[b]Fuel standardized lifetime discounted (6%) energy savings.
[c]Lifetime discounted (4%) energy savings.

measures to be implemented; housing stock; current technological specifications; unit cost of measures; lifetime of measures; fuel carbon content; related carbon savings; and discount rate. The main steps carried out to determine the energy savings under the EEC1 were: (a) annual energy savings (kWh/year) were estimated on an *ex ante* basis, (b) energy savings were discounted using a rate of 6% and assumed lifetimes, and (c) fuel standardization of energy savings was based on kW_e input of different fuels and carbon content.

To meet the mandatory energy saving target, gas and electricity suppliers assisted customers with implementing a variety of energy efficiency measures, including cavity wall and loft insulation, fridge-saver-type programme, condensing boilers, appliance replacement, compact fluorescent lamps (CFL), and new and additional tank insulation. Suppliers could include other measures, subject to the

authority's approval. The mix of measures took into account information provided by energy suppliers, EEC-related industries, and research groups (e.g., Building Research Establishment).

With EEC1 completed, its outcomes can be briefly summarized.[5] In terms of *energy-effectiveness* (i.e., suppliers' ability to meet the energy-saving target), the EEC1 outcome was positive. Suppliers partnered with a number of actors to achieve their energy savings, working, for instance, with contractors on insulation measures, with retailers on appliances and white goods, and with social housing programmes (SHPs) for the delivery of CFLs. As a whole, obliged parties exceeded the target goal by achieving 86.8 TWh (OFGEM, 2005a). However, parties having an individual excess of energy savings banked (or

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[5]For a detailed evaluation of the EEC1, see Lees (2006).

saved) 25 TWh (from the 86.8 TWh) for the second phase of the scheme (OFGEM, 2005a, p.67). As the banking of savings was allowed, around 25% of the EEC2 target (i.e., 130 TWh) was met during the EEC1 (OFGEM, 2005a). This means that the amount of savings redeemed for the EEC1 was 61.8 TWh. In addition, with two energy suppliers going into receivership the actual amount of energy savings achieved for the EEC1 target was ca. 60.6 TWh (Lees, 2006, p.27), or nearly 2% less than the EEC1 target (OFGEM, 2005a, p.8).

In terms of implemented measures, the dominance of insulation is clear. If one considers total energy savings (i.e., 86.8 TWh), the contribution of cavity wall and loft insulation was around 56%, followed by lighting (24%), appliances (11%), and heating (9%) (OFGEM, 2005a, p. 11). For energy savings counting against the EEC1 target (i.e., 62 TWh), savings were achieved through insulation (38%), lighting (34%), appliances (16%), and heating (12%) (OFGEM, 2005a, p. 66). Cavity wall and loft insulation were installed in around one million households (OFGEM, 2005b). From the financial viewpoint, energy savings costs were obtained at 1.3 p/kWh of electricity and 0.5 p/kWh of gas (Lees, 2006, p. 7). Overall, energy savings were met cost-effectively with *ex post* average energy savings estimated at nearly 1 p/kWh (DEFRA, 2006, p. 1), 20% less than the figure originally predicted by the authority. As far as trading of energy savings is concerned, a low activity level was observed. This situation is further discussed in Section 6.

3. Transaction costs and TWC

Transaction costs (TCs) are a critical factor influencing not only many aspects of energy efficiency improvements but also the creation of TWCs and the performance of the TWC trading market. In analysing transaction costs in the field of energy efficiency, the early challenge is theoretical rather than empirical. The actual components of TCs in the context of energy efficiency have been debated, particularly in terms of differentiating among transaction costs, hidden costs, and production costs. See for instance Ostertag (1999) and Sanstad and Howarth (1994). While not wishing to discuss semantics here, my opinion is that TCs should be considered a subgroup of hidden costs and certainly not as part of the actual investment and administrative costs. To guide the identification of TCs, I use the definition given by Matthews (1986, p. 906): "… the costs of arranging a contract *ex ante* and monitoring and enforcing it *ex post*, as opposed to production costs."

Before addressing TCs for the specific case of TWCs, it is useful to state the conceptual elements regarding TCs in general. TCs for an investment involve any expenditure not directly involved in the production of goods or services but essential for realizing the transaction (Coase, 1960). Ménard (2004a) gives a complete review of the concept and components of TCs. Generally speaking, TCs are related to, for example, due diligence, search and assess-

ment of information, negotiation with business partners, measurement and verification.[6]

Regarding the specific case of increased energy efficiency, TCs can be related, for example, to searching and assessing equipment; negotiating agreements to carry out and enforce a contract; and M&V of the actual level of improvement. The literature on the theoretical aspects of TCs and their negative impacts on energy efficiency improvements is extensive (e.g., Reddy, 1991; Sanstad and Howarth, 1994; Sioshansi, 1991). The problems regarding imperfect and asymmetric information may prohibit the purchase of equipment that aims to increase end-use efficiency. It is argued that end-users face high costs to get reliable, cheap, and opportune information when buying more efficient technologies (Sioshansi, 1991) and that the presence of TCs can decrease the financial gains of increasing energy efficiency (Sanstad and Howarth, 1994). By making new measures seem more expensive than conventional ones, TCs can thus favour inefficient or standard technologies. For small-scale energy efficiency installations, high TCs can make potentially profitable investments completely unattractive. As TCs are present in the interface amongst market agents, they are often assumed to be part of the variety of market barriers undermining the further penetration of more efficient technologies (Painuly et al., 2003; UNDP et al., 2000).

In several studies that present quantitative estimations of TCs of energy efficiency projects, a number of determinants that affect the *nature*, *scale*, and thus the *burden* of TCs on energy efficiency projects are found. For instance, endogenous determinants involve the type, size, and performance of the measure; the level of accuracy and reliability of data sources; baseline and M&V methodologies; and project developers' and beneficiaries' level of awareness of TCs and of the need to account for them. Exogenous determinants include market, institutional and policy conditions, and the specific circumstances in which projects take place. The difference between the *burden* and the *scale* is of prime importance when analysing TCs. Whereas the scale of TCs can have a fixed or constant component regardless of the size of the project, the burden can decrease with larger amounts of savings. Thus, one can identify a direct negative correlation between the burden of TCs and the size/performance of energy efficiency measures. Related studies show, albeit not clearly, that there is a common understanding of these terms, as it is argued that TCs can become an unbearable burden for low-performing and/or small-scale projects. Some authors (e.g., Björkqvist and Wene, 1993; Michaelowa et al., 2003; Ostertag, 1999) conclude that it is the size and performance of a measure that ultimately determines the burden of TCs.

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[6]The concept of TCs has been largely developed by the New Institutional Economics (NIE), of which TCs analysis is a fundamental component. The NIE focuses on how decisions and transactions made by market agents are frequently based on imperfect and asymmetric information, and also on how institutional frameworks influence the behaviour of these agents (Ménard, 2004b).

If one addresses TCs specifically in the context of TWC schemes, many more issues arise than in the case of solely increasing energy efficiency. As mentioned previously, a variety of issues affect the performance of TWC schemes, including market liquidity, marginal cost curves of the obligated parties' energy savings, monopoly power, penalties under the scheme, how ambitious the target is, etc. In our case, TCs can impact not only the development of energy efficiency projects that lead to issuance of certificates but also the creation of certificates themselves, and the size and performance of the market. Taking into account the life cycle of TWCs, I argue that TCs affecting the development (i.e., planning, implementation, and M&V phase) of eligible energy efficiency projects under TWC are just part of a wider set of TCs affecting the creation of TWCs.

From the microeconomic viewpoint, the negative implications of TCs for TWC schemes can be depicted as follows. Let us assume a TWC market in which there are two parties (1 and 2). In Fig. 2, both the supply (S) and demand (D) of TWC represent different marginal costs ($MgC_{1,2}$) that are functions of energy savings and thus the creation of TWCs. Both curves depend on the energy efficiency potentials and on the accessibility, variety, and costs of measures capable of yielding these potentials. For the case of D, the position and slope of the curve depend, *inter alia*, on how high the level of ambition of the TWC scheme is determined to be. While the y-axis is in monetary terms ($P(\$)$), the x-axis represents the quantity of traded TWCs ($Q(TWC)$). The marginal costs for party 1 (MgC_1) increase to the right, whereas the marginal costs for party 2 (MgC_2) increase to the left. Note that, in this example, the first units of energy savings and thus TWCs for party 1 can be yielded at negative costs. The equilibrium level is represented by QE at price PE, at which marginal costs for

both parties are equalized. Stavins (1995, p. 138) refers to this equilibrium as "the cost-effective equilibrium in the absence of transaction costs." However, in the presence of TCs, the equilibrium level is different from that without TCs. Assuming that TCs are positive and borne by the supply of TWCs (and thus end-users), the supply curve $S(MgC_1)$ of TWCs shifts upward and to the left, $S'(MgC_1 + TCs)$.[7] The presence of TCs implies that the quantity of traded TWCs is reduced from Q_E to $Q'_{(TCs)}$; and the price paid by D consequently increases to $P'_{D(TCs)}$.[8] Both effects take place regardless of the MgC functions of both parties. Note also that the first units of savings of party 1, potentially yielded at negative costs, are no longer feasible in the presence of TCs. With TCs, the marginal costs faced by both parties differ and the least-cost equilibrium is not achieved.

4. Nature of transaction costs in the EEC1

To identify the *nature* of TCs from the energy supplier's side (i.e., obliged parties) stakeholders and energy suppliers were asked to identify—via interview or questionnaire—what activities were performed during each phase of the TWC life cycle on a measure-by-measure basis (i.e., lighting, heating, insulation, appliances). Keeping in mind the life cycle of TWC, Fig. 3 summarizes the sources of TCs identified and further elaborated in the following sections.

4.1. TCs related to planning

The first source of TCs is related to the search for information, in terms of what measures to use and what customers would be willing to implement. Interviews and reported information strongly indicate that finding customers willing to implement measures, in particular labour-intensive measures (e.g., cavity wall insulation), was cumbersome. Energy suppliers relied on third parties to address this issue, mostly partnering with local authorities, SHPs, and charity organizations. For instance, suppliers held EEC awareness-raising workshops/seminars with local authorities to identify potential types of measures and customers. The interviews showed why active cooperation between suppliers and these third parties was highly needed: namely, householders' confusion and ultimately
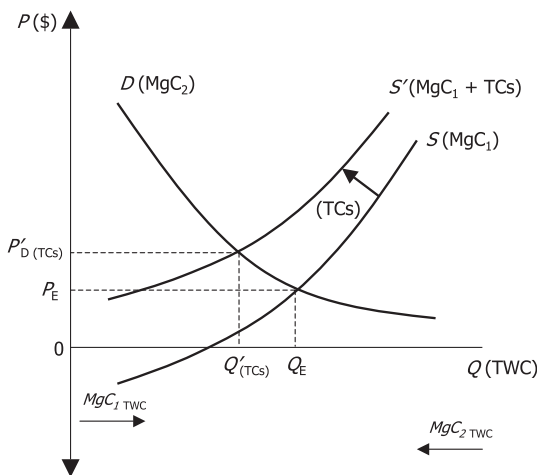

Fig. 2. Impacts of transaction costs on energy savings and trading of TWC.

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[7]In this example, marginal TCs decrease when TWCs increase because of volume discounts offered by installers of energy efficiency measures. Therefore, the slope of $S'(MgC_1 + TCs)$ is less steep because of the economies of scale of TCs associated with larger amounts of TWCs. Another examples could be given if (a) marginal TCs are considered to be constant, and (b) marginal TCs increase with the volume of TWC traded (i.e., slope of $S'(MgC_1 + TCs)$ is steeper). The latter case seems unlikely to occur, due to the fact that parties are likely to divide their transactions into a lower number of trades. This case could exist if marginal increasing TCs are combined with *fixed* TCs (Stavins, 1995).

[8]Note that regardless who actually pays TCs, how the burden of TCs is finally shared depends on the elasticities of energy saving cost functions. Parties facing higher marginal costs of energy savings (i.e., steeper MgC energy saving functions) will share a higher burden (Stavins, 1995).
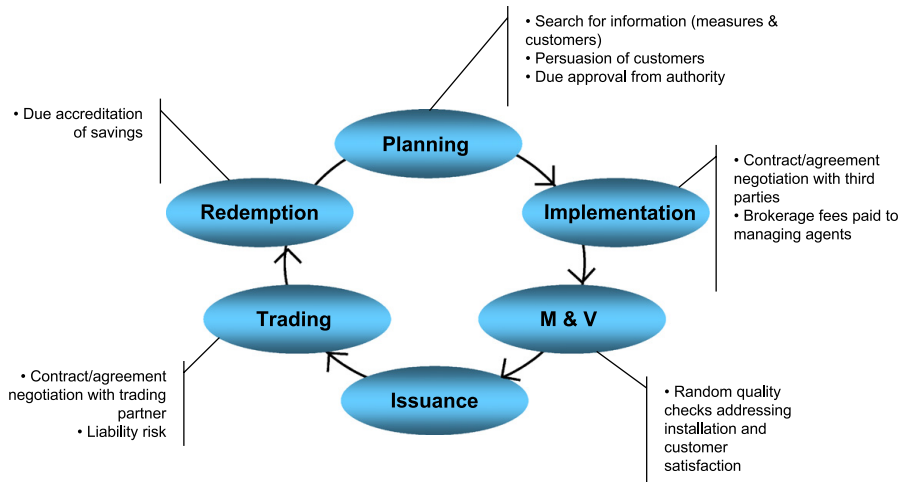
Fig. 3. Identified sources of transaction costs under the EEC1.

mistrust of energy suppliers who were urging them to save energy; hence, the importance of having "trusted intermediaries" between consumers and suppliers.

The second source of TCs during this phase is related to the persuasion of customers to implement measures. Persuading people was very critical during the EEC1, leading to intensive negotiation efforts and cooperation with third parties (see above). The cause of this source of TCs was the apathy and the lack of awareness of households regarding implementation of energy efficiency measures. Although the EEC was intended to change individual behaviour regarding energy efficiency, interviewees agreed that much of the success in terms of delivered savings was due to the efforts of energy suppliers rather than the enthusiasm of householders. It was claimed that even if households were aware of the financial and environmental benefits of energy efficiency and could get partly subsidized insulation (25% for non-priority group to 70% for priority group), monetary savings did not persuade people to implement these measures. In some cases, competition among suppliers for EEC customers in the same geographical area increased persuasion efforts.

The third source of TCs is associated with the due approval of proposed measures from OFGEM. Suppliers conducted the preparation of documents to gain approval from the authority, specifically, the person-to-person costs of researching and assessing information during this process. Having the correct information was critical for the suppliers, as endorsement by the authority was needed before implementation could take place. The authority's task was—and still is—to check whether a proposed measure qualifies under the EEC in terms of being *additional* when compared to business-as-usual. It has to be said that this process helped suppliers to lower risks in terms of compliance with their target. Once the authority

gave approval, risks were already reduced. Thus, it was revealed that there were no TCs in relation to the assessment of risk of failure.

4.2. TCs related to implementation

During this phase, the only source of TCs possible to identify was related to negotiation of agreements/contracts with third parties: consultants, contracting/installation services and retailers. Local authorities and SHPs also supported suppliers in facilitating the delivery and implementation of energy efficiency measures.

First, suppliers hired professional services to handle the EEC obligation. Two categories were identified:

(a) *Consulting services*: Mostly to guide on the type of measures to be implemented and facilitate understanding of the regulatory framework. No information was reported on related M&V activities because savings are estimated on an *ex ante* basis.
(b) *Managing agents*: To administer planning and implementation of measures, including identification of customers. It was stated that managing agents or "middlemen" helped facilitate arrangements between suppliers and local authorities. Where niche markets existed, they bundled disaggregated customers. According to the reported data, managing agents charged fees of up to £10 per installed insulation measure or customer identified. Suppliers perceived negotiation with managing agents as risky because if things went wrong, they, not their agents, would have to pay the penalty for non-compliance.

Second, suppliers hired insulation contractors. The relationship between suppliers and contractors was defined

as crucial for meeting the supplier's obligation. Almost 100% of insulation was outsourced; thus, companies relied heavily on sub-contracting. This source of TCs was also perceived as critical because of the risk of failure (although this was less than for managing agents).

Third, energy suppliers worked with retail companies to increase the penetration of efficient appliances (e.g., A-rated refrigerator) by negotiating larger storage capacity and rebates. Suppliers provided financial incentives to retailers to stock more efficient appliances by asking them to meet certain conditions (e.g., marketing efforts to make efficient appliances more attractive to the customer). The suppliers used the sales data to claim and declare their energy savings. Interviewees mentioned that more attractive discounts were given when equipment manufacturers took part in negotiations.

4.3. TCs related to measurement and verification

In this phase, the main source of TCs is directly linked to random quality checks activities performed by suppliers in relation to installation and customer satisfaction.[9] Once measures were implemented, suppliers were required to monitor a proportion of all installations with respect to the exact number of measures implemented, fulfilment of quality standards, number of assisted priority households, consumer satisfaction, and how consumers were utilizing the measures. For instance, when insulation and heating were installed, monitoring was performed in at least 5% of the households (OFGEM, 2005a, p. 57). According to the suppliers, telephone interviews, questionnaires, and random home visits were undertaken for monitoring. Because of apathy or indifference on the part of customers regarding feedback, suppliers often provided incentives (e.g., free TV set).

4.4. TCs related to trading

To facilitate least-cost compliance, the EEC1 allowed the trading of both obligations and energy savings among energy suppliers. It also allowed suppliers to retroactively buy energy savings from other government programmes. As very little trading occurred during the EEC1, policy makers and researchers speculated that TCs prevented

market activity. It must be mentioned here, however, that trading of energy savings and obligations did occur during the EEC1.

(a) *Trading of energy savings*: Six energy suppliers retroactively purchased energy savings generated under other government programmes (OFGEM, 2005a, p. 56) heavily linked to the UK fuel poverty strategy (e.g., Warm Front programme).[10] These trades contributed to almost 15% of all cavity wall insulations implemented under the EEC1.[11] Savings from insulation dominated overall. EAGA, one of the managing agents of the Warm Front programme, reported that during 2003–2004 around £10 million in energy savings were sold to suppliers (House of Commons, 2004, p. 25).[12]

(b) *Trading of obligations:* Two trades of obligations occurred during the EEC1. First, EDF Energy took on the entire Dee Valley's obligation of nearly 100 GWh (OFGEM, 2005a). Second, the suppliers Opus Energy and Telecom Plus decided to jointly achieve their obligations, which in practical terms allowed them to equalize their marginal compliance costs (NERA, 2006). No financial data could be obtained regarding these trades, but both were reported to and by the authority.[13]

The interviews and the questionnaire indicated that TCs did not prevent the trading of energy savings under the EEC1. It was revealed that the low level of trading was slightly affected by *perceived* TCs, which were only one of the causes of low trading levels (see Section 6 for details). For the suppliers, these perceived high TCs were associated with two sources: contract/agreement negotiation and liability risks. Regarding the former, suppliers stated that when negotiating energy savings, strategically sensitive information (e.g., compliance costs) could—hypothetically, at least—be disclosed to a buyer/seller who was actually also a competitor, with negative commercial effects. Regarding the latter, trading was hampered by the absence of clear procedures for determining liability for trades or measures not approved by the authority. Suppliers considered it too risky to embark on trading without being sure who was liable should things not go according to plan.[14] Although there was no formal trading platform, discussions did take place between interested buyers and

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[9]While institutional administrative costs were not the main focus of this study, random M&V activities were performed on behalf of the authority. The purpose of the audits was to check whether suppliers were delivering energy savings as planned, but no *ex post* measurement took place. Even if energy savings per type of measure were accredited beforehand, and with due approval, random audits were carried out during 2003 and early 2005. The costs for the former were around £90,000 and for the latter nearly £60,000. It was shown that energy suppliers had accurately reported their measures during the EEC1 (OFGEM, 2005a). According to the authority, a learning process allowed them to reduce the costs (33%) for the second audit. These costs were totally borne by the authority and represented less than 15% of its total budget to administer the EEC1 (£1 million) (OFGEM, 2005a, p. 4). The overall administrative burden for OFGEM represented less than 0.3% of the total agency's budget (£400 million).

[10]For further information visit http://www.DEFRA.gov.uk/ENVIRONMENT/energy/hees/index.htm.
[11]For further information see OFGEM (2005a, Appendix 1).
[12]Managing agents were required to invest the financial resources in similar measures.
[13]Energy savings or obligations that are traded have to be reported to OFGEM, which provides written agreement to suppliers regarding the trade of energy savings and/or target with another supplier.
[14]Note that, to some extent, this finding is consistent with the study done by NERA (2006, p. 41) as far as options for increasing trading of the EEC are concerned.

sellers; however, lack of standardized contracts prevented bilateral trading, as did lack of trading expertise.

4.5. TCs related to declaration (redemption)

OFGEM developed administrative procedures to check the delivery and supervise each supplier's progress against its individual target. During this phase, TCs were associated with the due accreditation of savings from OFGEM to the suppliers. Here, TCs were related to the person-to-person costs of researching and assessing information during the quarterly process of declaring savings to the authority. This process provided details of measures taken and energy savings achieved. Documentation was critical in terms of suppliers being accredited with energy savings to offset their obligations. Interviewees stated that this activity, though critical for suppliers, was not as burdensome as the planning and implementation phases.

5. Scale of transaction of costs and cost-effectiveness of energy savings in the EEC1

5.1. Analytical approach

The computational model to calculate the figures presented in the following sections is fairly simple and uses a handful of variables. First, TCs per category of measure were calculated using the estimates provided by the suppliers on measure-by-measure basis. The calculations were focused on two segments: lighting (CFL) and insulation (cavity wall).

Second, cost-effectiveness estimates of energy savings from the supplier standpoint were calculated, C_j, with index j referring to the specific category of measure

$$C_j = \frac{[I(suppliers)_j + TCs(suppliers)_j]}{S_j[1 - (1 + i)^n]}, \tag{1}$$

where $I(suppliers)$ represents the direct investment costs of suppliers, $TCs(suppliers)$ are the TCs borne by energy suppliers, and S represents the energy savings discounted over the lifetime, n, of a given measure. The discount rate, i, used during the first phase of the scheme was 6%. To reflect the different levels of primary energy used per kWh and its carbon content, lifetime-discounted energy savings under the EEC are expressed in fuel-standardized terms.[15] Thus, energy-savings-related figures presented here refer to fuel-standardized lifetime discounted energy savings; which is specific to the EEC.[16]

Third, and because different parties were contributing to the investments, total societal cost-effectiveness, SC_j, were

estimated

$$SC_j = \frac{[I(suppliers)_j + TCs(suppliers)_j + Ct(shp)_j + I(customers)_j]}{S_j[1 - (1 + i)^n]} \tag{2}$$

where $Ct(shp)_i$ is the financial contribution of the social housing programmes to realizing the measures, and $I(customers)_i$ are the investment costs borne by the customers (priority and non priority).

Fourth, with cost-effectiveness of energy savings (including TCs) already calculated, financial and economic benefits were estimated. This was done using household energy prices as a benchmark and negative externalities from electricity production as avoided costs, respectively. Values are in £ sterling 2004.

5.2. Quantitative estimates

Once the sources of TCs were identified, energy suppliers (i.e., obliged parties) were asked to provide figures in relation to the identified sources of TCs as a percentage of direct investment costs. These figures represented an aggregated estimation of TCs shown in Fig. 3. Based on the provided data, the scale of TCs was estimated to represent a maximum of 10% of investment costs for CFL. Taking into account the margin of error of the sample, this gives a confidence interval of 8–12%. For cavity wall insulation, the scale of TCs was estimated to represent 30% of investment costs, with a confidence interval of 24–36%. Interviewees agreed that the heaviest burden for insulation-related measures was the search for information and negotiation with managing agents/contractors. For lighting, the heaviest burden was identified to be the negotiation and contract agreements with local authorities, SHPs and large retail companies and manufacturers. Disaggregate estimates of TCs were not given.

Using the estimated scale of TCs presented above and formula (1), cost-effectiveness of energy savings per category of measure were estimated from the energy supplier's standpoint (see Table 2). For strategic and commercial reasons, it must be mentioned that suppliers did not report any data related to their investments, including related administrative (e.g., personnel devoted to the EEC) and marketing costs. In the absence of this information, direct investment costs found in other studies addressing the EEC1 were used to calculate average cost-effectiveness estimates (i.e., Lees, 2006; OFGEM, 2005a).

In Table 2, cost-effective estimates for the lighting segment, including TCs, range from 0.55 to 0.57 p/kWh. Estimates for the insulation segment are slightly higher, ranging from 0.59 to 0.65 p/kWh. The extrapolation of estimated TCs from these two segments to the entire set of delivered energy savings can be cautiously taken as representative, as the implementation of cavity wall insulation and installation of CFLs dominate the savings made under the EEC1. The amount of direct investment by the suppliers in lighting and insulation measures

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[15]For further information see DEFRA (2004, p. 10).
[16]Lees (2006, pp. 66–70) gives estimates of levelized energy savings costs by removing the proportion of energy savings taken from increased comfort and all the uplift factors that can determine actual energy savings under the EEC.

Table 2
Supplier's cost-effectiveness estimates (£2004)

Category of measure	Direct energy supplier investment costs (£M)[a]	Delivered energy savings against EEC1 target[b]		Supplier's cost-effectiveness estimates of energy savings (p/kWh)			
		TWh	Share (in %)	Without TCs	Including TCs		
					Lower bound	Average estimate	Upper bound
Lighting	104.6	20.6	34	0.51	0.55	0.56	0.57
Insulation	110.1	23.0	38	0.48	0.59	0.62	0.65
Heating	62.3	7.3	12	0.86		n/a	
Appliances	44.4	9.7	16	0.46		n/a	
Total	321.4	60.6	100				

[a]Derived from Lees (2006, pp. 62–65).
[b]Derived from OFGEM (2005a, p. 66).

Table 3
Societal cost-effectiveness estimates of energy savings (£2004)

Type of measure	Lighting	Insulation
Societal total cost (£M)	120.1	187.7
Including:		
(a) Customer contribution[a]	13.5	48.9
(b) SHP contribution[a]	2.0	28.7
(c) Energy supplier direct investment costs	104.6	110.1
Societal total cost (£M) including TCs borne by suppliers	128.5–132.7	214.1–227.3
Societal cost-effectiveness of energy savings (p/kWh)		
With no TCs	0.58	0.82
With TCs	0.62–0.64	0.93–0.99

[a]Derived from Lees (2006, p. 64).

represented around 67% of total investments (£321 m) and nearly 72% of the total amount of delivered energy savings.

From the societal point of view, the cost-effectiveness of energy savings for lighting and insulation were estimated using formula (2) (see Table 3). By including the estimated scale of TCs borne by the suppliers, the range of values of average societal energy savings range from 0.62 to 0.99 p/kWh, representing CFL and cavity wall insulation, respectively.

Using the energy prices paid by householders[17] during the EEC1 as a benchmark for comparing and estimating potential *financial* benefits of energy savings,[18] the results indicate that the EEC1 did yield net benefits (see Fig. 4). For lighting, where electricity is the obvious dominant

energy carrier, the estimated net financial benefit for society is between 2.06 and 6.06 p/kWh of electricity saved. Assuming that gas was the main energy carrier for insulation, the estimated net financial benefit for society is between 0.6 and 0.7 p/kWh saved. As consumers contributed a fraction of investment, their net financial benefits can be said to be higher if, and only if, energy suppliers did not transfer their contribution through higher energy tariffs.

To approach the potential *economic* benefits of energy saved during the EEC1, negative environmental and social externalities resulting from power production (e.g., mortality, morbidity, global warming, amenity losses) are considered. Based on the figures generated by the ExternE project[19], the range of external costs for electricity production ranges from 0.15 to 7 €cents/kWh, respectively, for wind and coal/lignite in the UK (European Commission, 2003, p. 13). Taking the minimum and maximum ranges of external costs of different energy sources in the UK and extrapolating them to the electricity fuel mix in 2003 (see IEA Energy Statistics, 2006) the estimated external costs range from 1.34 to 2.40 p/kWh.[20] These figures represent benefits or avoided costs for society resulting from the units of electricity saved under EEC1. Based on this, and taking the minimum and maximum financial benefits mentioned above for *lighting* only, it is found that the estimated *net economic benefit* ranges from 3.40 to 8.46 p/kWh of electricity saved, adding 65% and 40%, respectively, to the financial benefits (i.e., 2.06 and 6.06 p/kWh) of electricity savings. Thus, for every pound sterling saved by EEC1 in electricity costs, another 40–65 pence were saved by avoiding the negative external costs of power generation. Furthermore, while cost-effectiveness estimates address a 3-year period, benefits account for the

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[17]Based on DTI (2005) and DEFRA (2006).
[18]Gillingham et al. (2004) use a similar approach to measure the overall potential benefits of saved energy.

[19]For further information visit http://externe.jrc.es/.
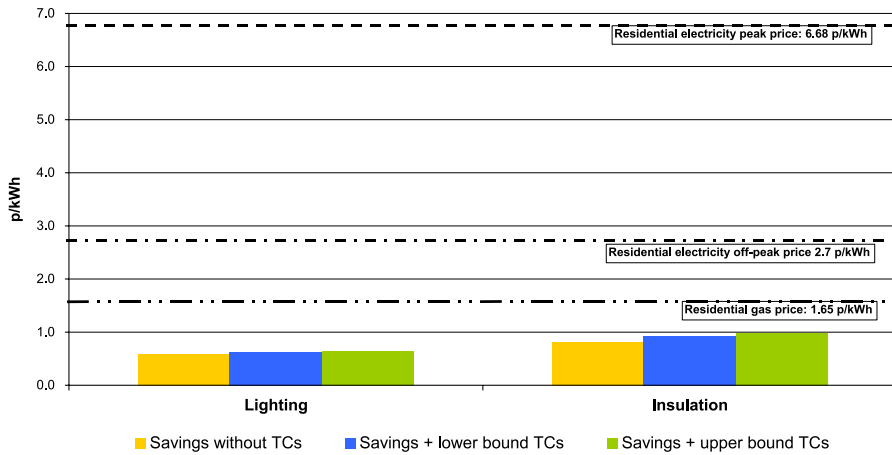[20]1 British Pound = 1.42 Euro on 31 December 2003.

Fig. 4. Societal cost-effectiveness of energy savings and potential financial benefits per kWh saved (excluding VAT, £2004).

lifetime of the measures, which is for instance 14 years for CFL (DEFRA, 2004, p. 30).

6. Discussion

It can be argued that design elements of EEC1—and thus coverage—greatly influenced the *nature* and *scale* of TCs, including the low administrative burden for the authorities. The most relevant design elements are the limited number of obliged parties, the handful set of eligible technologies, the *ex ante* M&V approach used, and that the household sector was the only eligible end-user. For TWC schemes in general, the larger and/or complex these elements become, the higher the scale of TCs could be faced and the more burdensome the administration and enforcement of the scheme. Indeed, many trade-offs exist in terms of liquidity, M&V, enforcement, and TCs. For instance, a higher number of buyers and sellers increases not only the liquidity of the market but also the sources and scale of TCs, adding to the administrative burden. A large and disaggregate number of obliged parties and eligible sectors, particularly if an *ex post* approach is used, can also pose a risk to significant M&V activities and enforcement. In fact, interviewees did agree that it would have been impossible to run the EEC1 cost-effectively without an *ex ante* M&V approach. This was supported by the fact that the technical performance of eligible measures was well understood so the level of uncertainty was relatively low.

Regarding the specific *nature* of TCs, the information gathered showed that search for information—measures and potential customers—and the persuasion of customers were demanding tasks. According to the suppliers, it became increasingly difficult to find customers willing to implement measures, in particular within the priority group, which is defined as key requirement in the scheme.[21] While the suppliers wanted a more balanced portfolio of EEC customers, the figures reported indicate that for every three non-priority customers, one priority customer was gained. Some market failures and barriers could explain this situation. For instance, interviewees mentioned that there was a *perception gap* among households regarding investment costs. People believed energy efficiency measurement (e.g., cavity wall insulation) would cost, say, £1000–2000 when the actual amount was around £100–200, depending on membership of priority or non-priority group. Furthermore, the *split-incentive problem* (Howard and Sanstad, 1995) was identified, with tenants from the priority group being reluctant to implement measures because they might move before realizing the financial savings. According to Train (1985), lower income households are less willing to invest in energy efficiency measures than high-income households because they have less access to capital and less liquid capital, even if returns on investments are sufficient to justify the investments. In fact, it is argued that low-income households use high implicit discount rates (e.g., up to 90%) when evaluating efficient technologies because they cannot or are reluctant to decide whether the investment is beneficial (Train, 1985). Hausman (1979) and Train (1985) found that implicit discount rates for the purchase of efficient equipments vary inversely with income.

The *apathy* or *lack of awareness* among EEC1 customers indicates that the way a policy instrument creating a TWC

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[21]One could expect that as the priority group is reduced in absolute numbers, finding low-income households would become more difficult and thus higher related TCs could be observed. In fact, some interviewees mentioned that the EEC should be de-linked from the "Fuel Poverty Strategy" to reduce TCs. The EEC2 review process, likely to take place in 2007, should cast light on this.
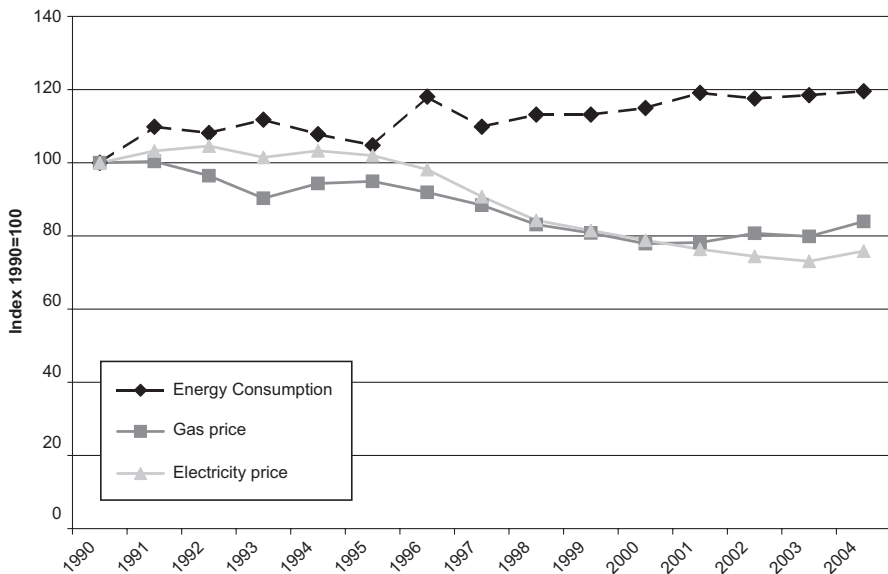
Fig. 5. Household energy consumption and energy carrier price indices in the UK (1990–2004) (*Source*: Derived from DTI Statistics, 2002, 2005).

scheme performs depends on how effective awareness raising is among end-users. This suggests that for a TWC scheme to deliver cost-effective energy savings, the effectiveness of informative policy instruments needs to be sufficiently high upstream in the scheme. Aware of this scenario, the UK government launched the "EEC Campaign" in early 2005 to raise awareness. Although the campaign had a £2.4 million budget, it had only a marginal influence on increasing awareness about the EEC (EST, 2005). This outcome could suggest that the provision of adequate information had little potential for encouraging increased energy efficiency among EEC customers. Among the different variables, the indifference of householders to energy efficiency could also be explained by fuel pricing. Since 1990 gas and electricity prices paid by UK consumers fell in real terms by approximately 16% and 25%, respectively, compared to 2004, lowering returns on investments in energy efficiency (see Fig. 5). Against this, energy consumption increased by nearly 19% during the same period.[22] As one interviewee puts it, low energy prices mean that "there is very little appetite for energy efficiency" in households. In turn, one can argue that it is up to the end-users whether obliged parties can meet their mandatory goal.

When it comes to the *scale* of TCs, some financial and managerial aspects need to be considered in order to have a careful lecture of the given estimates. First, direct investment costs are based on engineering studies because

suppliers did not report these figures. It remains to be confirmed whether these figures were over or underestimated. Second, when asked by incurred administrative and marketing costs a lack of specific accounting was identified. For instance, marketing costs were absorbed by the overall marketing budget, so drawing the line between general and EEC1 direct marketing costs proved challenging. Looking at energy efficiency programmes in general, Joskow and Donald (1992, p. 15) argue that accounting of administrative costs can increase the costs per kWh saved by 10–20%. In our case, even if a 20% of administrative costs per kWh saved is included in the estimations, the outcome would be same for the analysed measures: positive financial/economic estimated benefits. These figures basically do not change if the administrative costs—around £1 m—incurred by the authority (OFGEM) are included, as government expenditure was rather marginal compared to overall level of investment. Third, the accounting problem is also applicable to TCs. While suppliers were sometimes fully aware of their existence, they did not keep track of them. Once the sources of TCs were identified, an estimated scale was given only as a percentage of direct investment costs. However, the estimated scale should not be interpreted as a constant and positive correlation between the size and performance of the measures and the actual *burden* of TCs. For instance, the burden may decrease as energy savings increase because of the fix component of certain sources of TCs. I argue that economies of scale are likely to exist because some of the identified sources of TCs entail fixed costs (e.g., negotiation of contract/agreements with third parties) which might

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[22]For further information about household energy consumption in the UK, see DTI (2002, pp. 23–29).

indicate decreasing marginal TCs. Standardized and transparent full accounting systems should allow getting more precise figures. In any case, these estimates are not possible to extrapolate to other TWC schemes. In fact, it can be said that the *scale* of TCs for TWC schemes will undoubtedly vary and it will be scheme-specific. Apart from design elements, a number of exogenous determinants (e.g., market conditions, geographical context, portfolio of policy instruments, etc.) will explain the degree of uncertainty and its order of magnitude.

As far as the *trading* is concerned, the low level of trading has gotten the attention of international observers of the EEC1, and speculations that TCs negatively affected it were made. This study found that the trading of energy savings was slightly affected by the perceived TCs. Why, then, did a low level of trading activity characterize the EEC1? A number of interrelated reasons were found:

(a) *Cost-effectiveness and excess of energy savings supply*: For energy suppliers, it was cheaper to implement their own measures than to buy energy savings from other suppliers. In fact, successful energy saving measures led to an individual excess of supply of energy savings that hindered the demand of TWC and thus trade, amongst obliged parties. This excess of supply was also driven by the fact that suppliers wanted to avoid as much as possible the financial risks related to the penalty for non compliance, leading to an overachievement of their targets as a risk management practice.[23]

(b) *Increased branding*: Own energy efficiency measures allowed some suppliers to expand their product and customer portfolio, and enhance their branding and customer loyalty. In addition, and strategically speaking, some suppliers realized that purchasing savings from another supplier was commercial nonsense—as one interviewee put it, like "supporting the branding of a competitor."

(c) *Banking option*: Between mid-2004 and early 2005, suppliers already knew their obligations would be higher during the next phase and decided to increase their activity level. Six (out of eight) suppliers decided to bank their surplus of energy savings for the second phase of the scheme, as this was more beneficial than selling it. As some of the data, assumptions and legal requirements used to determine the savings for the EEC2 changed, certain measures would produce more savings in EEC2 than in EEC1 (e.g., insulation measures). Suppliers thus banked savings that were more beneficial in the next phase of the scheme. In all,

around 25 TWh[24] were banked—nearly 25% of the EEC2 target (OFGEM, 2005a, p. 67).

(d) *Strategic learning approach*: Despite the fact that the scheme was built upon the Energy Efficiency Standards of Performance programme (EESoP)—that ran from 1994 until 2002—energy efficiency was still such a new activity for energy suppliers. Thus, there was a learning process that affected the trading level. Rather than rely on a competitor to achieve their obligations, suppliers sought ways of meeting their target independently. Gaining knowledge and experience was strategically important for the suppliers in a long-term perspective.

(e) *Low market liquidity and financial gains*: The liquidity of the market was restricted as only obliged parties were allowed to trade. No third parties were permitted to trade except a handful number of government related programmes. Trading energy savings brought few financial gains to some suppliers. For instance, most contractors offered very similar prices for insulation measures. Regarding other measures, suppliers had the same access to these and faced very similar purchase costs. Therefore, the cost differences were marginal and provided few financial incentives.

Although most of the attention has been directed to the trading phase of the TWC schemes, the importance of the *target* in these target-and-trade schemes must be emphasized. It has to be stressed that the trading activity of any TWC scheme is not an objective *per se*, but a way of enhancing the scheme's efficiency to meet a mandatory energy saving target.[25] It can be argued that suppliers during the EEC1 did not face a *to-trade-or-not-to-trade* dilemma. However, it remains to be seen whether future market and policy conditions will similarly influence their market behaviour.

Concerning *brokers* or *intermediaries*, their participation was not observed in the trading phase due to the reasons mentioned above; however, they had a more active participation upstream in the scheme. Despite the significant challenge for suppliers to identify EEC customers, it is important to mention that while intermediaries (i.e., local authorities, landlords, charity organizations, and managing agents) added to TCs, their participation also help to reduce them. Indeed, interviewees agreed that without these actors TCs would have been probably higher. However, the future market role of managing agents is unclear partly because of their low level of risk sharing and partly because of the business opportunities created by the EEC for some energy suppliers. It was identified that suppliers started to set up internal management groups to prevent/diminish the level of outsourcing. These units (e.g., composed of 15–30 people) have begun to keep a tight control over contractors and managing agents. As TWC

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[23]It is also argued that the declaration process of energy savings counting against target—which takes place by the end of the compliance period—also imposed some extra risks and thus prevented trading (NERA, 2006, pp. 46–47). This is because of the uncertainties that obliged parties face in relation to their exact level of compliance before being certain about their potential surplus of savings.

[24]Measured in EEC2 terms, this is equivalent to around 35 TWh.
[25]Greenspan Bell (2005) addresses the same issue when discussing an emissions trading scheme in the context of climate change.

schemes emerge, the role of brokers is likely to be relevant. If trading takes off, brokers can play a critical important role reducing TCs if the regulatory framework allows them—including third parties—to participate.

7. Conclusions

This study shows that despite the presence and magnitude of TCs, increased energy efficiency under the British TWC scheme was estimated to yield net financial and economic benefits.[26] Taking into account negative externalities from electricity production as avoided costs and household energy prices as a benchmark, quantitative estimates indicate that the EEC1 benefited the society.

Results showed that the search for information and persuasion of customers were relevant sources of TCs upstream in the EEC1. The findings suggest that a number of market barriers and imperfections contributed to this situation. For instance the split-incentive problem and asymmetric information among end-users could help explaining their low level of awareness. These results confirm the broader view needed when analysing TCs under TWC schemes, in particular upstream in the TWC life cycle. Not only can the trading phase be subject to TCs but the development of eligible measures leading to the issuance of TWC as such. Indeed, lessons from the EEC1 indicate that high effectiveness of informative policy instruments to raise awareness upstream among end-users is critical, if a TWC scheme is to deliver cost-effective energy savings.

Downstream in the scheme, and to the surprise of many, the findings indicate that the low level of trading was slightly affected by perceived high TCs. With numerous benefits in their favour, suppliers having a surplus of energy savings were not enthusiastic about trading. The results indicate that the benefits of non-trading were higher than the potential costs of trading. However, a different scenario and market behaviour could have been seen if third parties—not only obliged parties—would have been allowed to participate in the trading. In fact, the design of the scheme heavily affected the liquidity of the market.

In all, TCs under TWC schemes are very likely to differ because of a number of endogenous (e.g., design, coverage, programme requirements, data reliability) and exogenous determinants (e.g., market conditions, geographical context, portfolio of policy instruments) explaining and affecting the nature and scale. While further research remains to be done, lesson learnt from the EEC1 point to a number of strategies for reducing TCs during the life cycle of TWC in general. For instance, standardized full cost accounting systems—including TCs—project bundling, *ex*

ante M&V approach, streamlined procedures, standardized trading contracts, and a trading platform should be evaluated and implemented accordingly.

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[26]It is interesting to notice that using a numerical model for a NO_x emissions trading scheme, Montero (1997) finds that even in the presence of high levels of TCs and uncertainty, such a scheme is still cost-effective because aggregate abatement costs are significantly lower than an equivalent command-and-control policy approach.

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Paper IV

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Market behaviour and the *to-trade-or-not-to-trade* dilemma in 'tradable white certificate' schemes

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Abstract This paper provides an empirical analysis of market behaviour under 'Tradable White Certificate' (TWC) schemes. It focuses on the entire set of 'flexibilities' granted to obliged parties to meet a mandatory energy-saving target cost-effectively, i.e. range eligible measures, eligible end-use sectors, banking provision, market engagement of non-obliged parties, and trading as such. We found that market behaviour responds to the unique design and context in which TWC schemes are implemented. Contrary to expectations, limited trading is observed so the 'to-trade-or-not-to-trade' dilemma is further analysed. A real TWC market has emerged only in Italy, where obliged parties (i.e. energy distributors) show preference towards 'to-trade'. In Great Britain and France, an autarky compliance approach is identified, with obliged parties (i.e. energy suppliers) showing preference towards 'not-to-trade' driven by, among many factors, commercial benefits of non-trading (e.g. increased competitiveness). At the same time, results

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show clearer indications of cost-effectiveness for Great Britain than for Italy. In general, high energy-saving effectiveness is observed, but low ambitious saving targets and pitfalls in the regulatory framework need to be considered to further develop TWC markets. Initial market and institutional conditions strongly suggest that trading might not be an immediate outcome. Ambitious energy targets can trigger a more dynamic usage of all flexibilities by eligible parties and thus active behaviour in TWC markets.

Introduction

In theory, the creation of tradable white certificate (TWC) markets allows obliged parties—hereafter the 'parties'—to meet a mandatory energy-saving target at lowest possible costs.[1] The Government, usually in co-operation with stakeholders, sets the target. Supporting the expanding willingness to experiment with market-based approaches in Europe (OECD 1999), TWC markets are created to take full advantages of market forces and to work in favour of increased energy efficiency; i.e. it is up to the parties to decide how to meet their given target cost-effectively. Parties are also given the option to trade certified energy savings to meet their individual

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[1] For a detailed description of TWC schemes, see Bertoldi and Rezessy in this special issue.

targets. For them, the market strategy depends on the market price of TWCs compared to the costs of yielding their own energy savings (i.e. credits). Whereas parties facing low compliance costs are likely to supply TWCs on the market, parties with higher compliance costs than the market price of TWCs are likely to demand TWCs. In general, some parties will benefit from tradable certificate schemes, and others will be made worse-off (Ellerman et al. 2000; Harrington et al. 2004; OECD 1999).

Due to the relevance of the *trading* component, most of the attention has been concentrated on the expected trading activity under TWC schemes (Capozza et al. 2006). In fact, the limited trading activity that has occurred so far has prompted the general opinion that TWC markets show little dynamism, if any. However, one has to bear in mind that more *flexibilities*—described in more detail in "'Flexibilities' in TWC markets: an analytical framework"—are present in these markets: (a) the set of eligible measures that parties can use, (b) the number of eligible end-use sectors that can yield energy savings, (c) banking provision for surplus of TWCs, and (d) market engagement of non-obliged parties. As in any tradable certificate/permit scheme, it is the whole set of flexibilities that deserves analytical attention (Ellerman et al. 2000; Nordhaus and Danish 2003; OECD 2002; Tietenberg 2006). In fact, to what extent a TWC market achieves energy savings cost-effectively depends on how obliged parties take advantage of all the granted flexibilities to reduce compliance costs. However, a detailed TWC market analysis has not yet been done because of a lack of empirical evidence, which this paper attempts to do.

The objective of this paper is to provide a comprehensive analysis of market behaviour in TWC schemes. Elaborating upon *cost-effectiveness*[2], the study focuses on whether policy design, existing energy market conditions, and corporate aspects inhibit or encourage parties to take full advantage of given flexibilities. This paper builds mostly upon research work developed within the EU EuroWhiteCert project[3] and seeks answers to the following questions:

- How can the *overall* market behaviour under TWC schemes be characterised?

- What are the drivers behind the *to-trade-or-not-to-trade* dilemma?[4]

We perform the analysis taking the early experience of the Italian TWC scheme and the Energy Efficiency Commitment (EEC; mostly first phase) in Great Britain as case studies.[5] The latter is usually regarded as a TWC scheme because it allows trading of energy saving and obligationsbut it is not a certificate-based scheme yet. In order to yield more robust conclusions, in particular for non-trading patterns, our analysis is complemented with early trends from the French TWC market and findings obtained through a simulated TWC marketusing game theory and interviews with key stakeholders (i.e. obliged parties, authorities, and policy makers). A definitive answer on whether a TWC scheme is an adequate policy choice is beyond the scope of this study.

The structure of this paper is as follows. "'Flexibilities' in TWC markets: an analytical framework" describes the theoretical cost-effective element embedded in TWC schemes and the set of flexibilities—including potential trade-offs. Specific research questions that our analysis seeks to answer are set, and altogether, these aspects represent our analytical framework. In "Early evidence of market behaviour from the Italian and British TWC markets", we analyse empirical evidence of market behaviour coming from the Italian and British TWC schemes. Due to the fact that non-trading is observed, "Commercial benefits of non-trading behaviour for obliged parties" deepens the commercial drivers of this scenario based on findings from Great Britain, which are then analysed in the light of early indications from France and our simulation outcomes. "Discussion on non-trading aspects under TWC schemes" discusses some underlying policy aspects of non-trading patterns. Finally, conclusions are drawn in "Conclusions".

'Flexibilities' in TWC markets: an analytical framework

Whereas there is a tendency to focus on trading as the crucial flexibility in TWC schemes, many more *flex-*

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[2] Defined as whether a mandatory energy saving target is achieved at lowest possible costs.

[3] For further information, visit http://www.eurowhitecert.org.

[4] To be taken as different from the policy dilemma of whether a TWC scheme is or not the right policy choice.

[5] Notice that the acronyms EEC1, EEC2, and EEC3 are used to denote the first (2002–2005), the second (2005–2008), and the third phase (2008–2011) of the EEC, respectively.

ibilities are embedded and granted to parties to fulfil their targets cost-effectively. Indeed, the central argument for least-cost compliance relies on how obliged parties take advantage of *all* the given flexibilities to reduce compliance costs. We identify the following ones.

Range of eligible measures For the first type of flexibility, the number of cost-effective measures and technology development is crucial. Policy makers define eligible measures that qualified to yield TWCs. Thus, the policy commitment is expressed through technology-based rules—like per output basis for $CO_{2\text{-eq}}$ abatement commitments (cf. OECD 1999). The broader the set of eligible measures, the more flexibility is given to parties to yield cost-effective energy-saving potentials. However trade-offs exist. For instance, a larger set of eligible measures can entail a heavy administrative burden for the authorities in relation to measurement and verification (M&V) activities, increasing the total costs of the programme. Within this flexibility, additionality is relevant because TWC markets are supposed to encourage measures that would not have implemented without the TWC financing (i.e. as depicted by the baseline). So far, experience shows that it is very case-specific how additionality is determined and/or applied (e.g. standards above existing building regulation). In general though, one can argue that measures that are additional are likely to be eligible. Aspects to be addressed in our analysis are, among others, what are the drivers behind dominant eligible measures? What are the saving costs per measure?

Number of eligible end-use sectors For the second type of flexibility, the larger the group of eligible end-use sectors in which eligible measures can be implemented, the more options parties have for meeting their obligation cost-effectively. Nevertheless, trade-offs exist because, whereas a larger sectoral coverage may be desired, a growing number of sources of transaction costs (e.g. persuasion of customers, search for trading partner, etc.) could be expected with market actors shouldering a higher burden—besides a heavier administrative burden for the authorities. Whilst the British scheme allows savings only in the household sector, the Italian and French schemes allow energy savings in all end-use sectors. For the latter, savings can be realised in all end-use sectors not yet covered by the European Emission Trading scheme (EU-ETS)—including the transport sector. When evaluating the market behaviour

for this particular flexibility, questions we attempt to answer are, for instance, what are the dominant end sectors in which savings are realised? Does a single eligible end-use sector hamper the efficiency (i.e. maximisation of net societal benefits) of TWC schemes?

Banking provision for surplus of TWCs For the third type of flexibility, 'banking' is allowed so parties that over-comply with their individual targets can save the surplus of TWCs for future commitment periods (e.g. as in Great Britain). The banking option can prevent trading, as it allows obliged parties carrying over unredeemed savings from one compliance period to subsequent ones. In fact, banking is usually denoted as 'inter-temporal trading' (cf. Rubin 1996). In order words, it is given as an inter-temporal flexibility for saving credits in order to mitigate the costs of over-investment (Ellerman et al. 2000; OECD 1999).[6] When evaluating the market behaviour for this particular flexibility, we address the following questions: How are obliged parties using the banking option? What are the market and regulatory aspects driving its usage?

Market engagement of non-obliged parties The fourth type of flexibility refers to the participation of other eligible parties that do not bear any obligation, but they can participate in the TWC market. These parties are entitled to implement eligible measures, gain TWCs for doing so, and also trade TWCs on the market—as long as they fulfil all the regulatory requirements. For a TWC scheme to be cost-effective, market liquidity[7] is of prime importance. In its full extension, high liquidity is affected by a number of critical conditions: a large number of buyers and sellers, market information readily available, high trading volume, low transaction costs, and minimum regulatory barriers to trade (Mundaca and Neij 2006; Voogt et al. 2006).[8] Within this context, a large number of eligible actors (i.e. obliged and non-obliged) are

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[6] Although not yet implemented in current TWC schemes, a 'borrowing' option for non-compliance can also be introduced. This means that a party that does not comply with its target commits itself to a greater target for the next compliance period.

[7] The term 'liquidity' is used to refer to the characteristic of TWCs whereby they can quickly be converted into cash at a reasonably predictable price.

[8] Notice that throughout the paper, we sometimes refer to liquidity to address only one critical condition: the number of eligible parties.

desired because they are likely to face different marginal costs at similar levels of achieved energy savings. However, more participants can also add transaction costs. When evaluating the market behaviour for this particular flexibility, we approach the analysis by answering the following questions: To what extent does the participation of eligible parties reduce or increase the compliance costs borne by obliged parties? Do eligible parties create price volatility on the market?

Trading option to equalise marginal compliance costs
The fifth type of flexibility in a TWC scheme is quite straightforward: trading as such. The central point is that, as long as an allocation of individual saving targets is not cost-effective—very likely due to asymmetric information between regulators and obliged parties—there is always an incentive to trade. This has to be done with due consideration to transaction costs (e.g. search for information, legal advice, negotiation with partners, etc.), non-economic barriers (e.g. lack of awareness among end users to increase energy efficiency) and commercial of non-trading (e.g. customer loyalty). Critical indicators for analysing the trading component of TWC markets are volume of trades, number of buyers and sellers, and price dispersion. When evaluating the market behaviour, we seek to answer the following questions: How can the trading activity be characterised? What are the key institutional and market conditions affecting the trading activity? Is it possible to identify a clear preference as far as the 'to-trade-or-not-trade' dilemma is concerned?

Early evidence of market behaviour from the Italian and British TWC markets

We argue that a comprehensive approach to portray the overall market behaviour in TWC markets is to systematically analyse the activity level of the 'flexibilities' they involve. Table 1 summarises our findings, which are further detailed in the following sections.

Eligible measures used to realise energy savings

Before addressing the type of measures used to meet the saving target, it is relevant to cast light on the actual amount of certified energy savings.[9] According

to the Italian Authority for Electricity and Gas (AEEG 2006) 286,837 toe or TWCs (approximately 3.33 TWh) were certified between January 2005 and the end of May 2006.[10] Table 2 summarises the number of certificates issued by the Electricity Market Operator (GME).[11] The issuance of total certificates corresponds to 184% of the overall saving target to be achieved by 2005 (i.e. 155,911).[12] Under the Italian TWC, different typologies of TWCs exist according to the energy carrier that is saved. Whereas TWCs related to electricity savings (type I) exceeded the minimum expected amount by a factor four, TWCs related to gas savings (type II) were almost two times the minimum amount requested to comply with the obligation in 2005. TWC related to other fuels (type III) had a marginal contribution. The higher number of TWC-I issued indicates a higher number of cost-effective savings available in the electricity segment. Figures recently released by AEEG (2007) show a clearer dominance of TWC-I (78%), followed by TWC-II (18%) and TWC-III (4%; as from January 2005 to December 2006).

The distribution of eligible measures that have been used to realise energy savings in Italy is shown in Fig. 1.[13] Values are valid for the end of the first compliance year and are shown according to the eligible sectors in which they were implemented. More than 60% of the total savings were achieved, realising saving potentials through micro-scale size and 'low-hanging fruits' in the commercial and household sectors. Almost 20% of total savings were achieved by district heating, either through the implementation of new grids or the extension of existing ones. Solar heating panel installa-

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[9] To complement the findings about the Italian TWC scheme, see other papers in this special issue.

[10] Under the Italian TWC scheme, notice that one TWC is equal to 1 tonne of oil equivalent (toe) or 11.63 MWh. Also, notice that obliged actors are allowed to comply with their saving obligation for a given year until May 31 of the following year.

[11] GME is in charge of the issuance of TWC management of the market. For further information, visit http://www.mercatoe lettrico.org/En/Default.aspx.

[12] It has to be mentioned that the target for 2005 was actually 200,000 toe. However, the target to be achieved by obliged parties was approximately 155,000 toe. This is because approx. 50,000 toe could not be apportioned amongst companies that did not meet the apportionment criterion of having a minimum of 100,000 customers. At the time of research, apportionment criteria for these companies still remained to be developed.

[13] No further details about the specific measures implemented in industrial sector were disclosed by the Italian authority in charge of administering and enforcing the TWC scheme (i.e. AEEG)

Table 1 Summary of market behaviour in TWC schemes

Flexibility	Italy	Great Britain
Key implemented eligible measure(s)	Appliances, lighting and micro-generation (e.g. PV) but no clear trends are observed as the 'retroactive' saving option (allows to claim savings realised prior the implementation of the scheme) dominated during the first compliance year	From a portfolio of approximately 20 measures, clear dominance of insulation measures (e.g. cavity wall) followed by CFLs
Key eligible end-use sector in which savings are realised	Household and commercial sectors dominated the first compliance year, but implementation in industrial sector may soon take off	Restricted to household sector. Requirement to yield at least 50% savings in the 'priority group'[a] has been met
Banking of TWCs	Unlimited. Around 42% of the second compliance year potentially achievable with credits generated during the first compliance year	Unlimited, largely used and driven by changes in accreditation methodology of measures. Savings carried over from EEC1 represent ca. 27% (or 35 TWh) of EEC2 target (130 TWh).
Market engagement of non-obliged parties	Great number of ESCOs have participated, but largely explained by a less stringent definition given by the regulatory framework. Combined with the 'retroactive saving option', the growing number of ESCOs creates conditions for the free-riding effect	Insulation contractors have played a crucial role. Furthermore, obliged parties have strategically partnered with a variety of actors to realise savings and/or deliver measures cost-effectively
Trading activity (What about the to-trade-or-not-to-trade dilemma?)	Market emerged and traded TWC volume (approximately 50% of total TWCs issued) has increased. Bilateral and spot trading accounted for 83% and 17% respectively during the first compliance year. A handful of actors participated on spot trading market and rent-seeking behaviour is identified. Prices have fluctuated but slowly falling. Preference towards 'to-trade' is observed	Market has not really emerged, but two trades of obligations took place and six obliged parties bought credits retroactively during EEC1. Several market and regulatory aspects influenced this pattern, including potential commercial benefits of non-trading. Preference towards 'not-to-trade' is observed

[a] Under the British scheme, at least 50% of savings must be realised in the so-called 'priority group', which is defined as "households that received certain income-related benefits or tax credits" (OFGEM 2005, p. 4).

tion, in particular, was responsible for 8% of the total savings achieved.[14]

The trends in Italy are unlikely to reflect market preferences towards any particular eligible measure. First, one has to consider that reaching the industrial sector typically requires ex-post M&V approaches, which are much more case-specific than those for the household/commercial sector.[15] After 2 years of operation, the

deemed or ex-ante approach has been mainly adopted, accounting for 70% of the total certified savings. Thus, the easiest approach has been to claim 'low-hanging fruits' in the household and commercial sectors. If M&V approaches for industrial applications are soon completed/developed, eligible measures in the industrial sector will soon get off the ground, and a different scenario may be observed. Second, Italian parties can

[14] More recently, the Italian authority released some aggregated figures covering a more extensive period, from January 2005 to December 2006 (AEEG 2007). See Pavan in this special issue for more details.

[15] In Italy, three different M&V approaches exist (see AEEG 2006; Adnot et al. 2006a): (a) ex-ante approach or 'deemed savings', (b) engineering estimates that require some on-field measurement and relies on simplified energy saving calculation, and (c) an energy monitoring plan (i.e. an ex-post approach based on direct measurement of energy consumption before and after the project is implemented).

Table 2 TWC issued in the Italian TWC scheme (January 2005 to May 2006)

Energy carrier	Certificates issued	Share (%)
Electricity (type I)	214,244	75
Gas (type II)	62,826	22
Others (type III)	9,767	3
Total	286,837	100

Data source: AEEG (2006)

Fig. 1 Distribution of implemented eligible measures in relation to energy savings (286, 837 toe) under the Italian scheme. From January 2005 until May 2006. Data source: AEEG 2006, p. 20
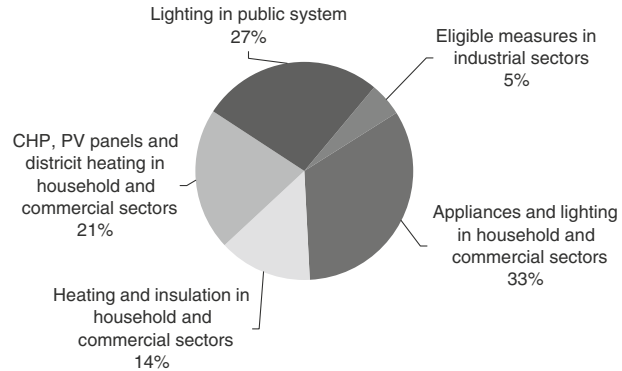
Lighting in public system
27%

Eligible measures in industrial sectors
5%

CHP, PV panels and district heating in household and commercial sectors
21%

Appliances and lighting in household and commercial sectors
33%

Heating and insulation in household and commercial sectors
14%

retroactively claim energy savings implemented from 2001 and onwards to fulfil their targets. In fact, a substantial share of measures (approximately 60%) was actually not triggered by the TWC market as such but prior to 2005. This 'early action' feature, in combination with the ex-ante M&V approach, can largely explain the dominance of the household and commercial sectors.[16] Although this regulatory aspect has given more flexibility to the parties, it also gives indications of free-riding, and provides little ground to identify eligible measures that were actually triggered and implemented (above or beyond certain level) once the scheme started to operate. Despite the fact that additional energy savings are defined in Italy as those "that are over and above spontaneous market trends and/or legislative requirements", the retroactive provision questions its achievement in terms of energy-saving effectiveness.[17]

From the end users' standpoint, the Italian scheme seems to be minimising the costs for meeting a given target—with due consideration to potential free-riding effect. Taking TWCs prices as proxies of actual marginal saving costs, and energy prices paid by Italian households in 2006 as benchmarks, net financial savings for

end users are estimated to be 5 and 6 Euro cents/kWh of electricity and natural gas saved, respectively.[18]

Looking now at the British scheme (first phase) and in terms of energy-saving effectiveness, the scheme has performed well with a minor shortfall during its first phase. Energy savings counting against the EEC1 target (62 TWh) reached almost 61 TWh[19] (OFGEM 2005, p. 8), and the usage of 'deadweight' factors has counteracted the free-riding effect.[20] According to OFGEM (2005), the slight deficit (approximately 2%) during EEC1 was due to two parties that went out of business. However, the total amount of savings accumulated during the EEC1 reached 140% of the EEC1 target or 86.8 TWh (i.e. savings accounted/redeemed against EEC1 target plus the amount of savings banked for

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[16] This 'early action' provision granted to eligible parties was likely the result that the scheme was supposed to be implemented in 2002. However, several aspects challenged its political feasibility and the scheme was finally implemented in 2005.

[17] Defined as whether obliged parties meet or not a mandatory energy saving target.

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[18] This is assuming average TWC prices of €71 and 94 in 2006 for electricity and gas, respectively (see "Trading activity"). Furthermore, we consider national tariffs of electricity and natural gas of approximately 5.6 and 6.8 Euro cents/kWh, respectively. Notice that 1 toe=11,630 kWh.

[19] Energy savings in the British scheme are expressed in fuel standardised lifetime discounted terms. This means that to reflect the different levels of primary energy input to a kilowatt of electricity (including the carbon content), a differential is applied to energy savings. For instance, the number of kilowatt-hours of saving is multiplied by 0.56 for coal savings, 0.8 electricity savings, and by 0.35 for gas savings. For further details see DEFRA (2004b:10, 46).

[20] 'Deadweight' refers to the level of investment activity carried out by parties under 'business-as-usual'. A deadweight factor is applied when energy savings from eligible measures are estimated (including costs).

EEC2 target; OFGEM 2005, p. 7).[21] Details are shown in Fig. 2. Parties scaled up their energy saving activity throughout the EEC1 period. Whilst 20% of the total savings were achieved during the first year of the EEC1, 35% and 45% of the savings were met during the second and third year of EEC1 (OFGEM 2005, p. 11). Both public authorities and obliged parties concur that this level of energy savings would have not occurred in the absence of the scheme.

In Great Britain, due to large cost-effective potentials in the household sector, the dominance of insulation measures was clear during its first phase, in particular cavity wall and loft insulation. Due to large cost-effective potentials in the household sector, these measures contributed to 56% of the total achieved savings or nearly 38% of the savings redeemed (see Table 3). Almost all measures can be labelled as mature and commercially available.[22] Depending on the eligible measure, parties worked together with different actors to implement eligible measures (see "Market engagement of non-obliged parties" for further details). According to Lees (2006), the impacts of market transformation have been visible for white good appliances (i.e. washing, dishwashing and refrigeration

equipments). For instance, the market transformation shows high penetration of A-rated cold appliances of up to 60% by 2006, with multiple policy programmes also influencing such a trend (e.g. EU energy labelling programme, consumer advice from specialised centres, etc.; Lees 2006, pp. 33–34). For heating measures, a steady growth of condensing boiler sales was observed—actively subsidised by obliged parties—reaching a market penetration rate of up 80% (Lees 2006, [. 37). It was found that, in this case, the building regulation enacted in 2005, which now defines B-rated boilers as the minimum standard sold in Great Britain, has played a critical role to transform the market (see Lees 2006). In fact, a variety of policy instruments (i.e. informative, command-and-control and economic ones) have also supported the deployment of eligible technologies and thus the performance of the British scheme as a whole (cf. DEFRA 2004b; Rohr 2004).

When it comes to the second phase of the scheme (i.e. EEC2), similar market trends are identified concerning eligible measures. First, a growing policy ambition is observed leading to a mandatory saving target of 130 TWh.[23] After two completed years of EEC2, approximately 88 TWh of savings have been realised. Again, the low energy level of the housing stock has allowed parties to yield cost-effective savings mainly from insulation measures. They continue to have clear dominance with a share of 85%, followed by lighting (8%), heating and micro-combined heat and power (CHP; 5%) and appliances (2%), respectively (OFGEM 2007). This activity level reflects the vast saving potential that the British dwelling stock still offers. If one considers also banking activity under EEC1 (see "Banking provision for surplus of TWCs"), the level of energy-saving effectiveness of EEC2 reaches 93% (or approximately 120 TWh) after 2 years of operation; see Fig. 3.

The focus on only one end-use sector has naturally limited the number of eligible measures of the British scheme. However, several measures have been used to meet the target, and the dominance of insulation measures is rather evident. Public authorities remain open to enlarge the list of eligible measures and develop appropriate baselines and methodologies to estimate ex-

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[21] The resulting environmental effectiveness of the scheme can be summarised as follows. Target achievement under the EEC1 was expected to save around 0.5 MtC/year in 2010 (DEFRA 2006c: (1) Notice that this year was chosen as a benchmark because it is the mid-point of the first Kyoto Protocol commitment period. The 0.5 MtC figure was based on assumptions regarding standards of comfort and electricity generation, and heating fuel mixes projected by the authority (see DEFRA 2004b). Once implemented energy efficiency measures counting against target EEC1 are considered (not including banking to EEC2), emissions reductions equate to 0.4 MtC/year in 2010 (including a deduction for estimated deadweight). Considering total UK CO_2 emissions to be approximately 150 MtC/year, of which household emissions contribute 40 MtC/year, the achieved emission reductions represent approximately 1%.

[22] In Great Britain, responsible parties must demonstrate that eligible measures would have not been implemented in the absence of the scheme. *Additionality* can then be justified in financial terms. For instance, landlords of social housing programmes can support obliged parties by providing written evidence of additionality. To implement eligible energy efficiency measures in low-income households, British obliged parties need to receive a written statement from the landlord stating that the measures would not have been implemented outside the programme. However, authorities recognise that it is difficult to draw the line between additional and non-additional measures when local energy efficiency programmes are in place.

[23] Saving targets for EEC1 and EEC2 are not directly comparable. This is because several assumptions in the methodology for estimating the EEC2 target are different from the ones used to determine the EEC1 target (e.g. time dependency of savings, discount rate, etc.). For further details see DEFRA (2004a).

Fig. 2 Energy savings achieved by category of eligible measures under the first phase (2005–2005) of British scheme—EEC1. Data source: OFGEM 2005, pp. 11–66
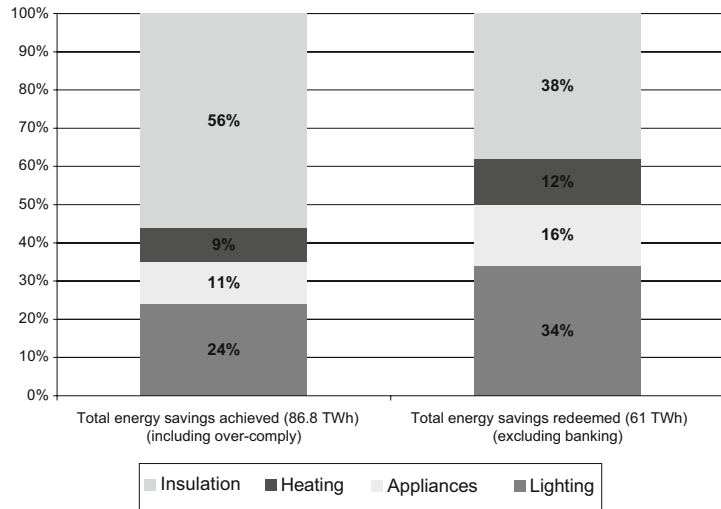
ante savings. Whereas authorities are keen to promote innovative measures, including micro-CHP and micro-generation from renewable sources, it is likely that these measures will have a marginal contribution in the short term because they are less cost-effective (cf. DEFRA 2006b). Moreover, it has been already indicated that due to large potentials, eligible measures will still be cavity wall and loft insulation during the next phase of the scheme (DEFRA 2006b, 2007). For instance, half of the UK housing stock will have loft insulation

Table 3 Eligible measures installed and total realised energy savings under the British scheme—EEC1

	Category/type of eligible measure	Number of measures installed	Achieved savings (GWh)
Insulation	Cavity wall insulation	791,524	25,069.27
	Loft insulation (top up)	528,496	4,138.78
	Loft insulation (virgin)	226,245	9,696.90
	Do-it-yourself insulation (m^2)	15,979,367	8,101.49
	Draught stripping	22,743	38.56
	Tank insulation	195,832	433.50
	Radiators panels (m^2)	38,878	13.39
	Solid-wall insulation	23,730	972.59
	Other insulation	2,625	21.14
Appliances	Energy-efficient cold appliances	2,956,084	7,381.18
	Energy-efficient wet appliances	3,551,737	2,260.32
	Other appliances	93,837	42.49
Heating	A and B rated boilers	278,991	2,361.90
	A and B rated boilers + heating controls	87,497	1,233.47
	Heating controls upgrade	2,366,128	1,220.49
	Fuel switching	41,077	2,763.32
	CHP/communal heating[a]	615	39.03
	Other heating	202	4.66
Lighting	CFLs	39,737,570	20,976.79
Total		66,923,178	86,769.27

Data source: OFGEM (2005: pp. 47–66)

[a] Number of household benefiting

Fig. 3 Cumulative energy savings counting towards EEC2 target (130 TWh) after 2 years (out of three) under the British scheme. Notice the substantial amount of savings (mostly from insulation measures) carried over from EEC1. Data source: Personal communication with Priya Patel, OFGEM
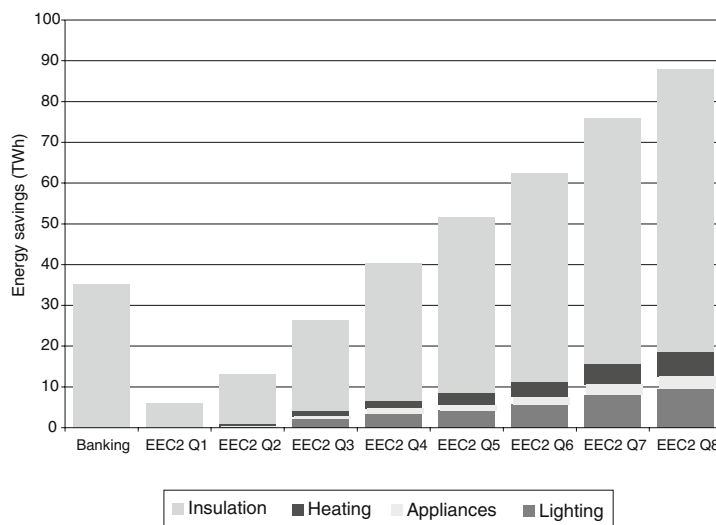
inferior to what is required by law in 2008 (NIA 2006, p. 4). Therefore, a rational option for parties is to continue relying on insulation measures to meet their obligation.

The British scheme grants energy savings based entirely on an ex-ante approach. The experience shows that an ex-ante approach is a reasonable option when a number of conditions exist. This is largely explained by the fact that the size, type and performance of the measures are well known and related estimates use best available data.[24] Thus, it would be inefficient to use an ex-post M&V approach; which would make eligible measures non-cost-effective under this scheme.[25] As a result, the burden of M&V for the regulator has been largely reduced (cf. Adnot et al. 2006a; Capozza et al. 2006; Mundaca 2007a). However, there are risks associated with purely ex-ante schemes, like partial realisation of savings or poor additionality, for instance.

Taking into account implemented measures, several indications of cost-effectiveness for EEC1 were found. Energy savings costs have been estimated to be around 0.8~1.4 Euro cents/kWh for lighting measures and approximately 0.7~1.3 Euro cents/kWh for insulation measures, respectively (Lees 2006, p. 27; Mundaca, 2007a, p. 4349).[26] These figures are lower than the estimated average cost savings of 2.5 Euro cents/kWh generated by the most likely alternative policy option (see OFGEM and EST 2003, p. 17)—and certainly much lower than energy prices paid by households during EEC1, approximately 2.3 and 9.4 Euro cents/kWh for gas and electricity in 2004, respectively.[27] Furthermore, it is estimated that energy savings costs were 20% lower than predicted by DEFRA (Lees 2006, p. 30). Finally, and using energy prices paid by households in 2004 as benchmarks, net financial benefits for end-users are estimated to be 8~8.6 Euro cents/kWh for electricity savings and 1~1.6 Euro cents/

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[24] Usually, the development and usage of M&V approaches depend on the complexities of eligible measures, number of eligible end-use sectors, relevant data available (e.g. baseline, climatic conditions, lifetime and performance of measures, etc.), and the consensus and negotiation between policy makers, regulator(s) and obliged parties.

[25] Personal communication with Iris Rooney (DEFRA) and Charles Hargreaves (OFGEM), October 2005.

[26] Notice that estimates given by Mundaca (2007a; i.e. 0.8 and 1.3 Euro cents/kWh) include transaction costs borne by obliged parties. 1 British pound = approximately 1.41 euro as on December 2004.

[27] At 6.68 p/kWh (approx. 9.4 Euro cents/kWh) for electricity and 1.65 p/kWh (approx. 2.3 Euro cents/kWh) for gas. See DTI (2005). The authority has mentioned that the year 2004 can be taken as the "centre of gravity" of EEC1.

KWh for gas savings (cf. Less 2006:27; Mundaca 2007a:4349).

Eligible end-use sectors used to realise energy savings

Under the Italian TWC scheme, savings can be realised in any end-use sector. As mentioned before, Italian market actors have largely focused on the household and commercial sectors. For the first compliance year, both sectors captured almost 70% of the realised savings, most of them retroactively though. Again, this 'early action' or retroactive option can largely explain the dominance of these sectors because complex M&V issues might have prevented eligible actors to claim savings in the industrial sector. However, this trend could also change if one thinks about the implementation of lengthy measures in the industrial sector—likely to be a large and more cost-effective supplier of TWCs. The development of M&V approaches for the industrial sector is slow, but larger measures will likely be implemented once these methodologies are ready. In turn, this may increase also the burden for public authorities when an actual larger sectoral coverage needs to be monitored and enforced.[28]

As for the British scheme, which covers only the household sector, the number of measures is limited compared to the Italian and French schemes, which covers multiple end-use eligible sectors. However, the level of ambition—as reflected in the energy saving targets[29]—is much higher in the British case. This relatively higher level of ambition than the Italian case also reflects the high energy-saving potential that the household sector offers in Great Britain. Importantly, British parties have faced during EEC1 and EEC2 the requirement that at least 50% of savings must be realised in the so-called priority group. During the EEC1, parties met this requirement by achieving 42 TWh of savings in the priority group—against the 32 TWh required (OFGEM 2005, p. 9). Available data show that parties could maintain a balanced portfolio

of priority and non-priority eligible customers (see OFGEM 2005, p. 10). After 2 years of EEC2, figures show that only 10 TWh (or 5%) of savings remains to be achieved to fulfil the 50% requirement (OFGEM 2007, p. 5).

No political signs can be identified as far as the enlargement of the coverage is concerned. This can be explained, inter alia, by the existing trade-off between a large coverage to boost cost-effectiveness and a higher administrative burden and transaction costs resulting from a larger coverage. In any case, one could think that the limitation of having only one eligible sector could hamper the cost-effectiveness of the scheme. Evidence shows that this has not been the case under the British scheme, as high-saving cost-effective potentials in the insulation segment allowed the EEC1 to yield net financial benefits for the end users (as noted in the previous section).

Banking provision for surplus of TWCs

When analysing the banking of TWCs in the Italian TWC market, one has to bear in mind that unlike Great Britain, TWCs in Italy are issued year-by-year[30] so the scheme does not use lump sum discounted savings.[31] Having mentioned this, indications can be drawn about Italian parties using TWCs for subsequent compliance periods. We estimated that the number of bankable TWCs for 2006 is approximately 130,926 TWCs[32]. This rough estimation corresponds to the total number of TWCs issued in 2005 (i.e. 286,837) minus the number of certificates needed to achieve the saving target for 2005 (i.e. 155,911). This figure may represent an underestimation of TWCs potentially bankable because

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[28] At the time of research, there had been no study on transaction costs under the Italian TWC scheme, thus it remains to be seen whether the coverage of the scheme involves numerous sources and a heavy burden of transaction costs for parties.

[29] Mandatory energy saving targets are as follows: 130 TWh in Great Britain (period 2005–2008), 67 TWh in Italy (period 2005–2009), and 54 TWh in France (period 2006–2008).

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[30] Note that issuances of TWCs is for 5 years in Italy, however for heating and air conditioning the issuance period goes up to 8 years.

[31] Note that under the Italian TWC scheme, 1 TWC = tonne of oil equivalent.

[32] This imply, for instance, that if a given saving measure implemented in 2005 generates 1,000 certificates during the 5 years of its lifetime, 200 certificates are to be issued in 2005, other 200 certificates are to be issued in 2006 and so on until 2009 unless, for some reason, the measure is not capable of generating the same 200 certificates in the years following 2005. In other words, saving measures employed to comply with the 2005 obligation continue generating the same amount of certificates during the following years depending on the year in which they were implemented and on the lifetimes of eligible measures.

not all parties achieved their target obligation by 2005. If the number of obliged parties does not increase, the obligation for 2006 is equal to approximately 312,000 TWCs. Considering that the amount of banking is unlimited, this would imply that about 42% of the 2006 target could be achieved by using the 130,926 TWCs not redeemed in 2005.

Regarding the banking option under the British scheme, many aspects were found. First, the EEC1 was built upon the Energy Efficiency Standards of Performance (EESOP) that ran from 1994 until 2002.[33] Under the EEC1, parties were allowed to carry over savings generated under the EESOP that accounted for up to 10% of each obliged party's target. At that time, nearly 3 TWh in savings were banked for EEC1 compliance, representing almost 5% of the target (OFGEM 2005, p. 52). Second, savings from cavity wall insulation heavily dominated the banking activity (as shown in Fig. 3). Third, parties that did not bank savings were basically new entrants by the end of EEC1. Parties that used the banking option were large energy suppliers. For instance, one of them achieved more than half of its EEC2 target with savings that were carried over from EEC1 (OFGEM 2005, p. 67). Fourth, parties were allowed to bank an unlimited surplus of energy savings from EEC1 to EEC2. Under EEC1, six parties banked savings approximately 25 TWh. Fifth, banking activity during EEC2 has achieved already 10 TWh, and it is likely to increase as the second phase comes to an end.

Regulatory aspects affecting the banking activity in Great Britain have heavily driven most of the trends listed above. Changes in the methodology for accrediting energy savings (e.g. lower discount rate, different heating patterns, etc.) have been critical to determine the level of banking. Adjusted in EEC2 terms, the above-mentioned 25 TWh from EEC1 are equivalent to approximately 35 TWh savings under EEC2.[34] Thus, parties redeemed savings for their EEC1 target that were less attractive for compliance under the EEC2 accreditation methodology (e.g. saving from lighting and condensing boilers). In other words, savings with "higher" values (e.g. cavity wall insulation) were not used to meet the EEC1 target but carried over to EEC2. This pattern can be observed

by comparing the two bars in Fig. 2. In turn, the amount of savings carried over from EEC1 accounted for more than 25% of the EEC2 target (130 TWh). The surplus of savings leading to high banking activity in Great Britain has been also driven by the fact that suppliers wanted to avoid as much as possible the financial penalty in case of non-compliance (i.e. up to 10% of supplier's turnover).

Market engagement of non-obliged parties

Besides obliged parties (approx. 34), another 573 gas and/or electricity distribution companies were entitled to participate in the Italian TWC scheme as eligible parties (see AEEG 2006).[35] Furthermore, the authority accredited more than 550 ESCOs between November 2004 and May 2006. Table 4 shows the level of activity of all these market actors as far as issuance of TWCs is concerned. As observed, the activity level of these eligible parties, in particular ESCOs, has been much higher than obliged parties. Some design features can explain this high activity level. Guidelines developed by the authority in 2003 established a broad or less stringent definition of ESCOs, which has driven the large number of these eligible parties participating in the scheme.[36] However, most of these ESCOs could be merely classified as providers or installers of energy efficiency equipment; which also questions the achievement in terms of energy-saving effectiveness. The share of ESCOs already active is not negligible. This is because many of them are still waiting to participate and others have not reached the minimum threshold of realised

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[33] For further information about EESOP, see OFGEM and EST (2003).

[34] For further information, see DEFRA (2004a, 2005).

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[35] In the created Italian TWC market, the criterion to define an obliged party addresses gas and electricity distributors serving more than 100,000 customers. This led the AEEG to identify 30 obliged companies (with 10 electricity and 20 gas distribution companies). A trade-off between the number of obliged parties and the complexity of the system to be administered is identified. For 2005, the total saving target apportionment criteria adopted in Italy implied that 22% of the total saving target was not apportioned. Lowering such threshold on the amount of clients served could have increased the total amount of savings apportioned. Nevertheless, such an action could have increased the administration burden for the authority to enforce and monitor the TWC scheme.

[36] Companies submitting an energy efficiency project for certification to the AEEG can be considered "ESCOs" if their object includes the provision of integrated services for the realisation and the subsequent possible management of energy-saving measures.

Table 4 Activity level of eligible parties during the first compliance year under the Italian TWC scheme

Eligible party	Issued TWCs (%)
Obliged electricity distribution grid companies	9.1
Obliged gas distribution grid companies	23.8
Non-obliged energy distribution grid companies	2.5
ESCOs	64.6
Total	100

Data source: AEEG (2006)

energy savings required.[37] Other accredited ESCOs have never operated on the spot market as such.

Whilst the typology of actors in Italy is limited, its number is substantially higher than in Great Britain. The high number of other non-obliged parties, including "ESCOs", determines a large market size for TWCs. The broad definition of ESCOs used in Italy might be encouraging the liquidity of the market (at least in terms of market players) but also stimulating free-riding effects. One could argue that the so-called "ESCOs" would have sold or implemented the same level of energy efficiency measures even in the absence of the scheme. In addition, the potential free-riding effect could be magnified by the option to claim savings retroactively, which also contributed had lead to an excess of TWCs. This could also have a negative impact on future compliance periods because of the unlimited amount of banking that is allowed.

The regulatory framework in Great Britain considers obliged parties as all energy suppliers of gas and electricity, serving more than 15,000 customers. They are the only ones allowed to trade savings and obligations. This feature of the scheme has resulted in only eight obliged parties acting on the market, reducing the number of eligible parties as such (cf. Mundaca 2007a; NERA 2006). The British authority has discussed the feasibility to modify the EEC so it becomes a formal TWC trading scheme—so the programme moves away from the current measure-based approach. In doing so, the authority has already pointed out, for instance, trade-offs concerning market liquidity and increased administrative burden. Although a larger number of market actors would increase competition and reduce compliance costs, administrative costs might increase because of monitoring, reporting and verification activities (cf. DEFRA 2006a).

In Great Britain, the legal framework does not have any definition of ESCOs as such. The British scheme promotes instead 'energy service actions' in households (i.e. where an energy audit for a whole house is carried out and at least two measures are installed). To encourage energy service actions, the regulatory framework grants obliged parties an additional credit of 50% of the savings realised. Albeit not defined, ESCOs are in principle eligible to realise savings under the British scheme, but they are not allowed to trade them. ESCOs that want to participate in the British scheme are dependent on the demand of the few obliged parties and are restricted to projects in the household sector. These actions must be carried out under the fulfilment of several legal clauses between the obliged party and the householder (e.g. eligible measures intended to achieve improvements in energy efficiency at the household premises by at least 13%; obliged party is required to undertake an energy efficiency audit, etc.; Gaudioso et al. 2007). It has been argued that some legal aspects (e.g. the '28-day rule' that allows a customer to terminate an energy supply contract on 28 days' notice) might hamper the provision of energy services under the British scheme (DEFRA 2004b).[38] In any case, this does not prevent that energy service actions on behalf of households can be realised (Gaudioso et al. 2007).

Focusing on one critical condition for high liquidity (i.e. large number of actors), the British scheme has embraced a greater typology of market actors than in Italy. Obliged parties have worked together with a number of market actors to deliver and implement measures and thus reduce compliance costs. In fact, it is found that parties have met their obligations partnering strategically with multiple actors. Key players support-

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[37] For ESCOs, the minimum amount of energy savings to be realised is 25 toe/year in case the energy efficiency measures are evaluated via ex-ante approaches, 50 toe/year in case measures are evaluated via the so-called engineering approach, and 100 toe/year in case of measures are evaluated through monitoring plans (i.e. ex-post M&V).

[38] The regulator has stressed several times that it remains open to discuss modifications to the 28-day rule with actual evidence on whether the rule has restricted or undermined any benefits resulting from the provision of energy services.

ing the activity level of obliged parties are as follows (Mundaca 2007a; NERA 2006; OFGEM 2005):

- *Insulation contractors*: To a large extent, obliged parties have relied on subcontracting insulation companies to realise savings. Basically 100% of all insulation was sub-contracted under EEC1. In turn, this increased opportunities for long-term partnerships—vital for parties to meet their obligation—and credibility for insulation products within the household sector.
- *Managing agents*: Obliged parties have also relied, to a lesser extent though, on subcontracting managing agents or 'middlemen' to plan and implement eligible measures. They have also supported parties to identify and bundle end users willing to implement measures. Due to the fact that dealing with managing agents has been considered risky, obliged parties started to reduce their level of outsourcing by creating specialised energy service departments. These units maintain a closed control over agents and contractors because parties still bear the responsibility in case managing agents or contractors fail to deliver.
- *Social housing programmes* (*SHP*) *and charity organisations*: Parties have partnered with these actors in order to identify customers and deliver eligible measures, in particular among the priority group. Through these partnerships, parties delivered insulation, heating and lighting measures. Working together with contractors, a large proportion of insulation measures (60%) were delivered through SHPs. In addition, 16 (out of 24) million of CFLs were distributed via SHP, charities and community groups.
- *Housing developers*: A number of obliged parties have also partnered with housing developers to implement measures. This co-operation has taken the form of parties providing necessary funding to implement insulation measures in new houses to exceed current building requirements.
- *Retailers and manufacturers*: Parties set up partnerships with these actors in order to increase the penetration of efficient appliances. Parties have given financial incentives to retailers to stock more efficient appliances in return for aggressive marketing efforts. In turn, obliged parties used sales data to claim energy savings. Parties have also subsidised market prices and negotiated with retailers/manufacturers rebates for customers. Working together with retailers and manufacturers, more than 6.5 million A-

rated appliances were delivered via a partnership of this type (see Table 3).

It is interesting to notice that, even though the number of eligible parties is restricted under the British scheme, numerous sources of transaction costs have been identified. This includes search for information, persuasion of customers, due approval of proposed measures, negotiation of agreements/contracts with third parties, random quality checks, contract/agreement negotiation and liability risks when trading, and due accreditation of savings.[39] Research shows that the search for information and persuasion of customers are relevant sources of TCs upstream in the scheme (Mundaca 2007a). Nevertheless, even though the estimated scale might appear burdensome (i.e. 10% to 30% of the total direct investment costs for lighting and insulation, respectively), the scheme has yielded cost-effective savings as previously mentioned. Furthermore, despite the fact that the number of identified players supporting obliged parties has triggered more sources of transaction costs, in particular during the planning and implementation phases of measures, these actors have also reduced the burden of transaction costs for obliged parties (e.g. identification of customer willing to implement measures).

Trading activity

The early experience of the Italian TWC shows intensive trading activity, at least compared to the British case. In the first compliance year, 145,796 TWCs were traded—17% on the spot market and 83% through bilateral contracts (i.e. company-to-company, not through brokers or exchanges).[40] The total traded volume represented roughly 50% of the total TWCs issued (286,837) for that period (see Fig. 4). Indications for market actor preference towards bilateral trade can be made. Until the end of the first compliance period, it could be partly explained by the fact that the organised market started on March 2006, only 3 months before the end of the first obligation period. It could also be explained by strategic partnerships between obliged parties and

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[39] See Mundaca (2007a) for an analysis on the nature and scale of transaction costs under the British scheme.

[40] Interestingly, notice that the bilateral market under the EU-ETS is estimated to be substantial. Point Carbon (2007) estimates that the direct bilateral market doubled in size, from 100 Mt in 2005 to 200 Mt in 2006.
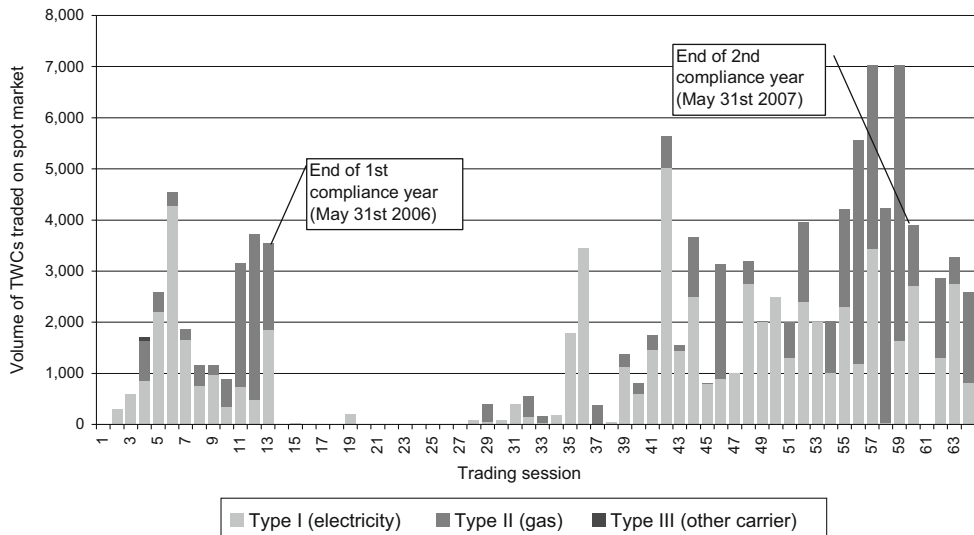
Fig. 4 Volume of TWCs traded on the Italian spot market. Data source: Gestore del Mercato Elettrico SpA 2007. Note that TWC type-III was marginally traded (only under session # 4)

ESCOs, which were set up prior to the establishment of the spot market. In fact, obliged parties with the aim to fulfil their obligation explicitly created some ESCOs, encouraging an 'intra-obliged party' trading. In addition, this could reflect the tendency in electricity and natural gas wholesale markets in which longer, lasting and bigger volume deals on the bilateral exchange are made and conditions can be kept privately (Philipson and Willis 1999). Prices for bilateral trade in Italy are unknown; however, higher values than on the spot market could be another incentive for ESCOs and other non-obliged parties to aim for bilateral trading.

In Italy, trading has emerged showing a clearer tendency towards 'to-trade'—contrary to the British trend (discussed below). For the spot market, the GME launched the registry for trading on February 2006.[41] As shown in Table 5, several market actors have registered since then.[42] With both the registry and electronic trading platform in operation, trading on the spot market

(i.e. organised by GME and as opposed to bilateral contracts) got off the ground on March 2006. During the first year, TWC type-I dominated spot trades (15,253), followed by TWC type-II (10,086). TWC type III was marginally traded. This can be explained by the fact that the cost-recovery mechanism (100 € per each TWC redeemed by obliged parties) established by the authority does not apply to savings related to TWC type III. Overall, the volume of TWCs traded has increased substantially during the second compliance year (see Fig. 4). Whereas nearly 25,000 TWCs were traded

Table 5 Registered market actors during first compliance year under the Italian TWC scheme (until May 2006)

Market actor	Number
Electricity and gas grid distribution companies	32
ESCOs	79
Traders[a]	7
Total	118

Data source: GEM (2006)

[a] A 'trader' means any registered user that is not an ESCO or an electricity/gas grid distribution company. Although TWCs are issued only for eligible measures submitted to the AEEG by ESCOs and electricity/gas grid companies for certification, any market agent is allowed to buy and/or sell certificates on the market.

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[41] Registered market actor pays an annual fee of €300 plus 20 Euro cents per each TWC exchanged either through bilateral contracts or on the market organised by GME.

[42] From the total number of actors, 76 obtained also the qualification of market operators by GME. Within this group, 21 are grid distribution companies, 49 are ESCOs and six are traders.

during the first compliance year, a bit more than 100,000 TWC were traded during the second year. As shown in Fig. 5, prices on the spot market have slightly fluctuated by slowly falling, in particular for electricity savings during the second year. This trend can be largely explained by the fact that the amount of certificates traded on the spot market increased by approximately 300%. TWC-II has been sold at a higher value than TWC-I. This has been driven by the higher volume of TWC type I, which has wider price dispersion than TWC type II (see Table 6). Despite the large number of non-obliged actors, no sign of price volatility is observed.[43]

Using a rather narrow definition of cost-effectiveness, pre-conditions such as common price and trading between parties facing different costs are identified in Italy.[44] However, the potential free-riding effect and possible market power exercised by some obliged parties (see below) add uncertainties to any indication of cost-effectiveness in Italy. In addition, no counter-factual or baseline was available to estimate cost savings resulting from trading.[45]

We found various market and regulatory aspects potentially driving the Italian trading activity. The already-mentioned option to claim unlimited savings retroactively from 'early action', the provision to bank an unlimited amount of TWCs and the less stringent definition of ESCOs may largely explain an excess of TWCs. Furthermore, the mandatory saving target for 2005 represents only a fraction of final energy use in Italy (0.3%). Thus, one can argue that the demand level for TWCs—scarcity determined by the mandatory saving target—is rather low relative to the (excessive) supply of TWC and final energy consumption of the covered eligible end-use sectors. In addition, market actors may interpret that the TWC scheme is only a one off burst policy effort because of the lack of long-term policy goals and political commitment post 2009.

Another factor likely to be driving the Italian trading activity relates to the potential market power exercise by some obliged parties.[46] For instance one obliged party held 90% of the apportioned electricity saving obligation in 2005. Facing an excess of TWCs on the market, this party might be creating monopsonistic market conditions (i.e. only one buyer), driving lower TWC prices. In fact, only handful number of actors constituted demand and supply of TWCs.[47] Moreover, taking into account the excess of TWCs, rent-seeking behaviour is also likely to be encouraged because of the cost recovery rate set by the authorities. Obliged parties obtain €100 for every TWC redeemed so they pocket the difference, i.e. windfall profits.[48] To confirm this rent-seeking behaviour, notice that a rather marginal number of TWC-III, which has no associated recovery rate, has been traded since the beginning of the spot market (see Figs. 4 and 5). The rent-seeking behaviour raises distributional equity concerns, as obliged parties could be getting windfall profits at the expense of taxpayers.

Concerning trading activity in the British scheme, trading has occurred but to a much lesser extent than in Italy. Despite speculations that no trading at all had occurred during EEC1, evidence proves the contrary. For the *trading of obligations*, two trades were identified (cf. NERA 2006; Mundaca 2007a). First, one party (EDF Energy) took over the entire obligation—nearly 100 GWh—of another party (Dee Valley; OFGEM 2005). Second, 'Opus Energy' and 'Telecom Plus' decided to meet their obligations jointly. In terms

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[43] High volatility is understood as sudden up and down movements of spot market prices over very short time periods.

[44] Ellerman (2003) uses a similar conceptual approach to address economic efficiency for the SO_2 cap-and-trade programme in the US. The author looks at the emergence of the market and volume of permits traded as primary evidence for economic efficiency—welfare effects (e.g. social benefits and costs) are not taking into account.

[45] Notice that ex-post evidence of administrative and transaction costs has not yet been produced.

[46] Market power is herein understood as how an obliged party under a TWC scheme can manipulate the market to its own advantage.

[47] During the period January 2005 to May 2006, the number of buyers and sellers was distributed as follows (AEEG 2006): (a) On the demand side, 16 companies bought TWCs via bilateral contracts only, 13 companies bought TWCs on the open market only and seven companies used both options. (b) On the supply side, 10 companies sold TWCs via bilateral contracts only, six companies sold TWCs on the open market only, six companies used both options, and (c) five companies (two of which were obliged actors and three ESCOs) both bought and sold TWCs. With the exception of the five companies that both bought and sold TWCs, the AEEG did not specify whether the companies above-mentioned were obliged actors or ESCOs, or eligible gas and electricity distributors.

[48] Note that according to Bohi (1994), if the regulator determines favourable cost-recovery mechanisms, parties are unlikely to engage in trading even when the cost of certificates are lower— a situation that could be seen in Italy.
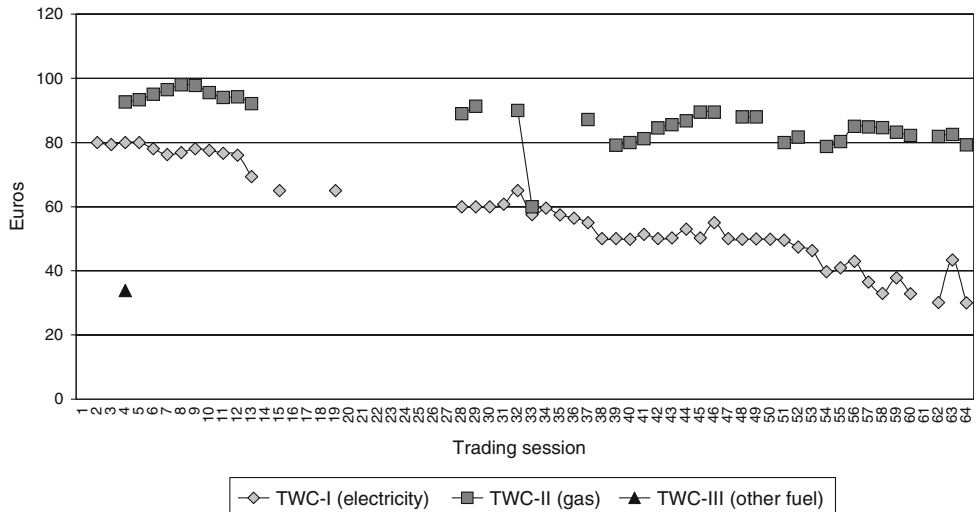
Fig. 5 TWC prices on the Italian spot market (Euro per TWC), March 2006 to June 2007. Data source: Gestore del Mercato Elettrico

of *trading of energy savings*, six obliged parties purchased energy savings retroactively but generated under other government programmes (e.g. Warm Front programme[49]). A retroactive 'trading' option was given only during EEC1. According to OFGEM (2005, p. 56), these retroactive trades contributed to 16% of all cavity wall insulations implemented under the EEC1. In financial terms, one of the managing agents of the Warm Front programme EAGA reported that around £10 million in energy savings were sold to parties during 2003–2004 (House of Commons 2004, p. 25). All trades were reported to OFGEM, which provides written approval to parties involved in trading. However, parties are not required to submit related financial data.

A number of interconnected drivers affecting the low EEC1 trading activity were found. Among others, potential commercial benefits of non-trading (see "Approach of British obliged parties" for further details), excess of individual supply of savings (driven also by a high cost-effective potential in the insulation segment and certainty about the penalty in case of non-compliance), limited number of eligible parties (raising high potential for market power) and perceived transaction costs (related to contract negotiation and

liability risks) were identified as critical factors deterring trading (cf. Mundaca 2007a; NERA 2007). The banking option also influenced a non-trading behaviour, as parties have seen the scheme as a rolling programme and increased their own activity level to use savings for further commitment periods (also driven changes in the accreditation of savings—as described in "Banking provision for surplus of TWCs"). Furthermore, the number of eligible parties has been restricted because only obliged parties are allowed to trade, reducing liquidity. This is crucial because large differences in saving costs among parties are also necessary to trigger trading. Obliged parties also thought that trading activity could embrace high negotiation costs, as strategically sensitive information could be disclosed

Table 6 Price statistics for TWC types I and II on the Italian spot market

	Type I (electricity)	Type II (gas)
Mean	56.3	86.5
Median	54	86.7
Standard deviation	14.5	7.3
Minimum value	30	60
Maximum value	80	98

$N=64$ trading sessions (March 2006 until June 2007). Values in Euros (nominal)

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[49] For further information, visit http://www.defra.gov.uk/environment/climatechange/uk/household/fuelpoverty/.

to a buyer/seller. In all, these factors have favoured market behaviour towards 'not-to-trade'. In addition, limited trading may have been also affected by a high concentration of obligation in certain actors and the need of approval from the authority.

Firm evidence of equalisation of marginal costs in Great Britain does not yet exist; however, with a handful numbers of actors dealing with similar contractors and third parties, saving costs were likely to be very similar so trading could add only marginal financial gains. Importantly, interviewees indicated that trading was not necessary because compliance costs were already equated during the competitive bidding process of subcontracting insulation measures—which have heavily dominated realised savings.[50]

Regarding trading activity during EEC2, no available data have yet been reported. However, due to the fact that cost-effective energy efficiency/Great Britain improvements in may soon be used up, trading is likely to arise as one concrete 'flexibility' for parties to meet their targets cost-effectively. In fact, British authorities have considered whether the EEC could formally operate as a TWC scheme from 2011 onwards (see DEFRA 2006a). However, it is unclear whether a more formal TWC approach would yield additional benefits to the ones delivered already by the scheme (DEFRA 2006a; NERA 2006).

Potential commercial benefits of non-trading behaviour for obliged parties

The lack of trading activity in TWC markets (as described for Great Britain in "Trading activity") has triggered concerns that obliged parties are not taking advantage of the cost savings that trading can generate. Indeed, stakeholders have mentioned that if a non-trading pattern exists, TWC schemes are significantly less cost-effective than expected—unless the costs of achieving the saving target are negative or zero for all obliged parties. The non-trading behaviour has revived discussions among scholars and policy makers about the to-trade-or-not-to-trade dilemma (i.e. preference to trade TWC or not). Besides several market and regulatory drivers identified, very little attention has

been given to commercial benefits of non-trading, and drivers behind this pattern have not been fully addressed.

Approach of British obliged parties

As found, a low level of trading activity characterised the EEC1. Among them, interviews with obliged parties revealed two important commercial benefits of increased energy efficiency that provided little incentive to engage in trading.

The first benefit relates to *attaining strategic knowledge* about energy efficiency. Although the EEC was built upon the EESOP, energy efficiency was still a new activity for obliged parties. Thus, instead of relying on a competitor for meeting their obligations, parties embarked to autonomously meet their target. As the EEC becomes a rolling programme, a strategic learning process has been crucial for obliged parties to gain the necessary operational knowledge of meeting their obligation in the long run. In turn, this knowledge has become a key building block for some parties that have taken energy efficiency, encouraged by the EEC, as a business opportunity (see below). They started to hire and train staff, and create energy service units to handle their obligation. It is found that all current obliged parties provide advice and support their customers to increase energy efficiency.

The second benefit relates to *increased competitiveness*. Some obliged parties have considered energy efficiency as a business opportunity for enlarging their product and customer portfolio. Interviews with some parties revealed that EEC1 triggered a change in their business paradigm, leading to corporate efforts for enhancing customer loyalty and branding (Mundaca 2007a).[51] Driven by climate change policies, energy companies have started moving away from the traditional energy supply business. More importantly, customer mobility appears to be the main driving force to use energy efficiency as a strategy to increase client loyalty. In fact, the already mentioned '28-day rule' for domestic energy service contract—that prevents households from being locked into long-term energy contracts—has also encouraged obliged parties to use the EEC as an investment mechanism to ensure long-term commercial relationships with their clients. A concluding argument in

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[50] Interviews with British obliged parties were carried in October 2005 and March 2006. Some results were partly published in Mundaca (2007a).

[51] Ibid.

this aspect also came from the fact that, for some parties, buying energy savings from another company was understood as strategically 'non sense', as it would imply direct financial support to the brand of a competitor (Mundaca 2007a). One interviewee pointed out that trading was unacceptable for executive board members.

Supplementary and more explicit indications about how the EEC is being used to boost the competitiveness of obliged parties are observed when reviewing recent annual reports. With an exclusive corporate focus on energy efficiency, EDF UK has delivered a commercial report fully dedicated to the EEC "calling for greater action to be taken on energy efficiency across Europe" (EDF 2006, p. 1). It is claimed that the EEC has brought benefits not only to households but also to EDF business. Furthermore, the EEC is seen as a value driver also for increasing staff awareness and reducing costs (e.g. because of competitive bidding process). Centrica—who owns British Gas, another obliged party—claims "our commitment to meet the growing consumer demand for energy services will be at the heart of our endeavours" (Centrica 2006, p. 1). In its corporate responsibility policy report, Scottish and Southern Energy (2007) mentions that is committed to promote energy efficiency amongst its customers. It has an energy service business unit that provides a range of products and 'beyond-the-metre' services to all end-use sectors.

Now, why have these benefit aspects of non-trading not been identified in Italy? A possible explanation lies in the design of the scheme. Obliged parties are distributors of energy, not suppliers as in Great Britain or France. For gas and electricity distributors, commercial benefits of increased energy efficiency might be less appealing or difficult to capitalise in the distribution businesses, as they do not have direct access to end users. Italian obliged parties do not have to deal with increasing customer mobility, as their direct clients are energy suppliers instead.

Early indications from a relevant French obliged party[52]

Early trends in the French TWC scheme also indicate that commercial benefits of non-trading might drive a non-trading pattern. We focus on EDF as this is the largest obliged party that bears 55% (30 TWh) of the total obligation (i.e. 54 TWh)—among 2,400 energy suppliers. Because of its high market obligation, it is likely that its strategic approach will influence much of the characterisation of the French TWC market.

To begin with, the business model of this party focuses on the changing role of energy suppliers towards creating value out of energy efficiency. Driven also by climate change policy aspects, this company wants to position itself as a provider of energy efficient and low-carbon solutions downstream on the energy market. Increasing the provision of energy services and integrated micro-scale renewable energy technology systems might do this. EDF claims that a TWC scheme represents an opportunity to strengthen and thus materialise this new business model. The company views it as a clever regulatory approach to encourage market change through energy suppliers.

Important to our study is the fact that the company has stated that it aims to increase its competitiveness by meeting its obligation autonomously. The TWC scheme is perceived as an opportunity to strengthen its business model. It is claimed that by integrating energy efficiency into its core business, increased competitiveness becomes a relevant benefit resulting from the (intended) decision to dismiss the trading option a priori. The most likely inter-organisational learning and strategic process between EDF France and EDF UK could also explain this approach. Based on its business model, indications of the intended autarky approach derived from:

- Introducing energy efficiency in all market segments, with specific targets for marketing and sales staff.
- Increasing capacity building for the supply of 'energy services',[53] partnering with ESCOs, manufacturers, retailers and contractors of efficient measures.
- Increasing demand of energy efficiency by launching customer awareness raising campaigns and advice centres, including the provision of soft loans.

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[52] For details, see Urvoas (2007) and Urvoas et al. (2007).

[53] The term *energy service* refers to the delivered benefits of useful energy consumption such as heating, refrigeration, lightning, cooking, transportation, etc., as opposed to the simple provision of units of energy as such (see Blok 2006; Johansson and Goldemberg 2002).

- Developing R&D programmes for integrated solutions and customer behaviour.
- Purchasing TWCs to third parties only when the market price is substantially lower than its own energy-saving costs.

It is unknown whether other obliged parties will adopt a similar business strategy; nevertheless, one has to consider that due to the high concentration of the obligation in only one party, market power is likely to arise in France—at least during the 'training period', as the French authority has described the scheme so far. EDF could influence the performance of the TWC market by setting TWC prices, which would create monopolistic (seller) or monopsonistic (buyer) conditions. Furthermore, given its high market share, the firm can exploit economies of scale in the implementation of measures. In any case, one has to bear in mind that the supply and demand of TWCs could be very sensitive to price changes and affect the EDF autarky position. This is relevant because high price sensitivity of TWCs supply could deter an obliged party with market power to benefit of its high market/obligation share (cf. Hahn 1984).

'Food for thought' from a simulated EU-wide TWC market

Based on game theory, we undertook a simulation study to explore the feasibility and desirability of trading under an EU-wide TWC scheme. In this section, we focus exclusively on aspects relevant to non-trading market behaviour. For details about the simulation exercise and its outcomes, see Adnot et al. (2006a, 2006b, 2007) and Duplessis et al. (2007). Project results and interviews with key stakeholders were used to design and simulate features of different TWC schemes. Appointed as obliged parties, a certain number of players were recruited among national stakeholders and project partners (from Austria, Bulgaria, Finland, France, Italy and the UK) to represent TWC demand. To simulate the TWC supply, we built a mathematical model based on technical and financial data of existing energy-saving potentials existing in the participating countries.[54]

Three different schemes were simulated and trading sessions took place via internet. During each of the three simulation rounds, a national saving target was established for each of the participating countries: 3% of domestic annual electricity demand in the end-use sectors considered for the supply of TWCs. Such a target was apportioned among the players of the same country (representing electricity suppliers) who could choose whether achieving their target by (a) implementing end-use energy-saving actions within their customer portfolio, (b) buying TWCs during the 12 market sessions (simulating 12 quarters of a 3-year compliance period) and/or (c) paying penalties at the end of such a period. An over-the-counter international market consisting of bilateral trades was designed for the first simulation round.[55] For the second and third round, simulated national TWC schemes integrated into an EU trading platform were analysed.[56] This entailed completely anonymous TWCs made of national surpluses that could be traded internationally either in one market session at the end of the simulated 3-year obligation period (second round) or during each market session across the obligation period. All simulation rounds allowed testing market access, auctioning rules (how bids were handled), market transparency and how variations of these features affected the size and distribution of trading flows as well as price development.

Findings suggest scarce interest towards cross EU-trading activity. For instance, during the third simulation round, only 9% of the issued TWCs were exchanged amongst obliged parties. At the same time, the observed TWC price remained almost constant during the first 10 trading sessions simulated, and such a price was significantly higher than its *own* energy saving costs. The dominant strategy for players was to regularly implement eligible measures within their portfolio of customers to meet their obligation cost-effectively. What seemed also observable from the bidding behaviour is that some participants were primarily driven by target fulfilment—

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[54] Such computational model automatically determines the number of TWCs available at a given price.

[55] Interviewees indicated that bilateral trading could be a preferred alternative compared to an open trading platform. This hypothesis is confirmed by the experience in Italy in which bilateral trades have dominated the trading activity so far.

[56] It has to be pointed out that the games carried out were in fact *auctions* instead of bilateral trade or trade via an exchange. This is because players were not informed about TWC spot price (at the opening of each market session, the 'auction master' gave only indications about TWC average price in previous sessions); the consequence of this was that there was *only one way trade* with the auction master according to predefined auctioning rules (how the TWCs exactly came from different saving potentials in different countries remained largely in the dark for the players).

triggering over compliance—and others by cost mini-misation.[57] In turn, an excess of TWCs was observed and partly explained by the penalty of €50/TWC in case of non-compliance.

The observed non-trading behaviour might be partly but not totally explained by the design of the simulated TWC scheme. Indeed, such design attempted to capture the potential loss of gross income of energy suppliers due to increased efficiency and its possible compensation by an increase in customers' loyalty. This feature was simulated by decreasing the obliged party energy-saving costs by 20% when TWCs came from their own customer portfolio. This incentive turned out to be relevant for driving a self-sufficiency compliance approach; however, this bonus was accounted at the end of the simulation game, so it was not explicitly represented when trading actually took place. Other reasons for the observed non-trading behaviour could be found in the misinterpretation of the rules by some players and also by the discontinuous participation in the trading sessions by some others.[58] Nevertheless, these issues were registered with very few players and do not seem to explain the observed trend.

Interviews performed with stakeholders when designing the exercise prior to the simulation game seem to support the thesis of scarce interest towards cross-EU trading. This may be partly explained by the awareness among players of the benefits that energy-saving measures implemented with their own customers might produce. At that time, interviewees representing energy suppliers in particular argued that implementing eligible projects would have a negative impact on energy sales but a positive effect on customer loyalty. For the latter, they mentioned that the implementation of measures within their portfolio of customers would be a rational strategy to secure or increase the number of customers and eventually also boost a hypothetical "green business image". Interviewees mentioned that increased energy efficiency,

triggered by a TWC scheme, should be seen as an opportunity to enhance competitiveness and differentiate from competitors. In fact, stakeholders from countries familiar with energy efficiency programmes stressed the view that the provision of energy services could be taken as a strategy to secure customer loyalty—moreover, in competitive energy markets in which fierce competition for clients exist. In all, interviews revealed that game players were conscious about ancillary benefits of increased energy efficiency. However, although the existing awareness of such benefits might partly explain the non-trading behaviour during the simulations, it has to be mentioned that such awareness was observed in particular in players from countries in which real TWC schemes are implemented. Therefore, it cannot be excluded that a different group of players from different countries could have yielded a different trading behaviour.[59]

Discussion on non-trading aspects under TWC schemes

Ellerman et al. (2000) argue that competitive trading markets will develop when policy design and implementation are encouraging. Although trading activity has shown opposite patterns in current TWC schemes, a number of exogenous and endogenous factors influencing trading can be identified. Among them, fierce customer competition, market liquidity, early/retroactive saving action, existence (or not) of a trading platform, transaction costs, cost-effective saving potentials, additionality, banking and familiarity with trading markets. It is clear that TWC markets are quite new so obliged parties do not have much of trading experience or business models to cope with this new policy instrument.[60] Still, we identify that policy makers can take several measures to encourage trading in TWC markets. Certainly, an ambitious energy saving target is a key

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[57] For example, it is remarkable that minimum and maximum price levels did not converge during the first simulation round; this fact in conjunction with the development of the average price level from Q1 to Q12 indicates that several participants either did not learn much (from an economic viewpoint) or were—at least in some quarters—guided by non-economic criteria. Personal communication with Adriaan Perrels (VATT), June 2006.

[58] For instance, one player decided to retain a surplus of TWC at the end of the obligation period, although no banking option was envisaged by the simulation rules established.

[59] To advance research in this area, future simulations should include a control group of players and explicitly represent obliged party's decision-making behaviour as far as commercial benefits of energy efficiency are concerned. Behavioural and experimental economics can greatly contribute to this task.

[60] Evidence shows that many obliged parties were unfamiliar with trading during the beginning of the SO_2 cap-and-trade programme in the US. This aspect motivated parties to exercise an autarky compliance policy (see Bohi 1994).

pre-requisite. Furthermore, the implementation of a clearinghouse to provide information about market prices, volumes and parties (both spot and bilateral) should be considered, thereby increasing transparency. A clearinghouse can keep market actors updated and well informed about the dynamics of the TWC market and its regulatory framework. In addition, an electronic trading platform can reduce transaction costs (e.g. search costs) by setting the place where buyers and sellers can meet up regularly, allowing bids and bilateral trading as well. The development of standardised contracts (or at least key contractual provisions) can reduce transaction costs related to legal services and perceived liability risks when trading. In Great Britain, the need of written approval for trading from the authority could be dismissed.

A non-trading trend also reminds us that trading is relevant but not an objective per se in TWC schemes—as in any tradable certificate scheme. We must remember that the trading component aims at enhancing the scheme's cost-effectiveness to meet a mandatory energy saving target at lowest cost. In line with some critics in the context of a cap-and-trade scheme for greenhouse gases (cf. Greenspan Bell 2005), we concur with the fact that what really matters in TWC schemes is the 'target' as such. Target compliance depends on many factors, among them, a functioning and enforceable regulatory framework. However, a crucial pre-condition to determine the demand level for TWCs is the establishment of mandatory energy saving/efficiency targets. If increased energy efficiency improvements are left to market forces alone, 'business-as-usual' trends are likely to be expected. Currently, the level of ambition of the mandatory saving targets of all implemented TWC schemes can be considered low as far as final energy consumption (on an annual basis) of the eligible sectors is concerned. For France, the saving target level equates to a reduction on energy consumption of 0.14% per year; for Italy, 0.3%; and for Great Britain, approximately 0.6% (Mundaca 2008). Undoubtedly, more ambitious targets can influence the trading activity and, thus, the scarcity of TWCs in the long term, driving a more dynamic market behaviour.

The findings on non-trading behaviour stress ancillary benefits with increased energy efficiency. Whereas regulators and observers seem to be mainly concerned with the cost savings that can be accomplished through trading, obliged parties—at least in Great Britain and France—also seem interested in commercial benefits of

increased efficiency. At first, it seems that parties might not be taking full advantages of TWC schemes, hampering the underlying cost-effectiveness rationale. However, we found that a non-trading behaviour is also explained by corporate and commercial strategies aimed at capitalising several ancillary effects of increased energy efficiency. As indicated by the British experience, the intended strategy of the main French obliged party and the market behaviour in the simulation exercise, policy makers and interested observers should not hold their breath for trading activity to take off. At least in the short run, it is likely that this is not an immediate outcome of TWC schemes. Although several aspects affected the trading activity in Great Britain, our findings suggest that commercial benefits associated with increased 'branding' and 'customer loyalty' could yield higher financial gains for parties than the cost savings resulting from trading. However, it remains to be seen whether this approach is an optimal choice for parties. At the EU level, one can also argue that a national autarky approach may be adopted to guarantee that ancillary benefits (private and social) of increased energy efficiency are captured nationally (e.g. reduced local negative externalities from power production, increased security of energy supply, etc.).[61] As suggested by the simulation game, distributional effects might trigger scarce interest towards international trading. Altogether, findings seem to support the hypothesis that distributional effects might deter international trading if an EU-wide TWC scheme were implemented (Mundaca 2007b). Non-trading aspects remind us that efficiency can be gained at the expense of equity—a complex trade-off and political issue.

Finally, one should consider that a TWC scheme could still be efficient even if limited trading and liquidity is observed. In fact, it is argued that a trading scheme in which no trading activity takes place is still likely to yield lower cost savings than a command-and-control approach. This is because obliged parties still have more flexibility in choosing their technological options (Stavins 1995; Tietenberg 2006). As shown, a high cost-effective potential in the insulation segment has allowed the British scheme to yield net financial benefits for end users. Indications of economic efficiency (i.e. maximisation of net benefits for the society) exist. It is estimated that for every euro saved in electricity costs,

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[61] See Mundaca (2007b) for a discussion on potential distributional socio-economic effects of an EU-wide TWC scheme.

another 56 to 92 Euro cents/kWh were obtained because of social and environmental benefits from the reduction of atmospheric pollution of power generation (Mundaca, 2007a, p. 4349). These figures do not change significantly if one considers administrative and enforcement costs borne by the regulator. Public expenditure was approximately 1.4 million euros (£1 million; see OFGEM 2005, p. 4), a marginal figure compared to the overall level of private investment costs, approximately 970 million euros (£690 million; see Lees 2006, p. 27). A recent study on the economic efficiency of the first phase of the British scheme estimates net present values for the society within the range of approximately €1,660 to 1,830 Million (see Mundaca 2008).

Conclusions

The objective of this study was to provide empirical evidence of market behaviour under TWC schemes. We focused our analysis on the full set of existing flexibilities present in the British and Italian TWC markets. We argue that the analysis of all flexibilities and potential ancillary effects (not captured by TWC trading) is crucial to have a holistic understanding of market behaviour under TWC markets. A non-trading pattern was identified so the 'to-trade-or-not-trade' dilemma was further explored. We have focused on cost-effectiveness as an evaluation criterion only. Our results are rather case-, policy- and country-specific; therefore, the analysed market behaviour and identified performance respond to the unique design, policy and market conditions in which the studied TWC schemes are implemented. Findings suggest that the overall market activity is dynamic and slowly emerging. However, further research should aim at 'de-linking' the effects (impacts and outcomes) of TWC schemes from other policy instrumentsa complex evaluation challenge.

In terms of cost-effectiveness, clearer indications can be drawn for Great Britain than for Italy. Concerning the former, indications that the scheme has met the target cost-effectively come from several angles: lower saving costs than an alternative policy option, equalisation of marginal costs during the bidding process of insulation measures, energy saving cost lower than expected and lower than energy prices paid by households. Even though trading activity was rather limited, trading did occur during the first phase of the British scheme. However, little can be said

about savings resulting from trading because parties are not required to disclose any related financial information. Regarding Italy, pre-conditions such as common price and trading between parties facing different costs are observed; however, the identification of an alternative policy instrument and development of a credible counterfactual situation remain as a challenge for a thorough evaluation under this criterion. For instance, we were not in the position to ascertain whether the substantial volume of trading (approximately 50% of the total TWCs issued) had an important cost reduction. Furthermore, the potential free-riding effect and the eventual market power exercised by some companies add complexities and uncertainties to this element. Regardless the identified design drawbacks, it can be concluded that obliged parties are using, to some or to a large extent, all of the flexibilities granted to comply cost-effectively. Our study shows that high liquidity is crucial for parties to take full advantage of all given flexibilities.

Concerning energy-saving effectiveness, the Italian scheme achieved the imposed targets for the first year; however, the potential free-riding effect created by the retroactive option to claim savings, combined with the less stringent definition of ESCOs and the unlimited amount of banking, prevent serious assertions in this regard. Concerns about the free-riding effect in relation to the early action provision are valid because it is unclear which proportion of eligible technologies were actually implemented in anticipation of the scheme or as a result of business-as-usual market trends. In addition, the low ambitious savings target questions its early performance. One can argue that a high energy-saving effectiveness is observed but at the expense of soft targets and pitfalls in the regulatory framework. Target compliance under the British scheme was nearly perfect, with a minor shortfall during its first phase. Parties relied on large cost-effective potentials in the insulation segment to meet their targets independently. Until now, mostly commercially available eligible measures have been implemented so technical change does not seem to be encouraged. However, this trend could change in the near term when the most cost-effective potentials are exhausted. In sum, our study shows that the integrity and effectiveness of a mandatory energy-saving target relies critically on how ambitious the target is, effective non-compliance rules, due enforcement, stringent and enforceable definition of additionality, and reduced free-riding effect. Furthermore, it also depends on energy

efficiency potentials in eligible end-use sectors, and thus the variety and related costs of current and new eligible measures that can yield those potentials. We suggest that the energy-saving effectiveness of TWC schemes should be weighted against the level of ambition that the saving targets involve. This level appears to be low when measured as a proportion of final energy consumption of eligible sectors—under 1% in all cases. Ambitious energy saving targets will trigger a more dynamic usage of all flexibilities and, thus, an active TWC market behaviour.

Initial market and institutional conditions strongly suggest that trading might not be an immediate outcome of TWC schemes. On one hand, a real TWC market has emerged only in Italy, in which obliged parties are energy distributors. Trading volume has increased, which shows a clearer preference towards 'to-trade' than in Great Britain. On the other hand, British parties (i.e. energy suppliers) have shown a clearer inclination towards 'not-to-trade' and seem to be more interested in increased competitiveness resulting from energy efficiency project activities. Combined with strategic commercial aspects, low market liquidity, a high penalty fee in the case of non-compliance, a banking option, among others factors, trading did take place but to a much lesser extent than in Italy. Obliged parties have been actively using the banking provision—at least under the British scheme. In Great Britain, the pattern was predictable as regulatory certainty encouraged parties to rationally and cost-effectively use the banking option. As the British regulatory framework evolves eventually towards a certificate-based market and cost-effective potentials become gradually used up, trading is likely to emerge in the long-term. Nonetheless, policy makers still have room to implement a number of policy measures to actively encourage trading. In all, findings strongly indicate that a simple but effective institutional framework is crucial for parties to take full advantage of given flexibilities. A secured long-term policy horizon is relevant to reduce regulatory uncertainties so obliged parties can factor the costs and benefits of increased energy efficiency into their business plan. Political commitment is critical in ensuring confidence in emerging TWC markets.

Finally an interesting, perhaps unexpected, outcome of TWC schemes seems to be their ability to influence the traditional business paradigm of energy suppliers towards increased energy efficiency. At first, it appeared that companies are not taking full advantage of trading.

Despite numerous markets and regulatory drivers preventing trading, corporate business strategies aimed at increased market competitiveness also drive a non-trading behaviour in Great Britain and France. With due limitations, the simulation game also revealed a national autarky approach under a hypothetical EU-wide TWC scheme. From a policy perspective, it still remains to be seen whether benefits of non-trading and positive externalities of increased energy efficiency—which also seem to influence a national autarky approach—add or not to the overall efficiency of TWC schemes. These findings seem to counterbalance the complex political factor for policy makers to force energy suppliers to actively save energy; boosting the political feasibility of TWC schemes. Further research on industrial competitiveness and positive externalities of increased energy efficiency needs to be done—posing a serious challenge for a thorough assessment. Aspects related to non-trading patterns strongly suggest that the performance of TWC schemes should not be evaluated exclusively on the basis of trading.

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A multi-criteria evaluation framework for 'Tradable White Certificate' schemes

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Abstract

Recent years have witnessed regained political momentum on energy efficiency and interest in establishing markets is growing. As a result, 'Tradable White Certificate' (TWC) schemes of differing design have been implemented in Great Britain, Italy and France. Greater attention is also being paid to justifying and evaluating such schemes. In this paper, we develop and apply a multi-criteria framework for evaluating TWC schemes - an approach that covers their individual design features. A broad evaluation is conducted regarding energy-saving and environmental effectiveness, economic efficiency, cost-effectiveness, transaction costs, political feasibility, the administrative burden, and technical change. The results show the design and performance of TWC schemes to be case and context specific thus generalisations are inappropriate. This evaluation supports the cost-effectiveness modelled for the British scheme and the assumption that a TWC scheme is an economically efficient policy instrument. For the other, more complex TWC schemes, more data and experience are needed to judge their merit. On the whole, a multi-criteria evaluation requires considerable data and various complementary methods. However, the proposed framework does improve the understanding of the broad effects and attributes of TWC schemes. It deals with various empirical and normative aspects that can be applied on their evaluation.

Keywords: Energy policy evaluation; multi-criteria, tradable white certificate schemes.

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1. Introduction

Growing concerns about climate change, combined with various economic and social aspects are encouraging governments and policy makers to refocus efforts to improve energy efficiency. When the EU addresses challenges such as climate change, energy supply and economic competitiveness, energy efficiency plays a horizontal role (European Commission, 2007). Indeed, increased energy efficiency is one of the cornerstones in the proposed new EU energy policy and is considered a cost-effective way of tackling multiple policy objectives. The EU Action Plan for Energy Efficiency targets estimated cost-effective potential above 20% by 2020 (European Commission, 2006:6). Overall, new policy frameworks are based on business-as-usual being insufficient to realise existing cost-effective energy efficiency potentials and many market barriers and imperfections still need to be eliminated. Aligned with this scenario, policy makers seek new policy instruments that can change or optimise current patterns of demand-side energy consumption.

This policy situation has increased member states' interest in creating markets for energy efficiency. Recent years have witnessed the design and implementation of 'Tradable White Certificate' (TWC) schemes with this objective. The intention is to achieve mandatory energy savings at the least possible cost. They are also motivated as instruments to reduce governments' administrative burden and expense. France, Italy and Great Britain have implemented TWC schemes, while others have embarked on ex-ante studies and/or implementation (e.g. the Netherlands, Denmark and Poland).

In simple terms, a TWC scheme sets a mandatory energy saving target that certain market actors (e.g. energy suppliers or distributors) are required to meet by implementing energy-efficiency measures in defined end-use sectors over a given period. Energy savings are measured and verified using different approaches and credited with certificates. To ensure parties meet their targets, regulators require verification in the form of certificates, usually by the end of the compliance period. The key theoretical argument for the choice of TWC scheme has relied on meeting a mandatory energy saving targets cost-effectively by granting the obliged parties extensive flexibility (on, e.g. eligible measures, end-use sectors and parties, as well as on banking and trading).[2] As in any tradable permit scheme, flexibility is crucial because it allows market actors to decide how to meet their target cost-effectively. With the purpose of equalising marginal compliance costs, parties have the option of trading TWCs to meet their individual targets. In the case of non-compliance, obliged parties are penalised. In the past few years, the literature on TWC schemes has grown rapidly. For in-depth descriptions of TWC schemes, see, for instance, Bertoldi and Rezessy (2006), Capozza et al. (2006), Hamrin et al. (2007), Langniss and Praetorius (2006), Monjon (2006), Mundaca and Neij (2006a), Oikonomou and Patel (2004), Pavan (2002), and Voogt et al. (2006).

The growing interest in TWC schemes has brought an increased awareness of their *evaluation* and *justification*. On the one hand, much of the actual implementation of TWC schemes has relied on the rationale of benefits resulting from increased energy efficiency (e.g. climate change mitigation, improved energy security) and a lack of evaluation methods can be discerned. On the other hand, and despite the complexities involved in TWC schemes, the handful of analyses that have been made use economic modelling tools mainly addressing the cost-effectiveness criterion (see Farinelli et al., 2005; Mundaca, forthcoming; Oikonomou et al., 2007; Perrels and Tuovinen, 2007). While modelling studies do provide useful insights, stakeholders should bear in mind that these outcomes

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[2] Whereas obliged parties are responsible for meeting mandatory energy saving targets under TWC schemes, eligible parties face no obligation but are allowed to participate in the TWC market in order to increase its liquidity.

must be viewed with due caution given the assumptions and limitations involved in the approach (e.g. well-defined consumer preferences and unbounded rationality). [3] Furthermore, conventional modelling tools barely captured investment decision processes and behavioural aspects (Hourcade et al., 2006). They also fall short in capturing policy-making styles and regulatory frameworks (Greening and Bernow, 2004). Finally, whereas the policy formulation of TWC schemes involves a variety of stakeholders with different preferences and interests, a single criterion evaluation approach (i.e. cost-effectiveness) seems inappropriate in addressing the context in which the policy instrument is formulated and implemented (cf. Greening and Bernow, 2004; Harrington et al., 2004). The lack of thorough evaluations can be partly explained by the fact that the development of policy evaluation in the energy field in general has been rarely carried out and practices are not well harmonised (Blok, 2006; Vreuls et al., 2005).

To systematically capture the impact and outcome of energy efficiency policy instruments, evaluation frameworks have been developed (see Harmelink et al., 2007; Khan et al., 2006; Sebold et al., 2001; SRC et al., 2001; Vreuls et al., 2005). However, evaluation studies of policy instruments addressing energy efficiency have traditionally targeted the narrow area—albeit challenging to quantify—of *impact*, in terms of energy savings, emission reductions, and saving costs (see e.g. Boonekamp, 2005; Gillingham et al., 2006; Harmelink et al., 2007; Vreuls et al., 2005). Some work also highlights the need to assess *outcome*, i.e. the changes in the energy system affected by the policy instrument. [4] We argue that the evaluation of *new* energy efficiency policy instruments, such as TWC schemes, requires a comprehensive evaluation approach—one that can capture their broad set of attributes and complement/improve results from cost-driven energy system models. Wider evaluations ought to be undertaken in order to better understand the effects (i.e. impacts and outcomes) of policy instruments in general and tradable permits in particular (cf. Harrington et al., 2004; Lahdelma et al., 2000; OECD, 2002; Tietenberg, 2006). We argue that decisions regarding the design, implementation and/or continuation of energy efficiency policy instruments, such as TWC schemes, can hardly be made in the absence of sound evaluations.

The objective of this paper is to *develop and apply a framework* for the evaluation of TWC schemes. The framework builds on a multi-criteria approach targeting key hypotheses regarding TWC schemes. The evaluation is carried out by means of *triangulation* to the extent data availability permits this. [5] Bearing in mind that there is no single-best method to evaluate TWC schemes (or any policy instrument), different quantitative and qualitative evaluation methods are used. The suggested framework aims at contributing to the development, use and integration of evaluation practices concerning TWC schemes. The proposed framework may be used not only for the evaluation of on-going TWC schemes, but could also support the design of ex-ante evaluations in countries embarking on the implementation of such a scheme. The framework and resulting outcomes should be considered a complement to modelling work conducted in previous studies. [6] On the whole, the suggested evaluation framework aims to provide a more comprehensive understanding and assessment of TWC schemes. In turn, the framework

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[3] For instance, reviewing several modelling exercises addressing TWC schemes, one can observe that the achieved performance of modelled TWC schemes has relied on various assumptions about the effectiveness of informative and other economic instruments.

[4] In the reviewed literature, an *outcome* is understood as the response to the policy intervention by obliged parties (e.g. implemented technologies, compliance strategies) and an *impact* (or final outcome) is defined as the changes generated by these outcome(s) on society and the environment (e.g. reduced energy consumption, reduced atmospheric pollution) (European Environment Agency, 2001; Hildén et al., 2002; Vreuls et al., 2005).

[5] To guide this approach, we use the definition given by Scriven (1991: 364-365) "the attempt to get a fix on a phenomenon or measurement (and, derivatively, an interpretation) by approaching it via several independent routes".

[6] See, for instance, Mundaca (forthcoming), Mundaca and Santi (2004), Oikonomou et al. (2007), and Perrels and Tuovinen (2007).

aims to support and structure a constructive policy debate.[7] It also attempts to constructively bring together the positivist approach to policy evaluation (i.e. factual knowledge) with the post-positivist approach that advocates for social values (see e.g. Chen, 1990; Fischer, 1995; Proctor, 1991). Merging empirical research with reference to normative aspects does this.

The structure of this paper is as follows: Section 2 briefly elaborates on the chosen evaluation criteria and related conceptual aspects, Section 3 presents the results obtained when applying the set of criteria to TWC schemes, Section 4 then discusses relevant policy and methodological aspects resulting from the application of the suggested evaluation framework and, finally, Section 5 presents our conclusions.

2. A multi-criteria evaluation framework

A multi-criteria framework departs from the fact that a number of criteria are relevant to policy formulation and evaluation (e.g. Fischer, 1995; Jacquet-Lagrèze and Siskos, 2001; Mickwitz, 2003). Policy instruments addressing the interplay of energy and environment issues usually tackle various policy objectives. In turn, this demands an evaluation from many perspectives. One that can capture empirical and normative issues, including different aspects of the policy problem and views from different stakeholders (cf. Fischer, 1995; Greening and Bernow, 2004; Harrington et al., 2004; Lahdelma et al., 2000).

Due to the fact that evaluation is principally normative in nature, value criteria are needed on which to base normative judgements regarding any significant impact (Bardach, 2005; Bemelmans-Videc et al., 1998; Mickwitz, 2003; Rossi et al., 2004). Criteria are evaluative standards that impose the framework upon which a policy option is judged and eventually chosen (Chen, 1990; Fischer, 1995). This means that policy evaluation needs a form or measure upon which the merit or success of, in our case a TWC scheme, can be determined or verified (cf. Fischer, 1995; Mickwitz, 2003; Rossi et al., 2004; Scriven, 1991).

The literature suggests a great variety of criteria by which policy instruments can be evaluated. However, very little guidance is given on which criteria are suitable for policy evaluation in the field of energy and environment issues (cf. Gupta et al., 2007; Harrington et al., 2004). When focusing on economic instruments—significant to our case regarding TWC schemes—the list of suggested criteria usually includes cost and environmental-effectiveness, economic efficiency, administrative burden, transaction costs and side-effects (see e.g. Anderson et al., 1977; Faure and Skogh, 2003; Nordhaus and Danish, 2003; Opschoor and Turner, 1994; Panayotou, 1998; Tietenberg, 1996; Turner et al., 1994; Sterner, 2003). Reviewing the literature on criteria applicable for the evaluation of environmental policy instruments in general, the list can be extended to also include relevance, legality, legitimacy, political acceptance, transparency and equity, etc. (see e.g. Mickwitz, 2003; Panayotou, 1998; Turner and Pearce, 1994).

In this paper, the selection of the evaluation criteria is based on the attributes and/or hypotheses attached to the justification of TWC schemes, i.e. the introduction of this policy instrument is based on the claims that a TWC scheme is economic efficient, cost-effective and involves a lower the administrative burden for public authorities (see e.g. Bertoldi and Rezessy, 2006, Langniss and Praetorius, 2006; Monjon, 2006; Oikonomou and Patel, 2004; Pavan, 2002; Voogt et al., 2006). In addition, the paper explores the assertions that TWC schemes are to support technical change (i.e. the introduction of new energy efficient technologies) and entail high transaction costs (cf. Mundaca and Neij 2006a; Mundaca, 2007). Finally, and due to the fact that the process of implementing these schemes has been

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also framed in terms of high legitimacy, the paper focuses on political feasibility as evaluation criterion. (cf. Bertoldi and Rezessy, 2006; Monjon, 2006; Pavan, 2002). These criteria include the following conceptual and evaluative aspects:

Energy-saving and environmental effectiveness is used to assess obliged parties' compliance level regarding saving targets and the resulting emission reductions (if explicitly acknowledged as a target) (cf. EEA, 2001; Langniss and Praetorius, 2006). It is mostly analysed in terms of mandatory energy saving targets, ambition level in target setting, goal achievement (including emission reductions) and additionality.[8]

Economic efficiency refers to the maximisation of the difference between total social benefits and costs (i.e. maximise net social benefits). It is assessed by means of a cost-benefit analysis, which is considered the suitable operational and pragmatic formulation by which to approach economic efficiency (i.e. to identify potential Pareto improvements) (Stavins, 2004; Tietenberg, 2006).

Cost-effectiveness focuses on whether an energy saving target can be achieved at the lowest possible cost.[9] It is analysed in terms of the equalisation of marginal costs across obliged parties (cf. Baumol and Oates, 1988) or, alternatively, by considering whether costs are higher or lower than the most probable alternative policy (cf. Tietenberg, 2006).

Transaction costs examines all the costs—other than investment and administrative cost—faced by market actors in initiating and completing transactions under TWC schemes (cf. Matthews, 1986). It is analysed in terms of sources (e.g. as due diligence, the finding and assessment of information, negotiation with trading partners, acquisition of legal services, measurement and verification) and the scale of transaction costs (cf. Mundaca, 2007).

Political feasibility addresses the obstacles that hamper or enhance the political acceptability of implementing a TWC scheme (cf. Nordhaus and Danish, 2003). From the target participant's perspective, it is analysed to what extent a policy instrument avoids conflict or interferes with their beliefs, interests and ambitions (Bemelmans-Videc et al., 1998).

Administrative burden specifically addresses the workload that public authorities face when a policy instrument is implemented and enforced (cf. Harrington et al., 2004; Rist, 1998). It also focuses on the administrative outcomes that the implementation of TWC schemes can generate for the public authority, looking at their internal response resulting from implementation.

Technical change analyses the development and dissemination of energy efficient technologies (cf. OECD, 2002; Tietenberg, 2006). This is achieved also by considering changes in the so-called selection environment (see Nelson and Winter, 1977; Kemp, 1997) and changes related to the role of obliged parties and their commitment, behaviour and organisational development to cope with a TWC scheme (cf. Mundaca, 2007).

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[8] In theory, TWC schemes encourage energy efficiency measures that are additional. In other words, measures that would not have implemented under the business-as-usual (BAU) scenario (i.e. as depicted by the baseline) are additional.
[9] Cost-effectiveness is sometimes labelled *static efficiency* (cf. Faure and Skogh, 2003; Harrington et al., 2004).

3. Evaluation

The aim of this section is to apply the proposed multi-criteria framework to TWC schemes implemented in Great Britain and Italy.[10] Most of the information comes from Great Britain where the scheme was introduced in 2002 (first phase) and is now being continued with a second phase (2005-2008). Early experience from Italy is also used to exemplify the use of the multi-criteria framework. The French scheme is used randomly as a lack of data prevents its analysis.

It has to be stressed that the analysed TWC schemes are used to exemplify the application of the framework rather than with the aim of providing an overall value judgement about their specific performances. Due to the extensive amount of information, only key findings are presented. Note that for each criterion results are presented and structured according to the research questions that guided the analysis.

3.1 Energy-saving and environmental effectiveness

The departure point for this analysis is to look at the level of compliance in relation to the mandatory saving target. Once the target is set, it automatically becomes the benchmark for evaluating how effective a TWC scheme is in terms of energy—and eventually also in terms of the environment. To ascertain the energy-saving and environmental effectiveness of TWC schemes, the questions that need to be answered are:

- What is the level of compliance?
- Do TWC schemes impose an explicit emission reduction target? If so, does the scheme achieve this?
- What are the critical regulatory elements influencing (non-) compliance with targets?
- Are there any indications as to how the portfolio of instruments influences the level of energy-effectiveness?

The evaluation is framed by evaluation theory, in particular by the goal-achievement model (Scriven, 1991:178-179).[11] To be able to answer the questions listed, multiple data sources were used. First, official documents and external reviews were used to analyse related data quantitatively. Second, background legal documents where examined in detail. Third, thematic interviews with policy makers, regulators and relevant stakeholders were carried out to fill in the gaps. Guided by the above-mentioned questions, the results can be summarised as follows.

A high level of energy-saving effectiveness is observed in Great Britain. The energy saving target for the first compliance period was set at 62 TWh. The measures implemented counting against the saving target yielded almost 61 TWh (OFGEM, 2005:8). According to the regulator, the slight deficit (ca. 2%) for EEC1 was due to two parties going out of business (OFGEM, 2005). Thus, one can interpret this performance as 98% energy-saving effective. However, a different view could be obtained if one considers the total amount of savings—those counted towards the achievement of the target plus the remaining surplus to be used in subsequent periods (i.e. because of the banking provision). Taking into account the banking of the surplus of savings, the total amount of savings

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[10] It must be mentioned that the British scheme is not a certificate-based mechanism. Nonetheless, it allows trading of savings and target obligations. Consequently, it is usually regarded as a TWC scheme.

[11] For the case of regulatory aspects and links to other policy instruments, intervention theory (see Chen, 1990; Vedung, 1997; Mickwitz, 2003) was used to guide the analysis. Vedung (1997:301) defines it as "all empirical and normative suppositions that public interventions rest upon".

realised during the EEC1 reached 86.8 TWh, or 140% energy-saving effectiveness in relation to the required target set for the end of EEC1 (OFGEM, 2005:7).[12]

Regarding environmental effectiveness, the reduction of atmospheric pollutants is explicitly stated as key policy goal in Great Britain (DEFRA, 2004). The performance can be summarised as follows. Target achievement under EEC1 was expected to save around 0.5 MtC/year in 2010 (DEFRA, 2006:1).[13] Once implemented, energy efficiency measures counting towards the EEC1 target (excluding banking) are estimated to achieve emissions reductions equating to 0.4 MtC/year in 2010. This includes a deduction for estimated "deadweight", i.e. the level of investment activity that would be carried out anyway under normal business conditions. In rough terms, environmental effectiveness is estimated to be approx. 80%. Now if we consider total CO_2 emissions to be approx. 150 MtC/year in the UK, of which household emissions contribute 40 MtC/year, the achieved emission reductions represent approx. 1%.

In terms of regulatory aspects, the following factors are found to be critical: the level of ambition, the additionality criterion and penalties for non-compliance. Regarding the ambition level in Great Britain, this reaches 0.6% of annual household energy consumption (see Table 1). This figure raises the question of whether high energy-saving effectiveness is met at the expense of soft targets or even simply represents business-as-usual trends. It is argued that the compliance level has simply reduced the growth rate of energy consumption but with little effect on consumption levels as such (Marsh, 2004; Owen, 2004). This is despite the fact that the scheme has counteracted the free-riding effect by means of "deadweight" factors; taken into account when both energy and cost savings from eligible measures are estimated (DETR, 2000:15). Moreover, obliged parties must demonstrate that measures are additional and it has been up to the regulator (i.e. OFGEM) to assess whether they qualify (e.g. "priority group").[14] Regardless of the actual level of ambition, the penalty imposed to address non-compliance has been strong—up to 10% of turnover in cases where parties fail to comply. This provided a direct incentive to obliged parties to comply with their targets (cf. Mundaca, 2007; Marsh, 2005; NERA, 2006).

Table 1: Target level in TWC schemes – as a share (%) of annual energy consumption of sectors under coverage

France (2005)[a]	Italy (2005)[b]	Great Britain (2004)[c]
0.14%	0.3%	0.6%

[a] Personal communication with Stéphanie Monjon (ADEME, 2007).
[b] Figures are derived from energy consumption in 2004. Energy consumption due to electricity and gas end-uses reached about 25 Mtoe for electricity and about 41 Mtoe for gas in 2004 in Italy (Personal communication with Nicola Labanca, eERG Politecnico di Milano). The savings target for 2005 was 0.2 Mtoe.
[c] The lifetime discounted fuel standardised energy saving during the first phase was 62 TWh. On annual undiscounted basis, this is equivalent to approx. 3.36 TWh (Personal communication with Penny Dunbabin, DEFRA 2007). Then, total household energy consumption in the UK by 2004 was 48.5 Mtoe (based on DTI statistics), which equates approx. 564 TWh. Notice that energy consumption here refers to the UK, which includes Northern Ireland. However, this country is *not* part of Great Britain, in which the TWC scheme is implemented. Therefore, the figure presented in the table is likely to be underestimated.

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[12] Notice also that during the first phase of the British scheme, parties were allowed to carry over savings generated under the EESOP, which accounted for up to 10% of each obliged party's target. At that time, nearly 3 TWh in savings were banked for EEC1 compliance, representing almost 5% of the target (OFGEM, 2005:52).

[13] Notice that this year was chosen for DEFRA as a benchmark because it is the mid point of the first Kyoto Protocol commitment period.

[14] The British scheme supports the Fuel Poverty Strategy, which aims to reduce the number of households that spend more than 10% of their income satisfying energy needs (DEFRA & DTI, 2005). Within this context, obliged parties must achieve at least 50% of their energy savings in the so-called "priority group", defined as households that receive certain income-related benefits and tax credits (OFGEM, 2005:4). In terms of additionality, landlords or social housing programmes dealing with the "priority group" can provide evidence to obliged parties. To implement eligible energy efficiency measures in low-income households, British obliged parties need to receive a written statement from the landlord stating that the measures would not have been implemented outside the programme.

In Great Britain, the scheme has been part of a cluster of policy instruments encouraging energy efficiency, which have also supported its effectiveness. The portfolio of instruments includes voluntary agreements, product standards, building codes and information campaigns (see Rohr, 2004; Lees, 2006). For instance, subsidies on behalf of obliged parties or governmental programmes have been available so end-users are motivated to implement eligible measures. This is relevant because it is up to the willingness of end-users whether obliged parties can actually meet their targets. Moreover, it is argued that highly effective informative policy instruments are crucial in raising awareness upstream among end-users if the British scheme is to deliver cost-effective energy savings (Mundaca, 2007). [15] Without informative and economic instruments, obliged parties are unlikely to tackle consumer behaviour to increase energy efficiency.

Looking at the Italian TWC scheme, the analysis of energy-saving effectiveness can be performed in a similar fashion. During the first year of compliance, certified energy savings accounted for 286,837 toe (AEEG, 2006). [16] This was higher than the required level of energy-effectiveness of 155,911 toe. Consequently, the total certificates issued by 2005 corresponded to 184% of energy-saving effectiveness. However, it has to be acknowledged that the actual target to be met by obliged parties was below the original 200,000 toe. The reason lies in the fact that around 54,099 toe could not be apportioned between energy distributors with less than 100,000 customers—the minimum market threshold used to allocate the overall energy saving target (Mundaca et al., forthcoming). Under the Italian scheme, no explicit target is set regarding emission reductions.

Although high-energy effectiveness is observed in the Italian TWC schemes, several regulatory aspects are likely to weaken the integrity of this achievement. First, the ambition level can be categorised as low. The original saving targets of 200,000 toe mentioned above represent only 0.3% of the total electricity and gas consumed in the sector covered. Furthermore, the scheme also provides the option of claiming unlimited savings retroactively. This provision had an important effect during the first year of compliance. In fact, up to 60% of the savings used to meet the target were implemented prior to the commencement of the scheme (cf. AEEG, 2006; Mundaca et al., forthcoming). Second, the broad definition and thus participation of Energy Service Companies (ESCOs) is another relevant aspect. Guidelines developed by the regulator in 2003 established a broad definition, which drove the large number of non-obliged parties considered as ESCOs—above 550 by May 2006. [17] However, most of these "ESCOs" could be classified as providers or installers of energy efficiency equipment rather than actual providers of energy services. [18] Third, the intensive participation of "ESCOs" is likely to trigger free-riding effects. TWCs issued to ESCOs during the first year of compliance amounted to almost 65% (AEEG, 2006:19). Thus, it also brings into question the additional component of eligible measures carried out by these so-called "ESCOs". [19] One can argue that the free-riding effect was not prevented by the additional component of eligible measures because of lack of enforcement. Finally, it is worth mentioning that, contrary to expectations, the

[15] In the energy/environment context, *informative policy instruments* are broadly defined as policy measures aimed at enhancing the understanding and awareness of how to increase energy efficiency and its related benefits. These include, for instance, information campaigns, eco-labelling schemes, customer advice and certification programmes.
[16] Under the Italian scheme, 1 TWC =1 tonne of oil equivalent (toe).
[17] Companies submitting an energy efficiency project to the regulator for certification can be considered ESCOs if their objectives include the provision of integrated services for the realization and the subsequent possible management of energy saving measures.
[18] Personal communication with Marcella Pavan (AEEG, 2007) and Nicola Labanca (Politecnico de Milano).
[19] Under the Italian TWC scheme, eligible measures are additional because they generate energy savings over and above market trends or legislative requirements.

lack of a pre-defined penalty for non-compliance has not seemed to hamper target compliance in Italy.

It was not possible to obtain any information concerning interactions with other energy efficiency policy instruments regarding the Italian TWC scheme.

3.2 Economic efficiency

In narrowing down what to evaluate in terms of economic efficiency, our evaluation begins by estimating/identifying and comparing *all* of the incurred programme costs (administration, investment and transaction costs) and benefits. The latter includes estimates of social benefits resulting from increased energy efficiency. The analysis focuses on the following questions:

- What is the estimated level of investment needed to meet the target?
- What are the costs of administering (monitoring and enforcing) the scheme? (see also Section 3.6)
- What is the burden of transaction costs faced by obliged parties? (see also Section 3.4)
- What are the social and environmental benefits due to increased energy efficiency?
- What are the energy costs savings and financial net benefits (if any) for society and end-users?

The evaluation builds on a cost-benefit analysis (CBA); which is the approach normally applied in efficiency assessments (cf. Rossi et al., 2004; Stavins, 2004; Tietenberg, 2006). From the societal standpoint, the discipline of environmental economics guides the analysis; in which the internalisation of negative externalities is a crucial theoretical aspect. From the end-user perspective—also an important financial and political factor—the analysis is complemented with insights from a utility maximisation approach (i.e. cost-revenue analysis); in which social and environmental benefits of increased energy efficiency are *not* considered. Due to data restrictions, the analysis is performed only for the first phase of the TWC British scheme. It focuses on measures that yielded most energy savings under the British scheme: compact fluorescent lamps (CFL) and cavity wall insulation (CWI). Data were not available allowing a similar analysis regarding the Italian scheme.

To obtain the necessary data, multiple sources were used. Official documents, external evaluation reports, and peer-reviewed materials were used to collate technical and financial information. Figures for social and environmental benefits were estimated based on the ExternE project (European Commission, 2003) and IEA statistics (IEA, 2006). To fill the gaps, several assumptions were made. In addition, assumptions and limitations involved in estimates originating in other studies were taken into account. Consequently, to reduce the level of uncertainty, only conservative estimates are presented. Furthermore, a sensitivity analysis was developed. The results can be summarised as follows.

Using different input data sources, several assumptions were made. For simplification and data availability, the resulting energy savings address only 10 (out of 19) eligible measures. However, the chosen set of technologies accounts for approximately 90% of the total savings realised. All fossil fuels savings were treated as equivalent to gas in cost terms, which underestimates cost savings resulting from non-electricity energy improvements. Social and environmental benefits were derived from the minimum and maximum ranges of damage costs for power production for the UK (European Commission, 2003:13) and extrapolated to the electricity fuel mix for 2003 (IEA, 2006). These values refer to the negative externalities avoided through the energy savings (mortality, morbidity, loss of amenity, ageing construction materials, global warming,

acidity, eutrophication, etc.). Only social and environmental benefits resulting from electricity savings were accounted for. This is because no estimates were available regarding damage costs from gas consumption— a fuel where significant savings have been achieved in Great Britain. Furthermore, other social and environmental benefits attributed to increased energy efficiency in the household sector (e.g. generation of employment, increased comfort, improved productivity, energy security) were not considered because no estimates yet exist. Regarding cost savings figures, constant energy fuel prices (9.4 Euro cents/kWh for electricity and approx. 2.3 Euro cents/kWh for gas) were used for the analysed period.[20] Cost savings for each measure were quantified for the full lifetime of that measure, stretching over a period from eight years (first CFL bulb) up to 40 (cavity wall insulation). On the whole, the results shown in Table 2 depict a conservative scenario. Figures are in Million Euros (2004).[21]

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[20] Based on DTI (2005).
[21] According to the authorities, the year 2004 can be taken as the "centre of gravity" of the first phase of the British scheme. In December 2004, £ 1 equalled approx. €1.41.

Table 2: Estimated costs and benefits (Million Euros 2004) under the British TWC scheme - Phase 1 (2002-2005). With the exception of administrative costs borne by the authority, all costs and benefits are derived from or refer only to the following selected group of eligible measures: cavity wall insulation, loft insulation (top-up), loft insulation (virgin), do-it-yourself insulation, tank insulation, cold appliances, wet appliances, A and B rated boilers, A and B boilers plus heating controls and compact fluorescent lamps (CFL). In terms of assumptions, key input data were taken from DETR (2000) Lees (2006), DEFRA (2004), OFGEM (2006) and DTI (2005). Furthermore, upper bounds of transaction costs of 12% and 36% of investment costs for CFL and CWI are used respectively—as estimated by Mundaca (2007:4348)

Estimated costs		
Investment costs borne by obliged parties[a]	399.4	
Transaction costs borne by obliged parties[b]	74.2	
Investment costs borne by end-users[a]	190.7	
Investment costs borne by others[a]	81.9	
Administrative costs borne by the authority[c]	1.4	
Administrative costs borne by obliged parties[d]	94.8	
Total costs	842.4	
Estimated benefits		
Discounted (6%) energy cost savings [e]	2 398.2	
	With lower (1.9 Euro cents/kWh) bound of social and environmental benefits[f]	With upper (3.36 Euro cents/kWh) bound of social and environmental benefits[f]
Discounted (6%) social and environmental benefits are	208.6	385
Total discounted (6%) benefits (energy cost savings + social and environmental benefits)	2,606.8	2,783.2
Internal rate of return	33%	36%
Discounted (6%) payback period	3	2.8
Net present value(NPV) at different social discount rates		
2%	2,652	2,874
4%	2,088	2,279
6%	1,665	1,831
8%	1,340	1,486
10%	1,084	1,213

[a] Derived from Lees (2006:64).
[b] Mundaca (2007:4349) estimates transaction costs to be about 8~12% and 24~36% of total investment costs for lighting and insulation measures respectively.
[c] See OFGEM (2006:4).
[d] According to DEFRA (2004:22), administrative and marketing costs are estimated to be approx. 21% of obliged parties' investment costs.
[e] Data sources for estimating energy cost savings resulting from eligible measures are as follows: DETR (2000:25-27), Lees (2006:25-32), DEFRA (2004:27-31); OFGEM (2006:47); and DTI (2005).
[f] Based on data from ExternE (2003:13) and fuel mix figures from IEA Statistics (IEA, 2006).

Having mentioned some critical assumptions, some key figures deserve our attention. Taking the official British discount rate of 6% applied during the first phase of the scheme, total benefits (i.e. energy cost savings and social and environmental benefits) range from € 2,606 M to €2,783 M. Correspondingly, this implies an overall benefit-cost ratio of 3.09 to 3.32. In other words, every € 1 invested generates € 3.09-3.32 in benefits. Certainly, energy cost savings (€ 2,398 M) alone represents the majority of the programme's economic benefits (86% and 92% respectively for the upper and lower ends of the range). Even though the figures used to ascertain the efficiency of the British scheme are conservative, the estimated internal rate of return (IRR) is remarkably high in both cases (about 33-36%). If the lower bound of social and environmental benefits is considered, the discounted payback period is estimated to be approx. 3 years at the test discount rate of 6% (see Figure 1). Looking at the overall performance, the figures were consistent with other ex-post studies (see DEFRA, 2006:9; Lees, 2006:32).
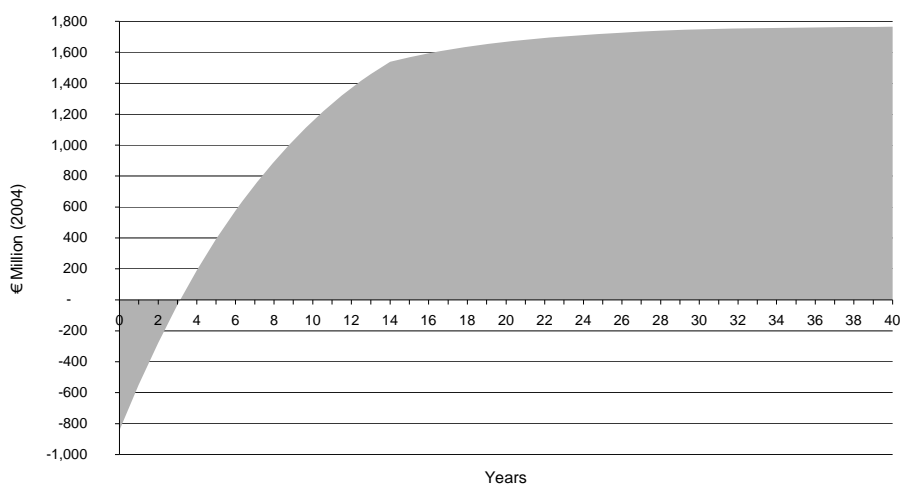

Figure 1: Estimated net social benefits and payback period under the British TWC scheme (phase 1). Discounted (6%) cumulative economic flow using the *lower* bound of social and environmental benefits in €Million (2004)

To illustrate the financial results from the perspective of end-users, we use the CFL (first bulb) and cavity wall insulation (CWI) as measures on which to perform a cost-revenue analysis. Consistent with the cost-benefit analysis for society, the results for end-users were also estimated to be beneficial. With a remarkable high internal rate of return (IRR) (126%), the discounted (6%) payback period for a CFL (first bulb installed) is estimated to be less than a year (see Figure 2a). This measure yields € 26 in net present value (NPV). Regarding CWI, this measure yields approx. €450 in NPV; with an IRR of 18% and a discounted payback period of nearly 6 years, also at the official test discount rate of 6% (see Figure 2b). Relative to their investment costs, both measures yield substantial financial net benefits for end-users.
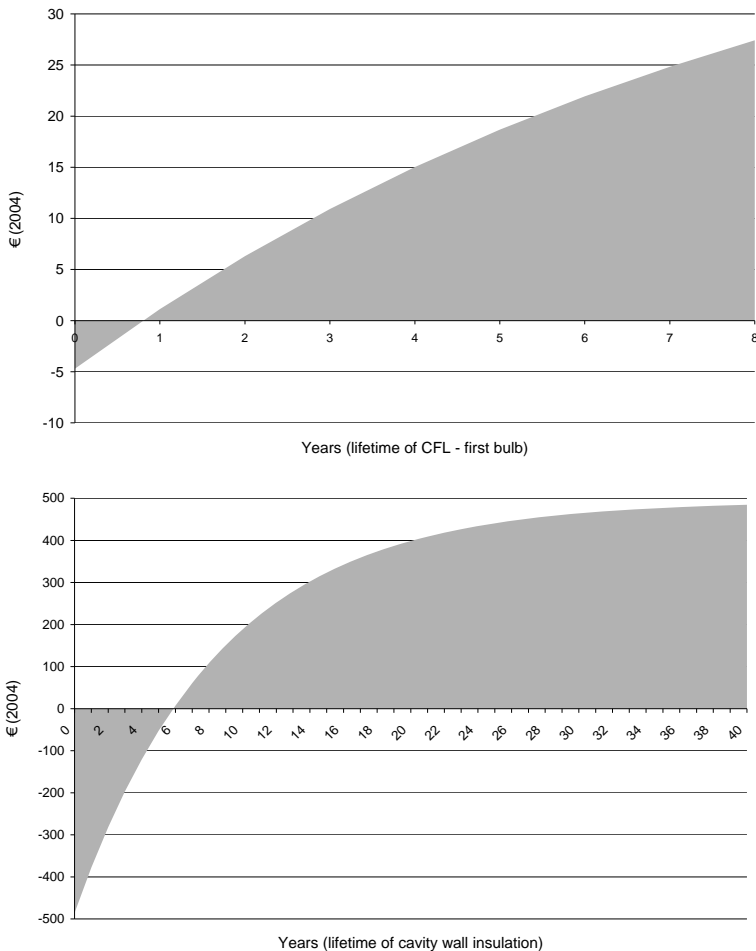
Figure 2: Cumulative cash flow and discounted payback period (6%) for end-users that implement: 2a) CFL (first bulb) and 2b) cavity wall insulation (CWI) in Euros (2004). It is assumed that an end-user affords 100% of the investment costs. Financial benefits are likely to be higher if the end-user that implements the technology affords only a fraction of the investment costs. Cross-subsidies among end-users can exist because obliged parties can equally distribute compliance costs across all end-users. In certain cases, compliance costs can be recovered directly through increased energy tariffs (e.g. Greatn Britain)

3.3 Cost-effectiveness

The evaluation of cost-effectiveness is based on different approaches. This is to determine whether a TWC scheme minimises the costs of meeting a given energy saving target. Several questions guided the analysis:

- What are the estimated costs of energy savings?

- To what extent do transaction costs make energy savings less cost-effective?
- Are these energy saving costs lower or higher that the most likely alternative policy?
- What is the level of trading activity? Or, are there any indications of equalisation in marginal compliance costs?

The study focuses on energy saving costs under a TWC scheme and saving costs yielded by the most likely alternative policy—not an optimum benchmark but a pragmatic one for comparison purposes (cf. Tietenberg, 2006). Moreover, energy and energy saving costs were also considered from the perspective of the end-user. Data were collected from multiple sources; including official documentation, external reviews and peer-reviewed papers.

Results for Great Britain show several indications of cost-effectiveness: a) energy saving costs were lower than expected and lower than energy prices paid by households; b) energy saving costs were lower than an alternative policy option; and c) equalisation of marginal costs was observed during the bidding process for insulation measures. Regarding energy saving costs, Lees (2006:27) estimates savings to be approx. 1.4 Euro cents/kWh for electricity and approx. 0.7 Euro cents/kWh for gas. These figures also include administrative and hidden costs, which are calculated at an average 20%.[22] According to Lees (2006:30), the estimated figures are around 20% lower than estimates predicted by the authority. Mundaca (2007:4349) also provides estimates: 0.8 Euro cents/kWh for electricity and approx. 1.3 Euro cents/kWh for gas. [23] These estimates include transaction costs of 10% and 30% for electricity and gas-related measures respectively (more details in Section 3.4). Both studies stress that neither indirect costs nor transaction costs hampered the cost-effectiveness of energy savings during the first phase of the British scheme. Taking into account energy prices paid by households in 2004 as benchmarks (9.4 Euro cents/kWh for electricity and approx. 2.3 Euro cents/kWh for gas), net financial benefits for end-users are estimated to be about 8-8.6 Euro cents/kWh for electricity savings and about 1-1.6 Euro cents/kWh for gas savings (see Less, 2006:27; Mundaca, 2007:4349).

An alternative approach regarding cost-effectiveness was to compare the estimated energy saving costs under the scheme to energy saving costs yielded under the most likely policy option. In Britain, the so-called Energy Efficiency Standards of Performance Programme (EESoP), which ran from 1994 until 2002, could be seen as a likely alternative policy approach (DETR, 2000). Under the EESoP, average energy saving costs were estimated at approx. 2.5 Euro cents /kWh (OFGEM and EST, 2003:17). This estimate can be taken as an indication that saving costs under EESoP were higher than those yielded by the British TWC scheme.

In Great Britain, confirmation of equalised marginal costs does not exist due to rather limited trading activity.[24] This lack of trading activity can be explained by a number of factors: excessive supply of individual savings; high penalties in case of non-compliance; perceived transaction costs; co-benefits of non-trading (e.g. increased competitiveness) and the competitive bidding process for insulation measures (Mundaca, 2007; Mundaca et al., forthcoming; NERA, 2006). However, an important indication arose when interviewing obliged parties and authorities.[25] These have relied heavily on contractors for insulation

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[22] Lees (2006:26) estimates indirect costs of 9% for CFLs and 24% for insulation measures, including certain sources of transaction costs, such as *monitoring*.

[23] Whereas the ideal case is to analyse data about *marginal* energy saving costs, there is in reality a lack of information, which leads us to estimate the cost-effectiveness of energy savings (i.e. costs per unit of final energy saved). Cost-effectiveness of *energy savings* is defined herein as the lowest life-cycle costs per unit of energy saved (i.e. €per kWh of energy saved). In other words, high life cycle costs per unit of final energy saved mean that a TWC scheme is *less* cost-effective.

[24] Although limited trading took place during the first phase, no financial data were disclosed by the obliged parties. For a more detailed analysis of trading activity under TWC schemes, see Mundaca et al. (2008).

[25] Interviews with British stakeholders too place in October 2005 and March 2006.

measures (i.e. 100% of all insulation was sub-contracted during the first phase) and agreed that most contractors offered very similar costs for insulation measures. Accordingly, cost differences were insignificant. In turn, savings from trading would have been marginal because compliance costs had been already equalised between the obliged parties (Mundaca, 2007). This aspect is relevant because insulation measures dominated the energy savings realised (see OFGEM, 2005:66).

Concerning the Italian scheme, there were no reliable data on which to estimate costs of energy savings. With due caution, estimates of cost-effectiveness for end-users could be estimated based on TWC prices (see below). These were taken as proxies for actual saving costs.[26] These values equated to 0.6 Euro cents/kWh and 0.8 Euro cents/kWh of electricity and natural gas saving costs, respectively. Then, we compared these cost figures to the energy costs faced by end-users in 2006, which were approx. 5.6 and 6.8 Euro cents/kWh of electricity and natural gas, respectively. With due caution, this gives indications of net financial benefits for end-users.

Regarding the equalisation of compliance costs under the Italian scheme, the emergence of the market and the volume of permits traded can be taken as primary, albeit insufficient, evidence of cost-effectiveness. In other words, pre-conditions such as common price and trading between parties facing different costs are observed (cf. Ellerman, 2003; Mundaca et al., forthcoming). In fact, there has been intensive trading activity and, on the face of it, parties with different compliance costs have actually been subject to a common TWC market price. During the first year of compliance 145,796 TWCs were traded, representing approx. 50% of total TWCs issued for that period (i.e. 286,837 TWCs). Trading activity largely took place through bilateral contracts (83%), with the spot market representing a far lower share (17%). For the latter, TWC prices have fluctuated slightly, slowly falling between March 2006 and June 2007 from €80 to €30 for TWC type-I (electricity) and from €92 to €79 for TWC type-II (gas), respectively.[27] However, it was not possible to estimate cost savings attributable to trading due to the lack of a counterfactual situation or baseline. Furthermore, no identification of an alternative policy instrument was possible to identify.

3.4 Transaction costs

The need for an evaluation of transaction costs (TCs) builds upon New Institutional Economics, in which the analysis of TCs is seen as a crucial element (Ménard, 2004). The study looks at the identification of the nature and scale of TCs. Theory-based policy evaluation (see Rossi et al., 2004; Mickwitz, 2006) supported the study in order to (re)construct the functioning of TWC schemes and the processes within them. The analysis is guided by the following questions:

- What are the key sources of TCs?
- To what extent are TCs borne by the obliged parties?
- What kinds of design elements and complementary policy instruments can be introduced to keep TCs as low as possible?

To gather the information, thematic interviews were conducted with obliged parties and authorities—including questionnaires circulated among the former. Official documentation and related studies were also reviewed. In terms of results, findings for Great Britain are summarised as follows.[28]

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[26] This was based on average TWC market prices of €71 and €94 in 2006 for electricity and gas respectively. For further information about the Italian TWC market visit http://www.mercatoelettrico.org/.
[27] Price information about bilateral trading has not been disclosed.
[28] These findings originate from work carried out by the corresponding author of this article. See Mundaca (2007).

First, the TWC lifecycle was constructed, involving the planning and implementation of measures, measurement and verification (M&V) issuance of TWCs, trading and redemption. Within this framework, many sources of TCs were identified. When obliged parties plan eligible measures, the sources of TCs identified were related to information searches (to e.g. identify the type of measure and the location of customers willing to implement them), customer persuasion and gaining approval from the authority. TCs related to customer persuasion were driven by the apathy and lack of awareness of householders regarding energy efficiency. Furthermore, having the correct information was critical for the suppliers during the planning phase, as endorsement by the authority was needed before implementation could take place.

During the implementation phase, contract negotiations with sub-contractors and fees paid to third parties to implement measures were observed. At this stage, obliged parties hired contractors to implement insulation measures. Some contracted third parties to handle their obligation (e.g. managing agents).

During the M&V phase, parties were required to monitor a proportion of all installations with respect to the exact number of measures implemented. Costs existed associated with random quality checks to assess customer satisfaction. There is no issuance of TWCs as such in Great Britain, thus no TCs were identified.

As far as the trading phase is concerned, contract negotiation with trading partners and liability risks in case of non-compliance were identified. Obliged parties perceived that trading could involve high negotiation costs as strategically sensitive information could be disclosed to a buyer/seller of savings. Furthermore, parties found it risky to embark on trading in the absence of clear legal frameworks for determining liability in case of non-compliance.

Regarding the redemption or declaration phase, TCs were associated with the person-to-person costs of assessing and compiling the information required by the authority.

The above-mentioned sources of TCs led to an aggregate estimation of their scale (see Mundaca, 2007). For savings derived from CFLs, it is estimated that transaction costs increased the costs of savings by 8-12%. Concerning savings realised through cavity wall insulation, the study shows that transaction costs entailed a burden ranging between 24% and 36% per kWh saved. Mundaca (2007:4348) concludes that even in the presence of high TCs, increased energy efficiency under the British scheme yielded net financial benefits.

Data has not been available to evaluate TCs for the Italian or French TWC scheme. To improve our knowledge related to TCs, a similar policy approach was examined as a supplementary case study. Such a scheme is the Free-of-Charge Energy Audit (FCEA) programme in Denmark.[29] Under the FCEA, electricity grid companies are obliged to provide energy audits to all public and private organisations that have an annual consumption of more than 20 MWh. The relevance of using the FCEA as a case study relies on the following aspect: organisational and administrative settings implemented by the companies to meet the obligation under the FCEA can be analysed in the context of the efforts that obliged parties under TWC schemes have to establish and perform in order to meet their mandatory saving targets.

Following the audit life cycle, the sources of transaction costs within the FCEA are shown in Figure 3.[30] The first source of TCs identified relates to information searching and the audit process as such. The former is related to the search for customers willing to obtain the FCEA. Grid companies sometimes found it challenging to find end-use

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[29] The FCEA programme is an informative policy instrument aimed at providing suitable information to organizations about energy efficiency improvements. For a detailed description of the FCEA see Dyhr-Mykkelsen et al. (2005) and IEA (2005).
[30] The findings presented here originate from the work conducted by Mundaca and Neij (2006b).

companies willing to be subjected to an audit. This is consistent with the fact that the programme has mostly been supply-driven, with the grid companies initiating the process rather the end-use companies demanding the audits (cf. Dyhr-Mykkelsen et al., 2005; IEA, 2005). When developing the electricity saving plan, grid companies interact with operations and maintenance (O&M) teams and manufacturers or dealers of equipment that potentially could be used. As far as the follow-up of the audit is concerned, grid companies contact the audited company. This involves site visits and phone calls, which allow grid companies to ascertain if implementation has been realised. When the outcome of the follow-up process leads to the implementation of measures suggested by an energy audit, grid companies contribute to the search for partners/contractors. The last source of TCs identified is related to the due accreditation of the energy audit. Interviewees found it time consuming to report audits on an individual basis—a key requirement under the FCEA. The accreditation process was sometimes even more cumbersome when case-specific energy audits needed to be accommodated to match the format and contents of the database. Overall, the estimated scale of TCs range from 5% to 20% of total audit costs (Mundaca and Neij, 2006b:11).[31] With due limitation, it can be concluded that the scale of TCs is higher when dealing with small end-use companies rather than larger ones.
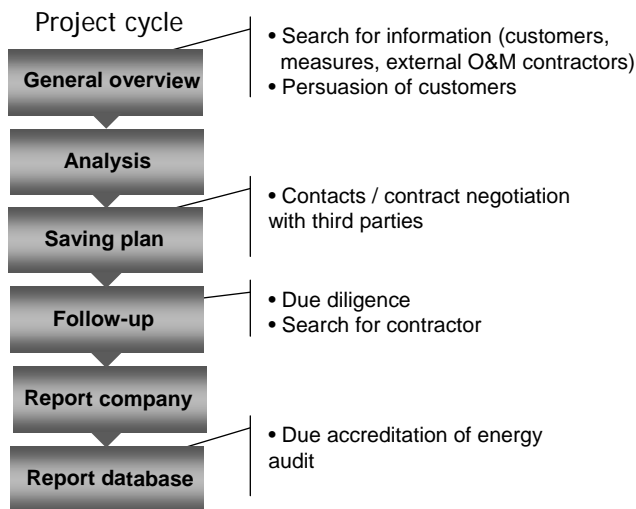

Figure 3: Project cycle under the Free-of-Charge Energy Audit programme in Denmark and identified sources of transaction costs

Based on the TC analysis of the British TWC scheme and the FCEA in Denmark, several design aspects can be identified that could reduce TCs. Importantly, a simple but clear institutional framework is crucial. First, the bundling or pooling of similar measures appears as a straightforward strategy to reduce TCs. This means that a project developer can group several projects and/or develop similar projects in order to reduce the financial burden of potentially fixed TCs. The adoption of this strategy reduces the burden of TCs

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[31] These figures must be taken with due caution. Note that assuming a margin of error of 10% and a confidence level of 95%, the recommended sample size for the survey under the FCEA was 17 companies, out of 20. In reality, the number of respondents accounted for only 5 (i.e. 25%) of the total population size.

related to contract negotiation, baseline development and M&V activities—if needed. Second, where it is required that energy savings be certified, an ex-ante approach should be developed whenever possible as a mechanism for reducing TCs related to M&V activities. The suitability of this approach is related heavily to knowledge of credible baselines and the performance of different types of measures. Due to the fact that there is a handful of measures— the technical performance of which is relatively well understood—the British scheme allows energy savings to be granted beforehand so there is no requirement for ex-post M&V as such. The Italian schemes also entail this approach, among others. Despite the uncertainties that can arise, the robustness and reliability of M&V approach must be balanced with simplicity and cost-effectiveness. Third, a clearinghouse and trading platform must be implemented where potential buyers and sellers can meet at any time. This must also permit bidding and bilateral trading. The clearinghouse should provide information on the prices, volumes and parties involved in trades (both spot and bilateral). This information platform can also be used to keep market actors informed on the dynamics of the TWC market and its regulatory framework. The development of standardised contracts (or at least standardised key contractual provisions) can reduce TCs related to legal services and perceived liability risks in trading. Rules and penalties for non-compliance must be clearly determined. All these design aspects can positively affect the level of information and thereby TCs and the efficiency of the TWC market.

Finally, the findings from the British scheme and the FCEA indicate that the search for information in relation to customers represent a critical source of TCs. The lack of awareness and apathy among end-users was clearly identified as a critical obstacle in the two programmes analysed. Consequently, raising awareness among this group can play a significant role in reducing TCs. Information campaigns, educational/information/call centres, labelling schemes, etc., need to be properly implemented.

3.5 Political feasibility

In general terms, the evaluation of political feasibility includes the political response of interference during the processes of policy choice, design, implementation and performance. In this study, however, the focus is limited to the early phases of policy choice and the design of TWC schemes. The following questions guided the analysis:

- What ability does a TWC scheme have to reconcile policy objectives (i.e. macro policy formulation level)?
- What are the key design elements that can generate/release resistance in target participants to accepting a TWC scheme (i.e. micro-policy formulation level)?

The evaluation is based on political discussions; reviewed through legal documents and parliamentary decisions. To complement the analysis, semi-structured interviews with public authorities, obliged parties and observers were carried out. The results are as follows.

At the macro-policy formulation level, numerous policy objectives support the rationale and justification of TWC schemes. In countries where they have been implemented, TWC schemes bring together policy objectives, such as increased energy efficiency and security of energy supply; boost industrial competitiveness and employment; enhance environmental protection (e.g. reduce atmospheric emissions); improve housing stock; and reduce fuel poverty (cf. Capozza et al., 2006; DEFRA, 2004; Monjon, 2006; Mundaca and Neij, 2006a; Pavan, 2002). Supported by the economic argument of cost-effectiveness, TWC schemes have secured political acceptance, as they are consistent with the liberalisation of energy markets and avoid price distortion (e.g. if compared to energy taxes) (cf. Pavan, 2002; Perrels et al., 2006). They are capable of creating incentives to privately

financed energy efficiency—as opposed to subsidies (Monjon, 2006). Likewise, it has been argued that TWC schemes can free up financial resources designated to replace or build new energy generation capacity (Capozza et al., 2006; Farinelli et al., 2005). Taking into account the ability of TWC schemes to tackle multiple and consistent policy objectives, it is possible to recognise a political acceptance that fits policy frameworks favouring market-based approaches (cf. Capozza et al., 2006; Vreuls et al., 2005).

Considering now the micro-policy formulation level, the political feasibility of TWC schemes faces different scenarios. The Italian experience shows that several obstacles exist even if there is strong political consensus on policy objectives. The scheme was supposed to commence in 2002 (as decreed in April 2001) but was finally implemented in 2005. This three-year delay was heavily influenced by lengthy discussions and time consuming negotiations and agreements about four main aspects: the level of ambition of the energy saving target; the development of M&V approaches; the allocation of savings obligations; and the existence of cost-recovery mechanisms.[32]

First, obliged parties and authorities negotiated mandatory targets extensively. Whereas the initial and final cumulative target remained unchanged, this process led to the relaxation of intermediate targets (see Figure 4).[33] Second, several discussions concerning M&V methodologies also influenced the delay. In this context, the use, development and coverage of M&V approaches were (and still are) dependent on the complexities of eligible measures, the number of eligible end-use sectors, relevant data available, and certainly the consensus and negotiation between the obliged parties and the authorities in charge of administering the scheme. Third, the opposition to the allocation of the obligation arose in terms of energy producers being reluctant to become energy savers. Italian obliged parties (i.e. distributors of gas and electricity) strongly opposed the obligation, basically claiming that their core business was remote from eligible end-use sectors and that they were therefore unable to implement measures to meet the obligation. In fact, discussions regarding who would be most suitable as obliged actors (i.e. distributors or suppliers) have been ongoing in Italy ever since. Fourth, a cost-recovery mechanism was not explicitly included in the initial regulatory framework. Guidelines covering a variety of design and implementation aspects, including cost-recovery mechanisms were proposed by the Authority in late 2002 (Pagliano et al., 2003). After extensive negotiations, a cost-recovery rate of €100 per TWC redeemed was finally set.[34] According to interviewees, this was done in order to make the scheme more "palatable" to obliged parties.

Based on the above-mentioned regulatory aspects, several modifications (e.g. target level and an option to claim TWCs retroactively until 2001) were made in 2004 to the Decrees introduced in 2001. Interviews revealed that the level of ambition of the mandatory target as well as the allocation of responsibility to meet it were, by far, the two most critical design elements affecting the political acceptability of the scheme.[35]

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[32] Personal communications with Stefano Alaimo (GME), Marcella Pavan (AEEG), Antonio Capozza (CESI), Walter Grattieri (CESI), Daniele Russolillo (Fondazione per l'Ambiente) and Nicola Labanca (Politecnico di Milano).

[33] According to McDonnell and Grubb (1991:11) "the selection of policy targets reflects the way policy makers view the incentive structures of those whose behaviour they are trying to influence".

[34] An estimated cost-recovery of ≥ €200 per TWC redeemed was suggested. For further information see Pagliano et al. (2003:1063).

[35] In addition to critical design elements, operational considerations have also slowed the implementation of the scheme at the regional level. For instance, after institutional modifications were made at the national level in 2004, regional governments, in cooperation with the relevant ministries, were asked to identify eligible projects and implement/promote best practices in the public sector. However, this task was only completed in 2007 (e.g. Piemonte). Furthermore, obliged parties have failed to prepare—as requested by the 2004 Decrees—an annual portfolio of eligible projects compatible with regional energy plans.
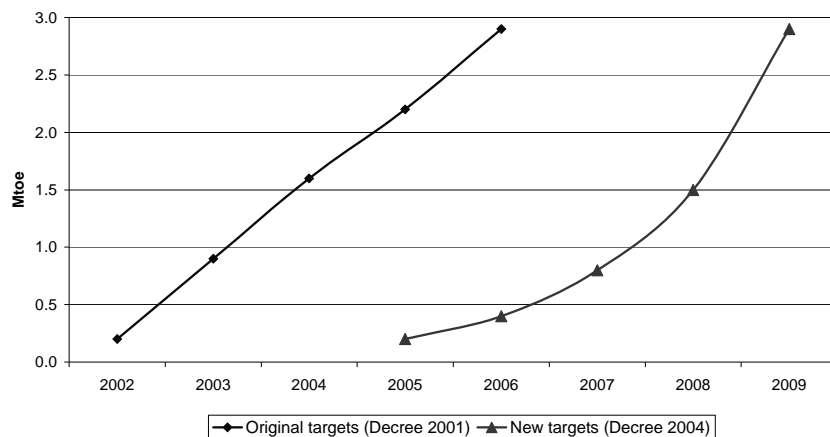
Figure 4: Several policy obstacles delayed the commencement of the Italian TWC scheme (first phase), also reducing intermediate cumulative energy saving targets (in Mtoe)

Regarding the political feasibility of the British scheme, many of the difficulties listed above (e.g. target negotiation/opposition, development of M&V methodology for eligible measures) could also be applicable to some extent. However, the implementation of the scheme was not delayed and its political feasibility seemed not to be jeopardised. This could be explained by a number of factors: (i) a high level of political commitment towards policies to reduce GHG emissions and increased energy efficiency, (ii) the ex-ante evaluation of the scheme's impacts (on a measure-by-measure basis and also at the aggregate level), (iii) an extensive and statutory consultation process prior to the implementation of the scheme, (iv) key stakeholders (i.e. policy makers, regulator, and obliged parties) already being familiar with the operation of the new scheme because it was built upon the former EESoP, (v) the limited coverage of the scheme (i.e. the household sector only), making it a workable policy instrument for the authorities and (vi) the fact that the scheme also supports the Fuel Poverty Strategy.[36]

3.6 Administrative burden

The evaluation of the administrative burden addresses human and financial resources that the authority incurs for administering a policy instrument. A key question is whether a TWC scheme is a workable instrument or involves disproportionate financial/informational costs for public authorities (cf. Sterner, 2003). To approach the evaluation in this respect, the following questions were used:

- What design features and policy measures are crucial to the efficient administration of a TWC scheme (i.e. to reduce the administrative burden)?
- Measured in monetary terms, what is the administrative burden of the scheme?
- Do public authorities have experience in administering and enforcing a TWC scheme?

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[36] The Fuel Poverty Strategy aims to reduce the number of households that spend more than 10% of their income to satisfy energy needs (DEFRA and DTI, 2005). In this context, obliged parties must achieve at least 50% of their energy savings in the so-called "priority group", defined as households that receive certain income-related benefits and tax credits (OFGEM, 2005:4).

- Is it necessary to create new institutions to administer such a scheme?

Qualitative analyses and quantitative estimates have conducted to answer these questions. To gather the data, thematic interviews were carried out with public authorities and official documents were reviewed. Administrative costs, here defined as the costs of implementing, monitoring and enforcing a given policy instrument, were critical to the analysis. They do matter in public policy but are often overlooked in evaluations, although ignoring them can bias the evaluation of policy options (Tietenberg, 2006).

Addressing the first question, the analysis of TWC schemes, indicated many design elements that influence the administrative burden. By far, the most relevant elements are the number of obliged parties, the number of eligible technologies, the number of eligible sectors, the number of energy carriers and the type of M&V approach. The larger and/or complex these elements grow, the more untenable the administration and enforcement of the scheme becomes. The British experience demonstrates the feasibility for public authorities to effectively administer a TWC scheme. Key design elements influencing the low burden for the authority include a single eligible sector, a rather limited number of obliged parties, an ex-ante approach and a handful of measures applicable to the household sector.

In monetary terms, the British scheme demonstrates a low burden. The institution in charge of the scheme's administration in Great Britain has reported costs for the scheme's first phase of € 1.4 M (OFGEM, 2005:4). With a team of around six professionals, this figure represents around € 460,000 a year—a rather marginal burden compared to OFGEM's total budget of approx. € 560 M. The largest share of costs was related to the external auditor and management of the database that keeps track of the progress of each obliged party. As far as the external audit goes, although energy savings per type of measure were accredited beforehand, certain random audits were carried out during 2003 and early 2005. Two random audits were conducted to check whether obliged parties were correctly reporting and delivering energy savings as planned—although no *ex-post* M&V took place. Official information states that energy suppliers had accurately reported their measures during the EEC1 (OFGEM, 2005a). Of the € 1.4 M in administrative costs, these random M&V activities represented 15%. The costs for the first audit were around € 125,000 and for the second nearly € 85,000. According to the authority, an internal learning process allowed them to reduce the costs for the second audit.[37]

In Italy and France no information exists concerning the financial burden on the relevant authorities. However one can envisage that, due to the extensive coverage of these schemes, including ex-post M&V of savings, they are likely to involve a greater amount of regulatory oversight. Thus, the administrative burden is likely to be much greater than in the British scheme. In France, there is no official data on administrative costs, although it is estimated that the scheme requires the equivalent of 15 to 20 full-time employees to support the development, implementation and enforcement of the scheme.[38]

The British scheme provides valuable insights into the implementation, administration and enforcement of a TWC scheme. It is argued that building upon existing policy instruments is crucial in minimising administrative costs and facilitating the activities of both the regulator and the target participants (Nordhaus and Danish, 2003). In Great Britain, the TWC scheme was built upon the EESoP and several lessons were drawn from the administration of the earlier scheme. These included the focus on saving targets rather than minimum expenditure, the option of banking savings and the need to check assumptions of ex-ante M&V approaches on a regular basis.[39] In fact, the British TWC

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[37] Personal communication with Charles Hargreaves (OFGEM).
[38] Personal communication with Luc Bodineau (ADEME).
[39] For an in-depth review of the EESoP see OFGEM and EST (2003).

scheme was introduced to replace the EESoP, and introduced saving targets three times more ambitious than the third phase of the latter. It was found that most of the relevant stakeholders (i.e. policy makers, regulators and obliged parties) were familiar with the new policy scenario that the implementation of the British scheme entailed.[40]

Another critical issue when considering administrative feasibility involves policy makers dealing with the challenge of assigning or creating the institution best suited to handling the new policy scenario (Rist, 1998). Again, in the Great Britain case, policy makers opted for an existing institution, the Office of Gas and Electricity Markets (OFGEM) rather than creating a new one. OFGEM is responsible for setting supplier's individual targets, assessing/approving proposed measures, monitoring activities, supervising trades, enforcing compliance and reporting to the government on progress. According to British policy markers, OFGEM has managed the whole scheme efficiently (see Jones, 2005). Obliged parties have also recognised the crucial role that OFGEM has played in the effective administration of the scheme (see OFGEM, 2005).

3.7 Technical change

In order to realise energy savings, energy efficient technologies must be implemented. These can either be technologies that are commercially available or new and innovative ones. The actual implementation of technologies depends on the selection environment and changes related to actors involved in the process. In order to guide the analysis of technical change, the following questions were used:

- Which types of economic and energy efficient technologies have been encouraged?
- Which actors have been actively involved in the innovation chain?
- What kind of structures (organisations and networks) are changed or created?

The analysis of technical change is based on official documents, independent evaluations and peer-reviewed articles.

The British scheme has been limited to energy efficiency measures in the household sector and came to focus heavily on investment in insulation measures. The dominance of insulation measures, in particular cavity wall and loft insulation, was particularly evident in the first phase. This contributed to 56% of the total savings achieved, or nearly 38% of the savings redeemed (see OFGEM, 2005). To some extent, the scheme also encouraged investment in A-rated cold appliances and energy efficient lighting (Lees, 2006; Mundaca et al., 2007). Very similar trends are observed for the second phase (see OFGEM, 2007). At all events, it was found that the implementation of these technologies have been also encouraged by other policy initiatives, such as the EU energy labelling programme, consumer advice from specialised centres, building regulations, etc. (see Lees, 2006; Rohr, 2004).[41]

Regarding technologies implemented under the Italian scheme, which also included the commercial and industrial sectors, almost 20% of total savings during the first year of implementation were achieved by district heating, either through the realisation of new grids or the extension of existing ones (AEEG, 2006:20). In addition, solar heating panel installation was responsible for 8% of the total savings achieved.

It is found that both the British and Italian schemes have mostly supported the dissemination of commercially available, mature technologies (cf. AEEG, 2006; Lees,

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[40] Personal communication with Charles Hargreaves (OFGEM), Martin Devine (DEFRA) and Russell Hamblin (Energy Retail Association).
[41] For instance Lees (2006) identifies that building regulation from 2005 was a critical driver for transforming condensing boiler market. In this case, subsidies given under the British scheme, in conjunction with efforts done by other institutions (e.g. Energy Saving Trust) were still relevant to support that market transformation.

2006; OFGEM, 2005). This trend was expected, as TWC schemes promote the cheapest technological options. These are the most cost-effective technologies and those where uncertainty on performance is lower than is the case for innovative or cutting-edge technologies. For instance, in Britain, it is very likely that micro-generation (e.g. solar PV or micro-wind) will make only a marginal contribution in the short and medium term due to the fact that eligible measures of this type are far less cost-effective than insulation measures (see DEFRA, 2007). Moreover, it has been already concluded that, due to their extensive potential in the heating segment, cavity wall and loft insulation will continue to represent mature technologies during the third phase of the British scheme (see DEFRA, 2007).[42] Overall, as improvements in energy efficiency potential become exhausted, one could also argue that there exist opportunities for long-term innovative measures.

With regard to players' involvement in the innovation chain to affect technical change, the British experience shows that obliged parties have enhanced their commitment to energy efficiency as a result of TWC schemes. Some obliged parties have hired and/or trained personnel to provide professional advice on energy efficiency to customers. This process has supported competence building to fulfil targets at the lowest possible cost, increase familiarity with key eligible measures and to enhance energy efficiency in general. Furthermore, obliged parties have developed numerous partnerships with various actors, such as insulation contractors, managing agents, social housing programmes (SHPs), charity organisations, housing developers, retailers and manufacturers to meet their energy saving targets.[43] In turn, this process has enhanced human capital (individual learning) and structural capital (organisational learning). More importantly, studies have shown that the British scheme has increased obliged parties' interest in energy efficiency, altering their business paradigms. Energy efficiency is now understood as a business opportunity through which companies can extend their product and customer portfolios, and enhance customer loyalty and branding (Mundaca, 2007; Mundaca et al., forthcoming).

Overall, outcomes of TWC schemes demonstrate dynamics effects and systemic changes that support the fulfilment of energy saving targets. Although technological change seems to be limited to the dissemination of mature technologies, the development of the actors involved (i.e. the selection environment) shows intensive activity. This is relevant because in the long-term, it is argued that innovation does not take place solely within a firm, but it occurs as a result of interaction and collaboration between firms and other organisations (see Burtraw, 2000; Edquist, 2005).

4. Discussion

This paper indicates a *need for* and *selection of numerous evaluation criteria* that can capture and characterise the multiple attributes of TWC schemes and the policy context in which they work. This is necessary to provide decision makers with adequate and comprehensive information on the performance of the scheme. Many aspects can affect the selection of evaluation criteria. These include, policy objectives, the regulatory framework and scope of the scheme, availability and reliability of data, the ambition level of the evaluation, the human and technical resources involved, budget, etc. Importantly, stakeholders should bear in mind that uncertainty regarding the impact and outcome of a TWC scheme represents an inherent and critical element of any evaluation criterion. Furthermore, this study demonstrates the importance of guiding questions for each criterion. These must be reasonable, appropriate and answerable (see Rossi, 2004). In addition, one must bear in mind that policy instruments do no work in isolation, so it is

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[42] Notice that, in 2008, half of the UK housing stock will have loft insulation inferior to that required by law (NIA, 2006:4).
[43] For instance, 60% of insulation measures were delivered via SHPs, with approx. 23,000 social households benefiting (OFGEM, 2005:47-56).

necessary that selected criteria provide indications about the interaction between TWC schemes and other policy instruments if we are to identify synergies and avoid overlaps. The criteria we have used offer the potential to characterise the relative importance of many attributes related to a TWC scheme. This can be achieved with a weighting or scaling method. However, this process can become a significant challenge for policy makers and evaluation practitioners.

The *triangulation* approach undertaken in this study further illustrates the qualities of different methods in evaluating the performance of TWC schemes. In particular, the appropriateness of triangulation was confirmed when used in multi-criteria evaluation. That is to say, no single method or dataset can be relevant to the analysis of all evaluation criteria (cf. Fischer, 1995; Greening and Bernow, 2004; Mickwitz, 2006). Different methods can also complement each other in providing relevant answers for the same evaluation criterion. However, many obstacles also exist when using the triangulation approach. Each method requires a specific set of data and the more methods applied, the more data will be required. Moreover, using several methods underscores the multidisciplinary nature of the task and the need for several competences. This also requires rigorous routines to ensure adequate data collection. Needless to say, evaluation methods, such as exhaustive cost-benefit analysis, pose a substantial a challenge and their reliability depends on the accessibility of estimates and their level of uncertainty— including the chosen social discount rate.[44] Such challenges characterise the difficulties and costs incurred in performing the evaluation. Experience with multi-criteria decision-making processes indicates that, in the absence of stakeholders with well-defined preferences, results can be heavily influenced by the methods used to generate value judgements (see Fischhoff et al., 1980).

On the whole, the *evaluation approach is time and information-intensive*. Our experience indicates that a triangulation-based multi-criteria evaluation requires a vast amount of data and adequate estimates. When applied to a single case, data availability is rather crucial to cover all aspects. This limitation may be more relevant when applying the framework from an ex-ante standpoint. However, this should be considered as part of the evaluation challenge and not a deficiency in the triangulation approach as such. In our case, asymmetric information made evaluation challenging, but it was possible. Nevertheless, processes to ensure adequate data should be devised and implemented with each new TWC scheme. Relevant and high-quality data will support the evaluation and thus adequate policy-making while facilitating the continued development of TWC schemes. Moreover, reliable and available data can, to a great extent, facilitate ex-ante evaluations of new TWC schemes. While the use of economic criteria constantly poses conceptual and practical problems, monetary valuation is argued to be rather relevant because economic aspects are of prime importance in public policy (cf. Bardach, 2005; Mickwitz, 2006; Rossi et al., 2004). Finally, although our evaluation exercise was time consuming, it must be said that multi-criteria analyses can take much less time relative to the overall policy formulation process (Lahdelma et al., 2000).

A major insight emerging from this study is that the *performance of the analysed schemes is rather unique due to case and country-specific regulatory and market conditions*. The British and Italian schemes were used as examples on which to apply the suggested framework and to cast light on relevant aspects of evaluation for each criterion. Although not the primary objective of this paper, our results strongly indicate that continuous case and country-specific ex-post evaluations are needed to improve the performance of implemented TWC schemes. Results from a TWC scheme in one country could not be generalised and applied for a TWC scheme in another. Energy saving

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[44] See Rossi et al. (2004:360-362) for some of the pre-conditions needed to apply a cost-benefit analysis in ex-post policy evaluation.

measures may not be as cost-effective in other countries as in Great Britain—transaction costs may differ between counties due to institutional parameters, etc. As is usually the case, things are somewhat less clear when examined in depth. Consequently, although extrapolation is possible, it should be used with due caution. In light of the evaluation results, we now briefly revisit the hypotheses stated in Section 2.

- *Can TWC schemes meet energy-saving target effectively?* High energy-saving effectiveness is observed in the cases analysed. However, this may be the outcome of saving targets reflecting a low level of ambition and pitfalls in the regulatory framework. The integrity of energy-saving effectiveness also relied on effective non-compliance rules, due enforcement and a reduced free-riding effect.
- *Are TWC schemes economically efficient?* The British case offers strong support for this hypothesis. As for Italy, much more data is needed in order to ascertain whether society has benefited by the TWC scheme or not. Furthermore, additional research is needed to gain a wider and improved quantification of all ancillary benefits related to increased energy efficiency; posing a remarkable challenge for thorough assessment.
- *Can TWC schemes achieve saving targets cost-effectively?* The Great Britain scheme supports both this hypothesis and outcomes from modelling studies. In Italy, the only pre-conditions identified were the market place (both spot and bilateral) and a common TWC price. However, indications of free-riding and the impossibility to identify an alternative policy instrument to be used as benchmark do not allow serious assertions in this regard. Overall, a thorough comparative analysis needs to be undertaken involving alternative policy instruments.
- *Do TWC schemes entail high transaction costs?* Whereas numerous sources of transaction costs were identified in Great Britain, entailing a substantial burden, results show that the scheme was still cost-effective and economically efficient. No estimates were drawn for the Italian case. In all, the nature and scale of transaction are likely to be different for each scheme, so no general assertions can be made.
- *Are TWC schemes highly feasible politically?* The Italian case does not support this hypothesis. Nevertheless, the British scheme indicates the contrary, with several policy aspects influencing a higher feasibility though. A recent study shows that commercial co-benefits of TWC schemes (e.g. increased competitiveness) can leverage their legitimacy by avoiding conflict with the beliefs and interests of energy suppliers (see Mundaca et al., forthcoming).
- *Do TWC schemes involve a low administrative burden?* The British case showed that a limited coverage is achievable for public authorities. However, the coverage of the Italian and French schemes may indicate the opposite. Further research is needed, but here too, results are likely to be case-specific.
- *Do TWC schemes support technical change?* Evidence does not support this hypothesis. Both schemes have basically supported the dissemination of mature technologies that are already commercially available. Combined with ambitious saving targets, a stringent and enforceable definition of additionality may yield a different scenario.

The results from this study indicate the *trade-off analysis resulting from multi-criteria evaluation*; which needs to be duly taken into account. One can observe that the object of each criterion used is not completely apparent or totally independent from the rest (Sterner, 2003). In others words, the policy formulation process and the debate/negotiation this involves can sometimes focus on different—if not fully opposed—policy objectives (cf.

Fischer, 1995; Greening and Bernow, 2004; Sterner, 2003). With many criteria being interlinked with others, several trade-offs exist.

The trade-off analysis regarding TWC schemes can be extensive and complex. For instance, political feasibility might be gained at the expense of soft energy saving targets. Likewise, higher cost-effectiveness can be gained with a broader set of eligible measures and sectors, but it also can increase administrative costs for the authorities and entail higher transaction costs for obliged parties. Once a TWC scheme is considered politically feasible, it is crucial to take into account how cost and benefits are distributed; including those resulting from a non-trading approach. If costs are unfairly distributed, legitimising TWC schemes may prove politically challenging, as efficiency may be gained at the expense of equity—in particular in a country with large income disparities. In fact, even if an instrument meets the efficiency criterion, very little—at best—can be said about the fairness of the distribution of costs and benefits. Thus, efficiency should not be a required or satisfactory condition in public policy choice (e.g. Anderson et al., 1997; Panayotou, 1998; Sterner, 2003).[45] The trade-off analysis regarding TWC schemes can be extensive and complex. If alternative designs for TWC schemes are evaluated, design elements should be translated into impacts and outcomes before a tangible trade-off analysis takes place among different design options. Then, competing impacts and/or outcomes can actually be confronted. Importantly, a common outcome in economic analysis is that trade-offs usually occur at the margin.[46]

Based on the above-discussed aspects, several *advantages* and *disadvantages* were identified when applying the proposed multi-criteria evaluation framework. These are summarised as follows:

Advantages:

- As TWC schemes have unique designs and cover many possible flexibility mechanisms to meet the set goal, and interact with country-specific policy contexts, a multi-criteria evaluation policy framework allows us to better understand the broad effects, attributes and complexities of TWC schemes.
- The evaluation process allows the inclusion not only of economic and energy-related aspects, but also socio-political, organisational and commercial factors, which allow us to identify trade-offs and co-benefits from TWC schemes.
- Due to the multi-disciplinary nature of the evaluation approach, a variety of specific results were produced, allowing a broader analysis compared to an evaluation using a single criterion and/or discipline. This avoids generalisations.
- By no means exhaustive, the chosen criteria cover aspects that are of particular analytical relevance—still to be tailored to a specific context—offering a basic template for the evaluation of current and future TWC schemes.
- The approach yields a variety of detailed results that provide a wider basis for a more balanced discussion concerning design and implementation aspects. In turn, this can contribute to better communication among stakeholders.

Disadvantages:

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[45] For details on distributional equity issues in TWC schemes, see Mundaca (forthcoming) and NERA (2005).

[46] For instance, an extra unit of saved energy—as expressed in the target—can be achieved with an extra spend of *X* monetary units. Policy makers should be confronted with the question of whether the society values that extra saved energy (including resulting positive externalities) more or less than the extra expenditure needed to achieve it. In simple terms, the more energy saved, the higher the marginal energy saving cost. Then, the decision process should continue until an extra unit of energy saving target is not worth the trade-off, thereby finally determining a given saving target. Likewise, administrative costs can be bearable up to a certain level for public authorities—quite logical if one bears budget restrictions in mind. Then, if the extra design feature (e.g. one more eligible measure) increases approval costs above that given level, policy makers need to decide whether that trade-off is worthwhile.

- There is a need for available, reliable, timely and useful data—in particular for quantitative analyses.
- Depending on the scope and ambition level, the approach requires a group of evaluators with skills in a variety of conceptual tools and social research methods.
- While there is need to use different evaluation methods, these are likely to yield conflicting results, which may add complexity to the overall analysis. Due to a lack of data, an assessment of all aspects may prove rather challenging.
- Due to the multi-disciplinary nature of this approach, results may be criticised for being too broad, as opposed to an evaluation performed using a single criterion from a single discipline—which would likely yield a more detailed but narrower analysis.

Finally, whereas the temporal approach of the evaluation presented in this paper is focused on an ex-post context; several aspects can be used to guide and *support an ex-ante evaluation*. A useful departure point is the characterisation of TWC schemes (i.e. saving targets, time horizon, eligible measures, etc.) and thus coverage (i.e. eligible sectors, eligible fuels, eligible/obliged parties). A multi-criteria framework can complement modelling outcomes by providing insights regarding non-market valued aspects, trade-offs between different (design) alternatives, co-benefits and views from different stakeholders (cf. Greening and Bernow, 2004; Lahdelma et al., 2000). Input data should be critically reviewed upon the design of the scheme and country-context in which it operates. A sensitivity analysis should be performed for key variables. Complementary methods, such as surveys and interviews, can aim at identifying and exploring optional design features. These might include the legitimacy of TWC schemes, critical institutional and market-related determinants, compliance strategies, trading patterns, transaction costs, etc. Gaming simulation exercises can also be an interesting analytical tool. This can allow the evaluation of system behaviour in response to actions and events via the use of archived data and pre-determined rules. With a group of experts and relevant stakeholders, panel methods can serve as a meaningful discussion forum to facilitate the negotiation and policy formulation process. Respondents can be exposed to findings from different methods, consulted about inconsistencies, and provide further guidelines and feedback about policy alternatives.

5. Conclusions

The objective of this paper was to develop and apply a multi-criteria framework with the aim of providing a more comprehensive evaluation of TWC schemes. When applying the proposed framework, the aim was to focus on aspects that are of relevance to policy when evaluating the British and Italian TWC schemes. Consequently, the aim was not to assert which scheme performs better, but to use them to test and exemplify the practicability of the multi-criteria evaluation. Several pros and cons were identified when applying the proposed framework. The proposed framework offers an approach to bridge the fact-value dichotomy that has been long debated in public policy evaluation. It has dealt with a number of empirical and normative aspects that can be applied on an evaluation of TWC schemes.

The results of the paper show the advantages of using a multi-criteria framework and complementary methods to better understand the scope, dynamics, complexities, and, thereby, effects (impacts and outcomes) of TWC schemes. Specifically, the results indicate the need for evaluations and methods to complement cost-minimisation models to evaluate the effects of TWC schemes. By stressing that there is no single-best method for policy evaluation, the undertaken triangulation approach proved to be challenging but feasible in attaining the objective. Likewise, the numerous evaluation attributes related to TWC

schemes indicate a need for a multi-disciplinary evaluation approach. Not surprisingly, the obstacles were numerous. The availability and reliability of data posed a significant challenge. However, instead of analysing detailed information from a narrow perspective, we conclude that the analysis of wide-ranging information by different methods can yield more significant and valuable results. The suggested multi-criteria framework—supported by the triangulation research approach—can provide a larger foundation for judging the merit of TWC schemes. This offers multiple views to support a constructive policy debate and to better communicate the justification to stakeholders. The framework also offers the potential to characterise the relative importance of each attribute related to TWC schemes. This can become a significant challenge for policy makers and evaluation practitioners.

The evaluation based on a multi-criteria framework has shown that the results of a TWC scheme are very case and context-specific. For this reason, outcomes from this approach are unsuitable for generalisation or comparative international assertions. In addition, policy formulation is unique and complex, and represents the outcome of several value judgements—policy agendas, decision-making styles, stakeholders, evaluation capacities, and negotiation processes, among others. Results strongly indicate that continuous ex-post evaluations are needed for each individual TWC scheme to improve its evolving and dynamic performance.

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Markets for Energy Efficiency
Exploring the new horizons of tradable certificate schemes

This doctoral thesis explores the implications of establishing tradable certificate schemes for improving energy efficiency (so-called 'Tradable White Certificate' [TWC] schemes). Carrying out different case studies, a set of complementary evaluation methods is applied in conducting ex-ante and ex-post evaluation studies. To analyse the attributes and complexities of TWC schemes, the thesis focuses on several aspects, including (i) the modelling of potential impacts, (ii) the identification and analysis of transaction costs, (iii) the investigation of trading patterns and other flexibilities used to achieve cost-effective compliance, (iv) the level of energy-saving effectiveness under TWC schemes, (v) the use of cost-benefit analysis, and (vi) the application of multi-criteria evaluation. The findings help answer questions concerning the impacts and outcomes of TWC schemes and identify critical endogenous and exogenous conditions that affect their performance. Furthermore, the research assists in developing an understanding of what aspects of TWC schemes need to be evaluated and how.

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