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Energy and climate policies to 2020 : The impacts of the european « 20/20/20 » approach

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ENERGY AND CLIMATE POLICIES TO 2020:

THE IMPACTS OF THE EUROPEAN "20/20/20" APPROACH

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ENERGY AND CLIMATE POLICIES TO 2020:

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Abstract

Purpose - The study aims to quantify the possible interactions between the three European objectives in the horizon of 2020: (i) the reduction of 20% of greenhouse gas emissions (GHG) (2) the saving of 20% of the European energy consumption and (3) a share of 20% of renewable energies in the overall energy consumption. Particular focus is, however, placed on the influence of the CO_2 emission reduction targets and on their consequences on the carbon price in 2020.

Design/methodology/approach - In order to explore the interactions among the three European objectives and their induced effects, a number of scenarios are tested within a combination of two modeling tools: the POLES world energy model and ASPEN, an auxiliary model dedicated to the analysis of quota trading systems. With reasonable assumptions for the burden sharing among the Member States, the energy efficiency objectives and the renewable energy targets are achieved using national quota systems in each European country (white and green certificate systems and their implicit prices), while the CO_2 emission reduction is carried out within the European Emissions Trading Scheme (ETS) in line with the objective of 20% emission reduction.

Findings - The paper shows, in particular, that the two quota policies (WC and GC) decrease significantly the European marginal emission reduction cost and consequently, the compliance costs for ETS participants. The high renewable target compliance cost could be reduced significantly if carbon price signal and energy saving policies are in place. The paper also shows that the sole carbon price signal has a limited influence for stimulating renewable energies and energy savings and thus concludes on the need for specific policies targeting these two areas.

Keywords - CO_2 emissions, carbon price, white certificate price, green certificate price, European objectives in 2020

Paper type - Research paper

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Introduction

The European Council on the 8 and 9 march of 2007 decided to achieve three ambitious obligations for the 2020 horizon: (1) the reduction of 20% of greenhouse gas emissions (GHG) (and up to 30% if an international agreement justifies it) (2) the saving of 20% of the energy consumption and (3) the share of 20% of renewable energies in the overall energy consumption. The key element of these ambitions, in relation to the fight against the climate change, is the reduction of GHG emissions (Criqui, 2007). The European emissions trading scheme (EU ETS, thereafter referred to as ETS) includes the energy intensive European industries and the electricity producers. It represents at least 45-50% of CO_2 emissions in Europe and will remain, according to the European institutions, the key instrument in reaching Kyoto and post-Kyoto targets. By January 2008, the Commission has introduced the first proposals for national targets in the "20/20/20" policy, and negotiations are going on. This paper is a first attempt to comprehensively deal with the economic fundamentals of the three-dimensional regulatory system proposed by the Commission for energy and climate.

For renewable energies, the Commission didn't specify the particular instruments for increasing the share of renewable energies to 20% in total energy consumption. However in recent years, the feed-in tariffs proved to be effective in increasing the development of renewable energies. Quota systems coupled with the exchange of "green certificates" (GC), which prove the origin of the production, also became an increasingly common instrument to facilitate the diffusion of renewable electricity (Bertoldi and Rezessy, 2006). Market instruments are equally high on the agenda for stimulating energy efficiency and savings. An instrument, frequently identified in the academic and political debate, is the one of energy saving obligations coupled with the exchange of certificates representing the savings achieved and often denominated as "white certificates" (WC).

Increased energy efficiency while diminishing the whole set of externalities associated with energy production will consequently decrease the cost of GHG emission reductions[1]. Likewise increased utilization of renewable energies, which are justified for considerations of security of supply, employment or regional or local benefits could participate in the reduction of GHG emissions. Strong interactions exist, therefore, in terms of emission reductions, but also in terms of costs of programmes chosen to reach their respective objectives. Several studies have analyzed the possible interactions on theoretical grounds (NERA, 2005, Bertoldi and Rezessy, 2006, Doucet and Percebois, 2007). Additionally, the authors analyze the integration possibilities of different quota systems in Europe: ETS, GC and WC. For the short term, they conclude in favor of separate quota systems for fear of double counting possibilities for one action undertaken as well as of the related complexities of integration, which, eventually, might dampen its benefits.

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[1] It should be noted that energy efficiency does not always produce energy savings for possible "rebound effects" (Herring, 2006). Energy savings might likewise result from the behavioral changes leading to conservation of energy. In our study, we keep in line with Bertoldi and Rezessy who consider that only "additional energy savings justify a policy intervention: policy may support measures that involve either investments or achieved savings (or both) provided that they are measured against the same system conditions" (Bertoldi and Rezessy, 2006).

Our study does not analyze the integration of the three quota systems nor their specific design, but aims at quantifying the consequences of the objectives that Commission proposes for 2020. The evaluation of relative efficiency of market-based instruments such as taxes *vs.* tradable permits or certificates is outside the scope of the study. Therefore, we consider that the respective national objectives for energy savings and renewable energies are being realized with quota systems in every country: WC and GC systems, which represent the national implicit or shadow prices that would be required to attain the objectives. CO_2 emissions reduction is carried out within ETS and is consistent with the EU's commitment of 20% emission reduction by 2020.

In reality, the implementation of the three objectives will interact simultaneously. However, due to the intrinsic difficulties in the evaluation of superposed actions, we examine the impact of one objective on the implementation of another objective in a sequential manner. For that, we create a number of scenarios representing the introduction of the sole quota systems or a combination of quota systems introduced in a sequential manner. The priority for the introduction is, however, placed on energy savings that is WC systems since the reduction of energy consumption is often considered as a structural, low-cost reduction option (Bertoldi et al., 2005). The scenarios are tested with a combination of two modeling tools: the POLES world energy model and ASPEN, which is dedicated for the analysis of quota systems[2]. A static and competitive equilibrium environment is assumed for the study.

The paper proposes a comprehensive approach of the economics of the “20/20/20” European policy. It develops along the following: in section 1, we introduce the principal policies for reducing GHG emissions as well as increasing energy savings and renewable energies in EU; in section 2 we first explore the interactions among ETS, GC and WC systems in a theoretical perspective and then display the methodology for quantifying these interactions; section 3 later delivers and analyses the main results of this study; lastly, we present our main conclusions in section 4. The paper shows, in particular, that the energy saving and renewable quota policies (WC and GC) significantly decrease the European marginal CO_2 emission reduction cost and consequently, the compliance costs for ETS participants. It also shows that the sole carbon price signal has a limited influence for stimulating renewable energies and energy savings, thus, affirming once again the need for specific policies targeting these two areas[3].

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[2] For a short description of the POLES world energy model refer to Annex 1, for a more detailed description refer to Lepii-Epe, 2006. For the functioning principle of ASPEN refer to Criqui et al., 1999, Lepii-Epe, 2001, Stankeviciute et al., 2007. Unfortunately, the ASPEN described does not include yet WC and GC systems.

[3] “Carbon” and “CO_2” are utilized interchangeably throughout the article.

1 The context of environmental policies in Europe: climate policies, energy savings and renewable energies

EU is generally acknowledged for playing a strategic role in climate negotiations. The policies adopted at the European level are important not only for the emission reductions in the Member countries, but also for the development of the international climate regime. The lessons learnt in formulating the coordinated climate change policy at the European level, in particular the failure of the introduction of the carbon-energy tax in the early nineties, have lead to a reflection on alternative policies, also efficient and appropriate to market conditions (Andersen, 2005). In establishing the ETS Directive and in proposing the quantitative objectives in the field of energy savings and renewable energies in 2020, the EU shows a marked preference for “cap & trade” or “baseline & credit” systems, where the quantitative objectives are known, but not the marginal costs of the actions to be undertaken, whereas with taxes, the accepted cost – at least the marginal cost – is known initially, but not the quantities to be eventually achieved (Weitzman, 1974). In theory, the market-based instruments minimize the cost for the society when reaching a certain objective (static efficiency) and also provide the incentives for adoption and innovation of new clean technologies (dynamic efficiency) (Jaffe et al., 2003).

1.1 The European emission trading system (ETS) in its regulatory context

The ETS is aims at providing an efficient way to be offered to the Member countries to ensure a significant part of their Kyoto obligations and to progress towards a low carbon economy in the future. The system relies on the creation of a price for carbon emissions by establishing the market for emission allowances or quotas. From the economic point of view, the market solution allows minimizing the total costs of a particular programme since the exchange of quotas equalizes the marginal costs of reductions, while mobilizing only the least-cost options (Criqui, 2002).

The ETS is supposed by the EU to achieve its Kyoto target at a cost of € 2.9 to € 3.7 billion annually (European Commission, 2004). This is less than 0.1% of the EU's GDP. Without the scheme, compliance costs are evaluated at € 6.8 billion a year. The system was initially founded on six main principles[4]: (1) it is a “cap & trade” system, (2) its initial focus is on CO_2 emissions from large industrial emitters, (3) implementation takes place in two phases (2005-07 and 2008-12) with periodic reviews and opportunities for expansion to other gases and sectors, (4) the allocation plans (NAPs) are decided periodically by the Member countries in line with Kyoto objectives, but require the approval of the Commission, (5) it includes a strong compliance framework (the penalty for exceeding the quotas is fixed for the two phases € 40 and € 100/tCO_2 respectively), (6) ETS taps emission reduction opportunities in the rest of the world through the use of Clean Development Mechanism (CDM) and

[4] Refer to Directive 2003/87/EC

Joint Implementation (JI) projects, and provides for links with compatible schemes in other Annex B countries (refer to Directive 2004/101/CE).

In operation, the ETS has shown itself so far to be an administrative success, with the overwhelming majority of installations reporting their independently verified CO_2 emissions and surrendering the appropriate number of allowances to cover them at the required deadlines (Environmental Audit Committee, 2007). However, the emission reductions turn out to be less impressive. The verified emissions in 2005 showed that the CO_2 market was long of allowances and not short as it was anticipated in the beginning of the programme. The surplus of allowances was due to a combination of two factors: (1) generous national allocations and (2) effective internal reductions. The market analysts consider that the first factor was by far the most important (Point Carbon, 2007), but some economic studies show that both factors have occurred, the second one even greater than the first one (Ellerman and Buchner, 2006). In either case, the European authorities have retained the lessons from the first experimental phase; the Commission review process of the second round of NAPs for the 2008-2012 period turns out to be more vigorous, involving reductions of initial national quotas for almost every Member country. The definite success of the ETS will be principally judged on two elements: the emission reductions obtained and the appearance of stable carbon price.

1.2 The European policies for energy savings

The Directive on energy end-use efficiency and energy services, which came into effect in April 2006, aims at fostering cost effective improvements of energy end use and at transforming and promoting the market for energy services (2006/32/EC). The Directive establishes an indicative energy savings target of an additional 1% annually in the nine years following the adoption of the Directive. The base year for the energy savings is calculated using the average energy consumption during the last five years before the entry into force of the Directive. It applies to all sectors of final energy consumption, except aviation and the industries under the ETS. To achieve this objective, Member States must prepare three national energy efficiency action plans and ensure that the public sector fulfils an exemplary role regarding investments, maintenance and other expenditure on energy-using equipment as well as energy services. Additionally, the implementation of the Directive on the energy performance of buildings (2002/91/EC), as from 2006, will permit a gain estimated at some 40 Mtoe between now and 2020 (European Commission, 2005a). To the extent that energy consumption has a significant impact on the environment, which is often the case for household appliances, the Commission aims at establishing energy-efficiency requirements for a large range of appliances and applications[5] (Directive, 2005/32/EC). Furthermore, the Union has implemented until now voluntary agreements with the car industry and labeling of cars on energy efficiency in order to limit the fuel consumption of vehicles (European Commission, 2005a).

[5] For example, the stand-by control for lighting, heating, cooling and electric motors.

According to the *Green Paper*, EU could save 20% of its energy consumption in 2020 (European Commission, 2005a). Experience shows that the diffused potentials for energy savings in the residential, service or transport sectors are not sufficiently exploited through the classical instruments used in numerous European countries – information of consumers, regulation, fiscal subsidies and incitations – because the feasible energy savings are not sufficiently valued by the decision-makers (Moisan, 2004). Furthermore, with the gradual opening of electricity and gas markets to competition, the instruments for promoting efficient use of energy should be compatible with the market conditions. Market instruments are relevant for completing the cost-effective exploitation of energy savings potential and are compatible with the new market conditions.

The combination of an energy saving obligation for some category of operators (distributors, suppliers, consumers, etc.) coupled with tradable certificates (WC) representing the energy saved has already attracted the attention of some European countries. Similar systems exist in Italy, France, United Kingdom and Flanders, Belgium. The discussions are in process for the establishment of such a system in Netherlands[6]. However, in their analysis Bertoldi and Rezessy show that the existing systems remain quite different one from another, with respect to the actors placed under regulation, to the eligible measures and sectors, and to the resulting performances (Bertoldi and Rezessy, 2006).

1.3 The European policies for renewable energies

Increasing the share of renewable energy sources in the final energy consumption and, in particular, in the electricity generation is also one of the Community's targets for 2010 as stated in the Directive of electricity production from renewable energy sources (2001/77/EC). The principal support schemes, adopted by Member states, comprise price-based feed-in tariffs (FIT), quantity-based quota systems or Green Certificates and, to a lesser extent, the calls for tenders and financial incentives.

The FITs allow the producers to sell the green electricity at a fixed price per kWh. This price or tariff is usually above the market price and is guaranteed for a number of years. The quota system or the GC system consists of: i. the establishment of quotas for the production of green electricity imposed on the operators intervening on the electricity market, i.e. distributors, retailers or producers-importers; ii. the flexibility associated with the trading of certificates among the operators under regulation. These can produce the desired quantity of green electricity, negotiate long term contracts with specialized renewable producers, or purchase certificates corresponding to a certain production of green electricity (Menanteau et al., 2002).

In general, the GC systems were favored by the Commission because they satisfy the cost-effectiveness rationale as well as unified market conditions comparing to FITs (Lauber, 2002). However, in a report of December 2005, the European Commission noticed that FIT regulations were very effective for promoting renewable electricity (European Commission, 2005b). They have proven their effectiveness by enabling the marked growth of the installed production capacities. The important

[6] Refer to Bertoldi and Rezessy, 2006 and NERA, 2005 for a detailed description of these systems.

increases in the green electricity production have occurred in Germany and Spain, those countries with FIT policy. The quota systems with tradable certificates that were implemented in some countries have not shown comparable results[7]. Additionally, the costs proved to be higher in countries with quota systems than in countries with FIT regulation, which also reflects higher risks for operators of facilities (European Commission, 2005b). Therefore, even if these systems present theoretical advantages, they remain complex to implement and operate well only if the necessary market infrastructure is very carefully developed. Several authors also indicate that GC systems introduced at the European level would probably be more efficient than those introduced at the national levels since a deeper market would produce more stable GC price and diminish the problems related to the fixing of adequate quotas (del Rio, 2005).

On the other hand, some argue that FIT regulation, because they generate rents, might be inefficient in terms of allocative resource efficiency and offer only little incentives for the reduction of the production costs, despite their undeniable effectiveness in the push of green electricity production (Menanteau et al., 2002). While both systems are said to have advantages and drawbacks, the discussion on which support system is best is not approached in this article[8]. The theoretic interactions among the three instruments: ETS, WC and GC are highlighted in the next section.

2 INTERACTIONS OF THE THREE REGULATORY SYSTEMS

Theoretical interactions have been analyzed in NERA (2005). Here, we recapture the aspects relevant to our empirical analysis, and then develop a methodology for the taking into account of these interactions.

2.1 Regulatory interactions in theory

The impacts of WC and GC systems on the overall CO_2 emissions and on the emissions in the ETS

The WC system alone can help to diminish the CO_2 emissions when the installations are not initially included in the ETS. The reduction of direct consumption of fuels in households and buildings fits well with a policy of emission reductions driven by a WC system. However, the limitation of network electricity consumption in households does not generate additional reductions because electricity is already included in the ETS. In theory, the WC system does not influence the reduction of emissions originating from ETS because the quota in ETS is defined *ex-ante*. Counting of the avoided emissions due to the WC system would result in double counting of CO_2 quantity since electricity saved also

[7] Latvia (combined with FITs), Belgium, Italy, Poland, Sweden and United Kingdom.

[8] For a discussion of FIT *vs* tradeable green certificates refer to: Butler and Neuhoff, 2005, Midttun and Gautesen, 2006, Lipp, 2007, Ragwitz et al., 2007.

reduces the emissions in the electricity sector under ETS. The displaced fossil fuel generation would free up ETS allowances that would be used to cover emissions elsewhere.

As to GC system for renewable energies, it would reduce CO_2 emissions only if the green electricity replaces polluting fossil-fuelled electricity generation. Indeed, the ETS already encourages indirectly low-carbon investment and punishes emitting technologies. However, ETS would spur the investments in renewable energy technologies only after all the low cost options have been exhausted on the market. Furthermore, the double counting problems would again appear if the emission reduction benefits were counted by the GC system (Sorell, 2003).

The impacts of WC and GC systems on the costs of the overall and ETS CO_2 emissions reduction.

The introduction of the WC and GC systems might lead to the reduction of the demand for allowances in ETS and, consequently, of the CO_2 price on the market. The preceding takes place when the WC and GC systems "pay" for certain emission reductions *via* the decrease in polluting production. Consequently, the allowance price and the compliance costs for the participants in the ETS are reduced. However, this decrease in costs does not mean that the overall costs of reducing emissions and achieving the cap is lower with certificate systems than without. The overall costs might even be higher, as the measures undertaken under WC and GC systems might be more expensive than those undertaken under the cost-minimizing optimum of ETS alone[9]. This situation is, however, less likely to occur for WC system since the majority of the reduction options are considered to be low-cost (Commission Europeans, 2005).

The impacts of WC and GC systems on the electricity market in the ETS

The WC and GC systems may decrease the price of electricity if the energy savings achieved or the renewable technologies replace fossil fuel-based electricity generation. The reduced demand for electricity may then lead to a lower marginal production cost (or to a decrease in polluting production, which usually fixes the market price) and therefore to a lower price[10]. This decrease could be, however, compensated by the pass-through of costs related to energy-saving or renewable technologies. Typically, the increase in electricity price should be more important when the three systems are in force together rather than within each one. In the long term, the impacts on the electricity producing mix and its price are less clear since they depend from the investments in new generation capacities, which in return, depend partially from the expected costs related to environmental regulations. The following section introduces the methodology used for quantifying different interactions among the three objectives in Europe.

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[9] "If the measures incentivised by WC and GC systems were the most cost-effective available, then these measures would anyway be incentivised by ETS, without the need for additional programmes" (NERA, 2005).

[10] It depends on the merit order in the electricity production of every country.

2.2 A practical methodology for the simulation of regulatory interactions

In order to analyze the economic fundamentals of the triple system of regulation schemes in the "20/20/20" policy, it is first necessary to precisely derive national and European objectives in the field of energy savings, renewable energies and ETS so as the respective national and European prices to attain these objectives. Secondly, we define the scenarios that are relevant for the analysis of interactions among the three objectives.

National objectives for energy savings are defined with respect to the European objective announced by the Council: saving of 20% of the EU's energy consumption compared to projections for 2020 (Council of EU, 2007). However, the share of the efforts needed by each Member country to achieve the European objective was not specified by the Council. In this study, we use the Reference scenario of the POLES model for the projections of primary energy consumption, which in a case without any environmental policies, corresponds to total emissions of 1995 Mtoe in EU25 in 2020[11]. In order to comply with the Council's objectives, primary energy consumption in the European community should be around 1590 Mtoe in 2020, which represents a cumulative reduction of consumption of 10.8% from the base year 2005 or an average reduction of 0.67% p.a. from 2005. We observed in the section 1.2 that the existing WC systems throughout Europe are not harmonized and differ in terms of actors involved, eligible measures and sectors. We assume that the national WC systems cover residential, commercial, industrial and transport sectors. Hence, we produce continuous marginal primary energy consumption curves for every country using successive simulations of the POLES model, with progressively increasing energy consumption taxes in the sectors mentioned. Furthermore, the curves are introduced in the ASPEN sub-model, which allows deriving the implicit national WC prices as a function of national objectives.

National objectives for renewable energies in our study are defined with respect to the indicative European target of one third in the electricity consumption in 2020 as it was indicated by International Energy Agency (IEA, 2007). With this assumption we do not fully stick to the European objective of 20% share of renewable energies in overall energy consumption in Europe in 2020 (Council of EU, 2007)[12]. However, it seemed of interest to us, to focus on the contribution of green electricity to the renewable objective in final energy consumption. As we will see later in section 3 of the study, the implementation of the indicative green electricity objective approaches the European renewable objective in the final energy consumption. Contrary to the objective of energy savings, the Council indicates that national objectives for renewable energies should be defined as a function of potentials and efforts already put in place:

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[11] The reference projections of the PRIMES model, on which the Commission bases its energy efficiency objective, amounts to 1990 Mtep in 2020 (European Commission, 2005a).

[12] Besides green electricity, renewable objective comprises heat from renewable sources as well as utilisation of 10% biofuels. Only green electricity is incentivised in our study, but all renewable energy sources are added up for calulating their contribution in the final energy consumption later on in the Table 5 of the article.

> "differentiated national overall targets … with due regard to a fair and adequate allocation taking account of different national starting points and potentials, including the existing level of renewable energies and energy mix"

> and "leaving it to Member States to decide on national targets for each specific sector of renewable energies (electricity, heating and cooling, biofuels)"

Taking these indications into account, in our study we employ the indicative national targets for 2010 under the Directive of electricity production from renewable energy sources, which are compatible with the objective of 12 % share of renewable energies in the final energy consumption and, in particular, with a 21% share in the electricity consumption; then, we adjust the indicative targets so that they approach the share of one third of the electricity consumption in 2020. Once the national objectives have been defined, the continuous marginal renewable electricity production curves are produced by a series of successive simulations with increasing FITs in the POLES model, which allows later the calculation of the implicit national GC prices from ASPEN module.

National objectives for emission reductions are defined with respect to European objective of 20% GHG emission reductions in 2020 comparing to 1990 for the EU25 (Council of EU, 2007). For modeling reasons, however, we cover in our study only CO_2 emissions. The burden-sharing scheme used is based on the study performed by the German Institute for Economic Research (2007), presented in Annex 2. The sectoral distribution of the 2020 emissions quota comprises the information from the second NAPs under ETS for the ETS sectors and the latest GHG emissions inventories for the non ETS sectors. The sectoral proportions found are then inserted in the 2020 national emissions quotas. Using the POLES model, we then produce a series of successive simulations with an increasing carbon value in order to derive the continuous sectoral marginal abatement cost curves (MACC) for every country and region. Afterwards, the MACCs are inserted to ASPEN sub-module model for the analysis of the emissions trading system. In function of the national and sectoral emissions quotas and their participation in the carbon market, ASPEN calculates the equilibrium carbon price, project-based credit flows, reduction costs and equilibrium burden sharing among the countries.

The carbon market in 2020 for its part beyond EU's frontiers is modeled by including: i. the participation of the rest of annex B countries that ratified Kyoto protocol with CO_2 emissions reduction constraints of 10% comparing to 2010 level, ii. the participation of the USA and Australia with constraints to stabilize their CO_2 emissions in 2020 to 1990 level as it was proposed by the American senators McCain and Lieberman[13] (Pizer, et al., 2003) and iii. the participation of non-Annex B countries through the emissions trajectories from the POLES reference scenario. For this latter category, no carbon constraints are imposed, but project-based mechanisms are allowed through CDM projects. However, only a restricted part of the theoretical potential is considered as potentially introducible to the market, due to high transaction costs that result from the lack of information or

[13] According to the proposal of McCain-Lieberman, during the first six years of the program (2010-2016), annual GHG emissions would be limited to the amount released in 2000 and in subsequent years, the limit would be reduced to the 1990 emissions levels.

skilled personnel, political or economical obstacles, trade barriers or general politics of the developing country.

In order to quantify the possible interactions among the environmental objectives we have created a number of scenarios displayed in Table 1. We notice that scenarios 2 to 5 are based on sole quota policies, while scenarios 6 to 9 consider the combination and different sequence introduction of such policies, although the priority is always placed on WC policy, which represents energy savings. Scenarios 6 to 9 are performed according to the following steps, e.g. for scenario 9: i. using the POLES model, the series of successive simulations are performed with a linearly increasing tax on final energy consumption, the results of which is treated in ASPEN to derive national WC prices; ii. a new set of successive simulations, including national WC prices is performed with a linearly increasing carbon value and analyzed in ASPEN module in order to obtain European CO2 ETS price; and finally iv. the last set of sensitivity analyses including both WC prices and CO2 ETS price is performed with a linearly increasing FIT and analyzed in ASPEN in order to derive national GC prices. The three set of prices are then combined to produce a final simulation of scenario 9 “WC+CO2 ETS+GC”.

Table 1: Scenarios

Scenarios	Description
1. Reference	No environmental policies
2. CO2 total	Sensitivities of carbon value applied to all energy system sectors → European CO2 price (no international cor
3. CO2 ETS	Sensitivities of carbon value applied to ETS sectors → European CO2 ETS price (in international context)
4. GC	Sensitivities of FIT applied to renewable electricity generation → national GC prices
5. WC	Sensitivities of energy consumption tax → national WC prices
6. WC+GC	National WC prices + (Sensitivities → national GC prices)
7. WC+GC+CO2 ETS	National WC prices + (Sensitivities → national GC prices) + (Sensitivities → European CO2 ETS price)
8. WC+CO2 ETS	National WC prices + (Sensitivities → European CO2 ETS prices)
9. WC+CO2 ETS+GC	National WC prices + (Sensitivities → European CO2 ETS prices) + (Sensitivities → national GC prices)

The distinction between scenarios CO2 total and CO2 ETS is the following: in the former, the objective of 20% reduction of CO_2 emissions is applied to all energy system sectors (ETS and non ETS) comparing to 1990 emission level (or 12.7% reduction based on 2010); in the latter, the objective of CO_2 emissions reduction for ETS sectors is calculated in line with the overall 20% objective and applied in ETS sectors (second NAPs are reduced by 11.7%)[14]. Therefore, CO_2 emissions in non ETS sectors are not addressed in this scenario, while in all following scenarios they are impacted either by WC or the combination of WC and GC quota policies, which indirectly contribute in reaching the overall 20% CO_2 objective. The full development of these scenarios opens up a diversity of interesting results, which are exposed in the next section of the study.

[14] Energy system sectors comprise ETS (energy industries, manufacturing and construction industries) and non - ETS sectors (transport, commercial, residential, agricultural sectors).

3 RESULTS

To start with the analysis of the numerous results, we first refer to the implicit national WC and GC prices as well as to the European or international CO_2 prices. Afterwards, we look more closely at the effects of different scenarios on the CO_2 market, renewable energies and energy savings, as well as on the changes in the European electricity production mix.

3.1 Implicit prices of white and green certificates, price of CO_2

Energy savings by 20% comparing to the reference projections in 2020 result in relatively high national implicit WC prices shown in Table 2[15]. There, it has to be emphasized that these prices correspond to the marginal cost of energy savings, *i.e.* the cost of the last and most expensive action to be engaged in order to meet the target. Thus the implicit price doesn't reflect the average cost of energy savings, which – with convex energy saving supply curve of the type produced here – will be (far) inferior to half the marginal cost. We also notice that the WC prices are heterogeneous among countries, which would be a prerequisite condition for the establishment of a WC system at the European level. The introduction of WC trading among the countries would equalize the marginal costs of energy consumption reduction and result in a European WC price of 880 €/toe in 2020. The equilibrium burden sharing that would equalize the European WC price among the countries is also exposed in Table 2. We recall however, that only national WC prices are taken into account in the rest of the study.

Table 2: National WC prices used for scenarios 5-9

EU25 countries	Cons. 2005, Mtoe	Objective 2020, Mtoe	WC price 2020, €/toe	Equilibrium Burden sharing comparing to 2005
UK	237	213	839	-10.9%
France	275	247	922	-9.5%
Italy	179	161	813	-11.2%
Germany	343	308	903	-9.8%
Spain	151	136	1211	-5.3%
Greece	32	29	1683	3.2%
Portugal	25	22	1285	-4.1%
Austria	35	31	754	-12.6%
Belgium, Lux	64	58	500	-16.8%
Denmark	22	20	1585	-2.7%
Finland	36	33	679	-13.8%
Ireland	16	14	1332	-1.6%
Netherlands	85	76	983	-8.7%
Sweden	51	46	193	-24.3%
Hungary	26	23	862	-10.6%
Poland	98	88	1062	-6.8%
Czech Rep.	43	39	795	-11.9%
Slovakia	16	15	739	-14.0%
Baltic countries	21	19	355	-22.3%
Sloven.-Malta-Cyprus	14	12	86	-24.6%
EU25	**1769**	**1590**	**EU25 WC price = 880 €/toe**	

[15] The early results from the Italian WC system lasting from 2005 to 2009 indicate the WC price of around 100€/toe (Bertoldi et al, 2006).

Producing one third of electricity with renewable energy sources in 2020 would imply the implicit national GC prices shown in Table 3. We recall that, as from Table 1, there are three sets of GC prices, corresponding to different sequence introduction of renewable policy: (1) **GC**, (2) **WC+GC** (applying also to **WC+GC+CO2 ETS**), (3) **WC+CO2 ETS+GC**. Typically, the most important national and European GC prices are in the **GC** scenario since the accomplishment of the renewable objective is performed in an isolated way, without any other environmental policies. The introduction of the trading of GC among the European countries brings the European GC price down to 0.1 €/kWh[16]. This price decreases to 0.07 €/kWh in the scenario **WC+GC**, due to the impact of national WC prices, which stimulate energy savings and thus allow to shrink the basis used for the renewable target. Finally, the implementation of energy saving objectives and CO_2 emission reduction objective in ETS in the scenario **WC+CO2 ETS+GC** reduces even more the European GC price to 0.05 €/kW. We notice that the carbon price signal created in the ETS (in combination of WC prices) reduces the renewable compliance costs of EU25 by 43% in the scenarios **WC+CO2 ETS+GC** compared to **WC+GC**.

Table 3: National GC prices

Scenarios	GC			WC + GC			WC + CO2 ETS + GC		
EU25 countries	Green electricity in 2020, %	Corresponding GC price, €/kWh	Compliance cost, M€	Green electricity in 2020, %	Corresponding GC price, €/kWh	Compliance cost, M€	Green electricity in 2020, %	Corresponding GC price, €/kWh	Compliance cost, M€
UK	29%	0.090	4563	25%	0.068	1850	25%	0.052	994
France	28%	0.092	5243	27%	0.068	3213	24%	0.049	1941
Italy	35%	0.098	2237	34%	0.079	1414	35%	0.063	854
Germany	20%	0.095	3483	19%	0.075	1929	20%	0.058	1032
Spain	40%	0.090	3100	42%	0.076	1996	42%	0.058	1231
Greece	42%	0.109	1134	49%	0.071	752	52%	0.055	365
Portugal	73%	0.128	740	78%	0.083	507	78%	0.060	301
Austria	78%	0.181	528	82%	0.179	317	83%	0.128	204
Belgium, Lux	27%	0.117	627	26%	0.074	418	26%	0.057	251
Denmark	37%	0.050	198	37%	0.040	162	36%	0.025	44
Finland	66%	0.108	2150	66%	0.068	1495	60%	0.050	879
Ireland	62%	0.108	558	63%	0.063	464	63%	0.048	266
Netherlands	16%	0.089	721	12%	0.066	254	11%	0.052	131
Sweden	90%	0.131	1563	91%	0.134	2023	91%	0.047	1067
Hungary	14%	0.086	41	17%	0.052	26	19%	0.031	6
Poland	24%	0.076	610	27%	0.053	463	30%	0.038	123
Czech Rep.	14%	0.209	135	16%	0.158	85	18%	0.177	68
Slovakia	18%	0.259	29	22%	0.100	6	24%	0.064	2
Baltic countries	21%	0.095	142	21%	0.065	116	22%	0.048	73
Sloven.-Malta-Cyprus	51%	0.009	11	51%	0.009	12	54%	0.066	2
EU25, % and €/kWh	**33%**	**0.095**	**27815**	**33%**	**0.071**	**17499**	**33%**	**0.0530**	**9834**

Turning to the analysis of the CO_2 market, we now consider the price, emissions, project-based credits as well as the reduction costs (Table 4). Looking at the Table 1, we notice that we should have four sets of CO_2 prices corresponding to scenarios: i. **CO2 total**, ii. **CO2 ETS**, iii. **WC+GC+CO2 ETS** and iv. **WC+CO2 ETS** (applying also to **WC+CO2 ETS+GC**). A distinction should be made between the first scenario **CO2 total** – where the CO_2 market is confined to Europe that is all the reductions or purchases of allowances are produced within the EU25 – and all other scenarios, for which the

[16] The cost of solar energy (the most expensive renewable energy today) is in the order of magnitude of 0.5 – 0.8 €/kWh in 2005 and of 0.15-0.3 €/kWh in 2020 (TECHPOL database developed in Lepii-Epe).

international carbon market is assumed, as in section 2.2. Therefore, we observe in Table 4, that the reduction objective or shortfall is highest in the scenario **CO2 total** compared to all other scenarios and amounts to 1329 MtCO_2. The absence of project-based credits makes the realization of European objective of 20% emission reduction very costly in terms of reduction costs and CO_2 price, which in this case reaches 93 €/tCO_2. The reduction objective as well as European marginal reduction cost is also high under the scenario **CO2 ETS**, since the carbon price only affects the ETS sectors. The import of project-based credits is, therefore, needed to alleviate the efforts of European industries. However one can notice that the domestic European reduction far exceeds the purchase of project-based credits with 531 against 309 MtCO_2. This is explained by the new flexibility margins created by a longer time-period (2020) for the change in investment patterns, which compensates for the increasing pressure created by stronger emission reduction targets.

The required CO_2 emissions reductions as well as the marginal reduction costs decrease significantly in the last two scenarios. This is due to the introduction of the other environmental policies aimed at achieving European objectives of energy savings and renewable energies. The combination of WC and GC systems in the scenario **WC+GC+CO2 ETS** reduces the CO_2 emission shortfall by 73% compared to **CO2 ETS** and by 83% compared to **CO2 total**. The decrease is also important in the compliance costs for ETS participants. The combination of the three quota systems in the scenario **WC+GC+CO2 ETS** allow EU25 to reduce its emissions over its own target and sell the extra allowances on the international market. Nevertheless, the international carbon price is only slightly affected: it is of 31,2 €/tCO_2 in the scenario **WC+CO2 ETS** and of 30,5 €/tCO_2 in the scenario **WC+GC+CO2 ETS**, compared to 35,6 €/tCO_2 in **CO2 ETS**. The addition of GC prices next to WC prices in the scenario **WC+GC+CO2 ETS** has a minor impact on the international carbon price.

Table 4: CO_2 market in 2020: prices, reduction costs, sales / purchases of credits (negative value: sales)

EU25	Reduction objective, MtCO2	European reduction, MtCO2	European Marginal Reduction cost, €/tCO2	Sales / Purchases of credits, MtCO2	Reduction costs without trading, M€	Reduction costs with trading, M€	European CO2 price, €/tCO2	International CO2 price, €/tCO2
CO2 total	1329	1329	92.5	0	75318	45304	92.5	-
CO2 ETS	840	531	63.2	309	35792	20124	-	35.6
WC+GC+CO2 ETS	220	248	27.2	-27	5921	3005	-	30.5
WC+CO2 ETS	361	335	33.8	26	12278	6141	-	31.2

3.2 Impacts on the fundamentals of the energy sector

The following analysis focuses on CO_2 emissions, renewable energies utilization and energy savings achieved under all scenarios listed in Table 1. Therefore, Table 5 shows the results of final simulations that combine the prices from Tables 2 to 4, depending on different scenarios. From the environmental point of view, the **Reference** scenario would be a failure in all the three fields targeted by the Commission. Scenario **CO2 total** complies with the objective of 20% reduction in CO_2 emissions, it increases the renewable energy utilization to 15% in the final energy consumption and it saves 12% of primary energy consumption in 2020. The price to pay is nevertheless high: a carbon value of 93€/tCO_2 should be indeed imposed to all energy sectors (see Table 4). Scenario **CO2 ETS,** represented only by the actual ETS and a quantity of project-based credits that facilitates ETS participants' reduction efforts, diminishes the CO_2 emissions in EU25 only by 3%. The same scenario does even less for reducing energy consumption (only 5%) and increasing the use of renewable energies (14% in the final energy consumption).

In the scenario **GC**, represented by a regulated green electricity supply in Member countries, the renewable energy utilization grows to 17% of final energy consumption. However, this scenario discourages energy savings and CO_2 emission reductions. Besides the increases in energy savings, CO_2 emissions might be reduced by 6% in the Community under scenario **WC** as a result of relatively high national implicit WC prices (see Table 2). Two quota policies, represented by scenario **WC+GC,** further decrease CO_2 emissions to 13%.

The contribution of the international carbon market in the scenario **WC+GC+CO2 ETS** allows fulfilling the Council's expectations in all three targeted areas, but equally does the scenario **WC+CO2 ETS+GC**. The magnitude of the compliance cost reduction with the renewable target impacted by CO2 ETS price is larger (from 17499 M€ to 9834 M€ in Table 3) than the magnitude of the compliance cost reduction with ETS objective impacted by GC prices (from 6141 M€ to 3005 M€ in Table 4). Once WC policy has been implemented, for the same level of environmental performance **WC+CO2 ETS+GC** seems less costly to implement, with a total cost of 15976 M€ (for the joint CO_2 ETS and Renewable targets) to be compared with 20503 M€ in scenario **WC+GC+CO2 ETS**.

Table 5: Impacts of the scenarios on emissions, renewable energies and energy savings in 2020[17]

Scenarios	**CO2 emissions**			**Renewable energies**		**Energy savings**
	ETS, MtCO2	Non-ETS, MtCO2	Reduction comparing to 1990, %	% in the final consumption	% in the electricity production	% comparing to the Reference (in the primary energy)
1. Reference	2559	1948	14%	12	17	0
2. CO2 total	1370	1816	-20%	15	30	12
3. CO2 ETS	1895	1945	-3%	14	21	5
4. GC	2261	1949	6%	17	30	1
5. WC	2061	1680	-6%	13	18	16
6. WC+GC	1765	1680	-13%	20	30	17
7. WC+GC+CO2 ETS	1468	1665	-21%	20	31	20
8. WC+CO2 ETS	1643	1667	-16%	15	22	18
9. WC+CO2 ETS+GC	1462	1667	-21%	20	32	20

Finally, we examine in Table 6 the changes in the European electricity production mix that is implied by the different scenarios. Typically, the electricity production is at its lowest in the last three

[17] We notice from the results of final simulations shown in Table 5 that due to the dynamics of the model and with national prices found for **GC** and **WC** scenarios *via* sensitivity analysis, we come close, but not enough to reach the respective council's objectives: 17% for renewable energies and 16% for energy savings. Therefore, additional iteratives simulations were performed to attain the objectives, but the national GC and WC prices found were extremely high meaning that the achievement of the objectives should not be based on sole mechanism, but accompanied by other policies like in scenarios 7 or 9.

scenarios, where all – or almost all – environmental objectives are achieved. We notice, however, that despite of similar electricity production levels in these three scenarios, green electricity is lowest in **WC+CO2 ETS**, while fossil-fuel based generation is strongly reduced in **WC+GC+CO2 ETS** and **WC+CO2 ETS+GC**, since the introduction of GC prices still further encourages green electricity production.

The scenarios that include all environmental policies (**WC+GC+CO2 ETS** and **WC+CO2 ETS+GC**) reduce the fossil-fuel based electricity generation by around 460 TWh in 2020, compared to scenario **CO2 ETS**. As a consequence, in the presence of other environmental policies, future CO_2 allowance cap under ETS should probably be reduced for the electricity sector in order to account for the possible decrease of polluting electricity production. We notice also that the **CO2 ETS** carbon price signal alone does not stimulate sufficiently green electricity nor induce savings in the electricity production. This brings a strong rationale for introducing specific support policies and economic instruments for any further development of renewable energies and energy savings.

Table 6: Impacts of the scenarios on the electricity production in 2020, TWh

	Reference	CO2 total	CO2 ETS	GC	WC	WC+GC	WC+GC+CO2 ETS	WC+CO2 ETS	WC+CO2 ETS+GC
Thermal	2884	2335	2473	2547	2546	2234	2052	2287	2067
of which:									
Coal	1318	602	946	1115	1128	928	721	863	732
Gas	1303	1436	1232	1063	1191	965	979	1162	989
Biomass and wastes	123	199	168	275	120	268	273	156	266
Nuclear	869	904	905	808	802	754	792	851	800
Hydro+Geoth	386	395	391	411	385	404	408	389	406
Solar	1	2	2	1	2	2	2	2	2
Wind	221	321	299	589	213	543	564	282	534
Hydrogen	0	1	0	0	0	0	1	1	1
Total	4362	3957	4069	4357	3948	3938	3818	3810	3810

4 CONCLUSION

The methodology employed in the study allows for a comprehensive evaluation of the possible interactions among the different objectives for 2020: i. the reduction of 20% of greenhouse gas emissions (GHG), ii. the saving of 20% of the energy consumption and iii. a share of 20% of renewable energies in the total energy consumption. In line with the quantitative objectives fixed by the Commission, energy savings and renewable energy objectives in the study are feasible with the national quota systems – WC and GC systems – while the CO_2 emission reductions are carried out through the ETS. We have calculated, therefore, the respective implicit national and European prices as a function of a set of consistent scenarios. Additionally, supposing the trading of certificates among the European countries, we expose the European WC and GC prices to attain the respective objectives. This may drive further research towards the analysis of the advantages of the creation of integrated WC and GC markets in Europe.

The two scenarios **WC+CO2 ETS+GC** and **WC+GC+CO2 ETS**, which represent different sequences for introducing the CO2 ETS or GC constraint, show comparable results in terms of environmental efficiency. From the economic point of view, **WC+CO2 ETS+GC** seems less costly since the carbon price signal created in CO2 ETS (in combination with WC prices) has a stronger impact in terms of magnitude on the reduction of compliance cost with the renewable target than the GC prices have on the compliance costs of ETS participants. Nevertheless, the two quota systems (GC and WC) reduce significantly the European marginal emissions reduction cost and, consequently, the compliance costs for ETS participants. This is also confirmed by the changes in the electricity production mix, where the implementation of all environmental policies reduces significantly the use of fossil-fuel based electricity generation and, consequently, CO_2 emissions. Furthermore, the sole carbon price signal, in the scenarios **CO2 ETS** or **CO2 total**, is clearly insufficient for stimulating renewable energies and energy savings to the level required by EU policy, which confirms once again the need for specific policies targeting these two areas.

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Annex 1: Poles model and reference scenario

POLES is a partial equilibrium world simulation model for the energy sector (Criqui and Kouvaritakis, 2000, Criqui and Viguier, 2000). It works in a year-by-year recursive simulation with endogenous international energy prices and lagged adjustments of supply and demand by world region. The model enables to produce:

- Detailed long term (2100) world energy outlooks with demand, supply and price projections by main region;
- CO_2 emission Marginal Abatement Cost curves by region and/or sector, and emission trading systems analyses, under different market configurations and trading rules;
- Technology improvement scenarios – with exogenous or endogenous technological change – and analyses of the value of technological progress in the context of CO_2 abatement policies (LEPII-EPE, 2005).

The reference scenario used to produce the marginal abatement cost curves describes a world that would develop on the basis of the economic fundamentals and technical constraints. Projecting long-term energy profiles involves a large number of assumptions. World population is expected to increase from 6.5 billions today to 8.9 billions in 2050 with a marked decrease in average growth, which is due to the demographic transition and to stabilize in the second half of the century. The rate of economic growth in industrialized regions converges to under 2%/yr in the very long-run. Growth in Asian emerging economies falls significantly after 2010, while conversely it accelerates in Africa and the Middle East. As a result, global economic growth is expected progressively to slow from 3.5%/yr in the 1990-2010 period to 2.9%/yr between 2010 and 2030 and then 2.2%/yr until 2050. Total world GDP in 2050 is four times the present GDP. The US Geological Survey is the base source of information used for oil and gas Ultimate Recoverable Resources. It provides a set of estimates and attached probabilities that are consistent on a world and region-by-region basis. Technological developments regarding energy technology costs and performances are derived from a dedicated database TECHPOL[18], which allows maximizing the consistency of the exogenous hypotheses for the different time horizons and across the different technologies.

[18] developed in the framework of European projects: FP6 SAPIENTIA and CASCADE-MINTS.

Annex 2: Burden sharing in EU-25 for 20% reduction of GHG emissions in 2020 relative to 1990

Country	Reduction, %
Belgium	-19
Denmark	-26
Germany	-31
Finland	-22
France	-22
Greece	-6
UK	-30
Ireland	-6
Italy	-14
Luxembourg	-14
The Netherlands	-19
Austria	-10
Portugal	3
Sweden	-24
Spain	11
Estonia	-51
Latvia	-56
Lithuania	-57
Malta	5
Poland	-29
Slovakia	-38
Slovenia	-14
Czech Rep.	-36
Hungary	-29
Cyprus	8
EU-25	***-20***

Source: German Institute for Economic Research, 2007