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Towards a Competitive Low-Carbon Economy:
On Firms' Incentives and the Role of Public Research

Annette Bongardt and Isabel Cabrita

Submission of Papers for Publication (Para submissão de artigos para publicação): Prof. Francisco Torres (ftorres@iee.ucp.pt or ftorres@egi.ua.pt). Universidade de Aveiro, DEGEI, Economia, Campus Universitário de Santiago. 3810-193 Aveiro. Portugal.

TOWARDS A COMPETITIVE LOW-CARBON ECONOMY: ON FIRMS' INCENTIVES AND THE ROLE OF PUBLIC RESEARCH[1]

by

Annette Bongardt and Isabel Cabrita

UML and IEEI (abongardt@)sapo.pt) and UML and INETI (isabel.cabrita@ineti.pt)

Abstract

This paper considers the prerequisites for implementing a competitive low-carbon economy in the European Union from the point of view of firms' incentives, the role of policy and the contribution of public research. It suggests that the reduction of the environmental impact of energy can be a new competitiveness factor. Rather than being treated as a constraint and cost-aggravating factor, addressing climate change can offer economic opportunity and contribute to growth. The paper looks at both static (energy efficiency) and dynamic (innovation – new products, processes, technologies or sectors and consumption patterns) dimensions of competitiveness.

JEL classification: M21; H23, H44
Keywords**:** Economic competitiveness; low-carbon economy; energy; technology; and public research.

[1] We benefited from comments and discussions with Francisco Torres, Ibrahim Gulyurtlu and João Gata. We are of course responsible for any remaining shortcomings of this paper.

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1. Reduction of environmental impact of energy

The environmental impact of economic activity has been giving rise to concern as to the sustainability of present production and consumption patterns, with most visibility in the context of climate change. Energy is a fundamental input to economic activity. However, energy consumption levels and energy mixes rich in fossil resources are contributing significantly to greenhouse gas emissions and thereby to global warming.

Total environmental impact is the result of population size, the level of economic development and technology. In the light of world population growth and taking into account that a great part of the world aspires to higher levels of well-being through economic growth, it becomes clear that economic growth and environmental damage must be decoupled for sustainability. More precisely, present unsustainable production and consumption patterns need to be altered and technology has an important role to play in reducing environmental impacts.

The European Union (EU) has long been committed to the objectives of economic growth and environmental sustainability (by Treaty but also for instance through the Lisbon objectives). More recently, the European Commission has called for a competitive low-carbon economy (a kind of industrial strategy), a goal confirmed by last July's Competitiveness Council. This presupposes finding ways to reduce CO_2 emissions while assuring competitiveness, and to do so against the need for substantially increasing cuts over time. Note that the envisaged medium and long-term reductions in CO_2 emissions are substantial, requiring a significant change in production and consumption patterns and energy-efficient technologies. At the last Spring Council, the European Union committed itself to CO_2 reductions that go beyond its 8 per cent Kyoto obligations for 2008-2012 and to unilaterally reduce CO_2 emissions by 20 per cent until 2020 or by 30 per cent in the case that third countries adequately match its efforts. Taking a longer time horizon (until 2050), larger reductions of between 50 and 80 per cent are being envisaged with a view to sustainability.

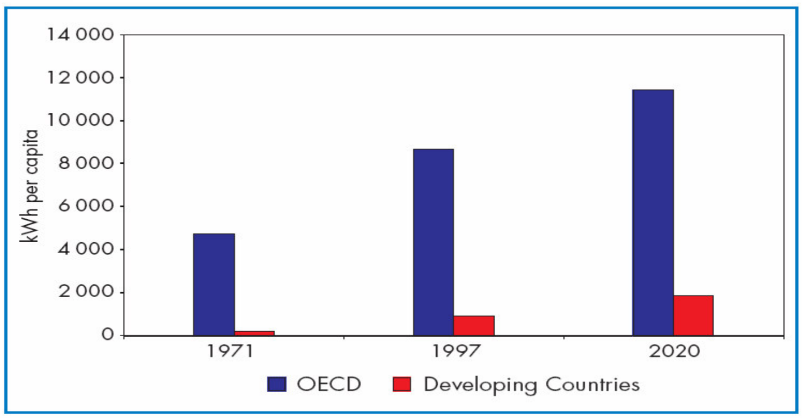
This paper addresses the reduction of the environmental impact of energy in terms of competitiveness, as a new competitiveness factor, and in the light of offering economic opportunity and contributing to growth rather than a constraint and a cost-aggravating factor. It looks at both static (energy efficiency) and dynamic (innovation – new products, processes, technologies or sectors) dimensions of competitiveness.

2. Energy and CO_2 emissions

Worldwide energy demand has been increasing with a direct influence on the consumption of fossil fuels, leading to decreasing levels of reserves as well as increasing greenhouse gas emissions that have an influence on climate change. Emissions are predicted to rise by 28 per cent by 2015 and are expected to grow by more than 50 per cent by 2030 (International Energy Agency, 2006b, pp. 37-83). Developing countries are expected to contribute with more than two-thirds to the growth in world energy use. Other things equal, economic development and population growth will have an impact on demand and hence, on the magnitude of climate change.

Installed electricity capacity varies across countries, being larger in more developed countries where demand is higher. Figure 1 illustrates that as yet there are large differences between OECD countries and developing countries in terms of per capita electricity consumption. However, it also reflects the expectation that differences will become less pronounced in the future, with rising levels of consumption in line with continuing economic development in developing countries.

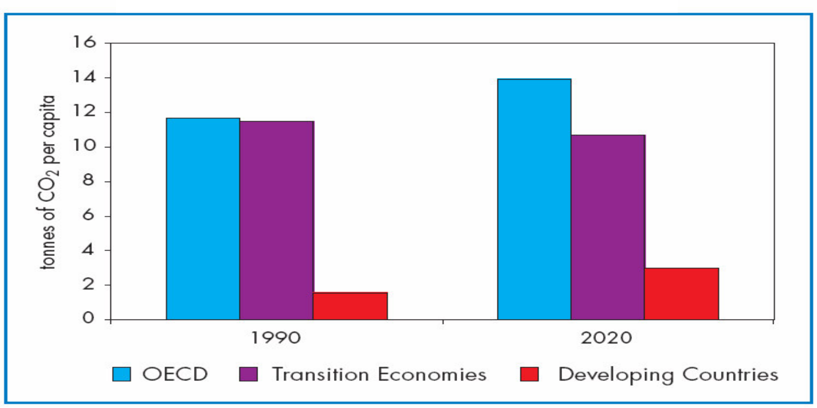
Figure 1 – Electricity consumption per capita, OECD and developing countries



Source: International Energy Agency (2000).

Figure 2 indicates that this increase will have a direct impact on the level of CO_2 concentration in the earth's atmosphere. With economic development, regional differences in CO_2 per capita are expected to become less pronounced, resulting in an increase in global emissions.

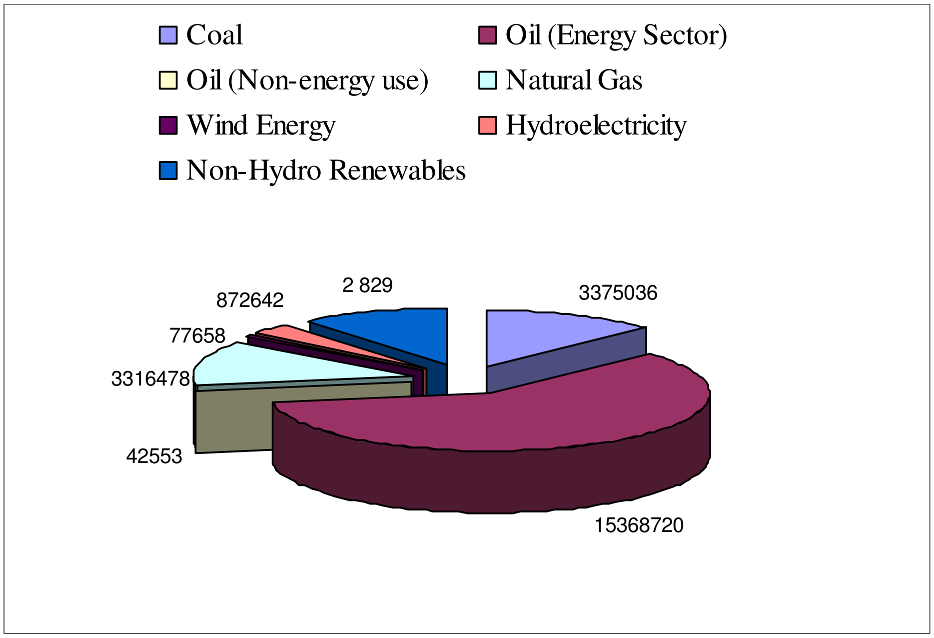
Figure 2 – Carbon dioxide emissions by region and per capita



Source: International Energy Agency (2000).

Portugal is highly dependent on imported energy resources, which is also a burden on the Portuguese economy. Figure 3 represents the Portuguese energy situation (primary energy in tonnes of oil equivalent - toe) by resource. It calls attention to the high share of fossil resources in the national energy mix, with oil, used mostly in the transport sector, standing out.

Figure 3 – Total primary energy mix in Portugal, by energy resource



Source: Portuguese Directorate for Energy and Geology (DGEG, 2004).

A country's CO_2 emissions depend on its energy mix but also on its energy efficiency. Portugal displays high energy intensity. Note that in terms of CO_2 emissions, Portugal has already gone beyond its Kyoto Protocol targets despite (or because of[2]) the fact that it was allowed to increase CO_2 emissions by 27 per cent in comparison to the 1990 base year, under the umbrella of the EU overall target of an 8 per cent reduction in the period 2008-2012.[3]

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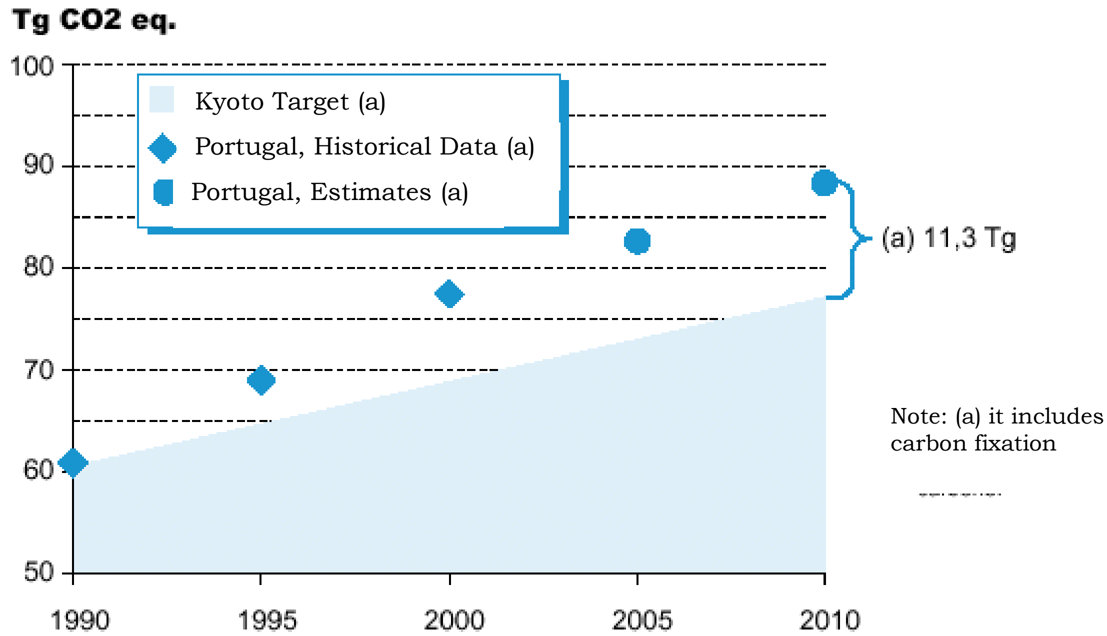
[2] If one takes the view that this policy allowed for not addressing the need to change production and consumption patterns and adopt adequate policies.

[3] With a view to the need to invert these tendencies and to contribute to CO_2 reductions, the 2005 Portuguese Government's new energy policy (Ministry of Economy and Innovation, 2007) includes the following goals: to guarantee supply security by diversifying primary energy sources and energy services and optimizing energy efficiency in both the supply chain and on the demand side; to stimulate competition promoting the protection of consumers as well as firm competitiveness and efficiency; and to guarantee an adequate environmental impact of the whole energy process, namely in terms of carbon intensity with respect to the gross national product (GDP).

Figure 4 – CO_2 emission projections for Portugal



Source: Programa Nacional para as Alterações Climáticas - PNAC (2001).

Taken together, these facts imply the need for Portugal to act on both the supply and the demand side. Below we discuss how economic growth and environmental impacts may be decoupled, looking at how to best alter unsustainable production and consumption patterns and considering the role of technology and the state therein. Technology is not treated as a panacea to avoid changes in production and consumption patterns and thus environmental impacts, but rather in terms of its potential to facilitate them. Last but not least, we address the implications for making compatible the objectives of a low-carbon economy and competitiveness.

3 Changing unsustainable production and consumption patterns[4]

3.1 Firm incentives and the internalization of negative external effects

The above short discussion indicates the EU and its member states (case of Portugal) need to modify their production and consumption patterns with a view to environmental sustainability.

Pollution and environmental damage constitute a negative externality, with the result that the market mechanism does not deliver the social optimum. There will be over-supply of the bad (pollution) unless environmental damage is priced so that economic agents take external effects into account when taking a decision to produce or to consume. Conversely, there will be under-supply of the good (for instance more environmentally-friendly technologies) if polluting producers do not pay for the damages they cause society. Correcting relative prices according to environmental impact will affect supply and demand of environmentally-damaging or friendly goods by altering the behaviour of economic agents that causes those impacts.

[4] This section draws on Bongardt and Torres (2007c).

The time frame within which that occurs as well as the consequences in terms of who - producers and consumers of polluting goods - pays how much of the production cost increase are conditioned by the price elasticity of demand. That is, the existence of substitute products will lead to a large reduction in demand and consequently of pollution (associated with the production of those goods). In contrast, if close substitutes do not exist the effect on demand and pollution reduction will not be large in the short term and consumers will pay a larger share of the cost increase. The existence of alternative, less-polluting goods and technologies will therefore promote a fast reduction in environmental impacts. Alternatively, there will be an effect in the medium run as producers see a profit opportunity associated with supplying less polluting goods and will invest in the development and deployment of those goods and technologies.

With respect to correcting the incentives and thus behaviour of economic actors, the EU has been reinforcing the polluter-pays principle (PPP). The PPP is an expression of the economic logic of the internalisation of environmental externalities, that is, of making the polluter financially responsible for pollution control and/or environmental damage (although the PPP tends to be narrowly interpreted rather than amounting to a right to a clean environment). The application of the PPP raises production costs of the producer/polluter and the price that the consumer of a polluting product pays, and thus promotes the shift of production and consumption patterns towards less-polluting alternatives and substitute products, and induces other firms to invest in less-polluting products and technologies.

Far from constituting a mere cost-aggravating factor, the correct pricing of environmental damage can be the basis for EU firms' competitive advantage through eco-efficiency and environmentally-friendly innovation of new products, processes and technologies that meet with demand in global markets and may even give rise to new emerging sectors and clusters. The environment and environmental technologies are ever more regarded as a sector of economic opportunity for EU firms with a potential market at a world scale. There seems to be an increasing awareness that eco-innovation may be a way to increase competitiveness in a dynamic sense while escaping the rise of competitive, especially cost pressures and to take advantage of the opportunities offered by the new economy and globalisation. A recent Commission report on trends and developments in eco-innovation (2007) provides evidence for the strong growth of eco-industries in the EU.

3.2 Using the market mechanism

Sustainable development can only be successfully achieved provided that the EU finds ways to make the competitiveness and economic growth objective compatible with environmental protection. This in turn implies adopting adequate policies that best decouple growth (production of goods and services) – desirable – and pollution and environmental damage (bads) – undesirable, and to do so in a way that creates the right incentives for economic agents and conditions for competitiveness. This highlights the importance of institutions and appropriate environmental policies with a view to modifying present non-sustainable production and consumption patterns.

Competitiveness has a static and dynamic efficiency dimension, namely in terms of cost (short run) but also innovation (medium run). Environmental protection might not necessarily be a win-win situation (as is the case of cutting subsidies for pesticides which improve the environment and state finances) but imply a trade-off (less pollution but also less production) in the short run.

In the latter case, as to minimize possible short-run trade-offs between production and growth and to reap a growth stimulus from innovation, it is essential that economic agents be given the right incentives and regulatory framework. The European internal market is key as it promotes competition on the basis of efficiency and innovation. It can be made to work in favour of static and dynamic efficiency as well as far as the environment is concerned, by internalising negative externalities, provided that environmental costs (an inefficiency) are (made to be) borne by polluters through the pricing of environmental damage (for instance a carbon tax or a transferable emission quota).

Now, with a view to EU competitiveness in conjunction with environmental sustainability, but also EU international credibility and clout, the fundamental question is how to best implement environmental protection with a view to competitiveness. From an economic perspective, one should aim at implementing the optimal (efficient) level of pollution, that is, pollution should take place up to the point at which the marginal (social) costs of pollution become just equal to the marginal (private) benefits from production so as to maximize total benefits from the point of view of society. On the one hand, this calls for conducting cost-benefit analyses to select environmental policies with a view to the optimal level of pollution and to select cost-effective policies[5], and on the other, at a microeconomic level and via an adequate regulatory framework, to induce economic agents to implement the efficient pollution level or implement a given pollution level at least-cost for society. Note, however, that the challenge to attribute a monetary value to environmental damage is often not negligible. While the benefits from pollution (production) tend to be well-known, the costs to society are often inherently uncertain, accrue over long time horizons and are difficult and costly to calculate.[6]

As far as the policy instruments for the implementation of environmental goals are concerned, it is market-based instruments that are the type of instrument most prone to achieve least-cost solutions and dynamic advantage in the single market.[7] They can be implemented at a low administrative cost through the tax system and have a dynamic effect. In contrast, command-and-control type instruments work via quantitative limits, mandatory technologies or prohibitions and generally suffer from the fact that the state, for lack of information or cost reasons, does not impose the least-cost pollution control solutions on polluting firms and that they have a one-off impact. Market-based instruments such as environmental taxes or marketable emission quotas work with the market mechanism, that is, through the pricing of environmental damage. Their impact is dynamic, in that firms will always try to lower pollution levels

[5] Preferences of society might of course include other than economic criteria (such as moral / ethics). In any case, a cost-benefit analysis provides an important input for an informed choice.

[6] The 1992 Maastricht Treaty already introduced two important requirements that potentially increase efficiency and/or cost-effectiveness in the implementation of environmental policies: environmental mainstreaming (requiring taking into account the environmental dimension at the time of the inception of other policies, thus taking into account that prevention is often cheaper than remedy) and the requirement of cost-benefit analyses in regard to environmental policies (although they seem rarely to be complete in practice).

[7] The state can basically count on three types of instruments to implement environmental goals: communication instruments (to remedy market failure due to information problems), market instruments (with efficiency properties and with a dynamic impact) and command-and-control type regulation (often more costly to implement and with a static, one-off impact). Firms will conduct an analysis at the margin (producing until marginal cost becomes equal to marginal benefit at the last unit produced) to minimize taxes / maximize their margin with a view to the price of emission rights. The state/government could theoretically also achieve the same result but typically will lack the information to do so or the cost to procure it would be prohibitive.

in order to reduce payments of the tax, or to augment their margin (difference between their abatement costs and the market price of their emission quota), respectively. This incentive for continuous improvement of processes and products in terms of environmental impact leads to least-cost pollution abatement from a social point of view. Firms know better than the state (because of asymmetric information or prohibitive costs of data collection) what their least-cost solution to reduce environmental impacts is and whoever can easily and cheaply abate pollution will do more of it. Moreover, the market instruments penalize polluting firms in the market for their inefficiency since their costs (competitiveness) will be aggravated in comparison with less-polluting rivals.

With a view to competitiveness, market-based instruments should be reinforced as they work with the market and tend to better promote static and dynamic efficiency. A switch to a knowledge-based economy (EU Lisbon Strategy) that emphasizes competition and innovation brings about the opportunity to switch to environmentally sustainable production and consumption patterns since a knowledge-based economy by itself is potentially less energy and raw-material intensive and even more so if carbon emissions are priced. Still, the EU unanimity requirement in tax matters is a serious obstacle to the implementation of EU-level environmental taxes (raising the issue of distortions with different taxes or tax rates across the EU). The maintenance of the unanimity requirement goes a long way in explaining the ill fate to date of a carbon tax since long proposed by the Commission to combat climate change, despite the efficiency properties associated with environmental taxes and the double dividend (better environment and tax income for the state)[8]. In the EU, the implementation of the Kyoto Protocol came to rely to an important degree on marketable emission licences instead, another market-based pollution control instrument.[9] Subsidies, another market-based instrument, can be used to raise adoption rates when new, environmentally-friendly technologies are initially more costly and adoption happens to be sub-optimal from the point of view of society.

When there are short-run trade-offs and with a view to competitiveness it is important to choose those environmental policies that imply the smallest sacrifice in terms of lost output (efficient solution if the socially-optimal level of pollution is known or cost-effective solutions, meaning the adoption of the least-cost alternative). Firms need to have the relevant information, instruments and the incentives to adopt least-cost solutions of pollution abatement and to innovate in environmentally-friendly products and processes. The existence of and access to relevant environmental information is important for governments to choose the most adequate environmental protection programme[10], for a firm to choose the most adequate pollution abatement solutions and for consumers to make an informed choice[11]. High levels of environmental protection might also work as a forward-looking industrial policy.

[8] See Torres (2003).

[9] It should be noted that the Commission concludes in its recent mid-term review of the 6th Environment Action Programme that the use of market instruments, i.e. environmental taxes, needs to be strengthened in the EU. See Bongardt and Torres (2007c).

[10] The European Environmental Agency for instance, like national environmental agencies, fulfils that function, in that the existence of data on environmental damages facilitates cost-benefit analyses of environmental policies and comparisons. The diffusion of environmental studies and information also facilitates pressures on polluters, for instance by investors or by civil society.

[11] There is a variety of EU measures that influence firms' adoption of environmental instruments or technologies. For instance, the EMAS standards (along the lines of the ISO 14000 standards but going a bit beyond, created in 1992 for industry and extended in 1999 to services), contribute to firms' taking stock of their environmental performance and to continuous improvement, while being a credible signal

Political economy considerations might go some way to explain why the dynamic efficiency properties of market-based instruments are as yet not more fully exploited. The initial impact of pricing of environmental damage might be to raise the costs of less efficient firms in the short run, putting them at a disadvantage, and to raise prices. Also, if some firms (say in a given member state) pay while their rivals in other states do not, those firms might see their competitiveness impaired in the short run although they might benefit from more innovative products in the medium term. In addition, in price-inelastic markets without close substitute products firms will be able to shift a larger share of the cost increase onto consumers who might resent those taxes on those grounds (for example on petrol). Energy costs are obviously a competitiveness factor and the substitution of energy is difficult for firms and families. In the case of energy, the challenge for the EU amounts to achieving at the same time the pricing of negative environmental impacts of energy sources, the shift to less polluting energy sources and technologies, low prices through the increase of competition in a common European energy market and, last but not least, security of supply.

3.3 Energy and the market

As regards competitiveness and environmental protection, the energy sector – a large contributor to greenhouse gas emissions – had already been included in the European Emissions Trade System. However, for this market instrument to work, one needs a functioning market, scarcity of emission licences and suppliers with different cost structures. Promoting the shift from polluting to clean energies hence requires the pricing of environmental damage plus competition between suppliers, including that consumers have a choice between different energy sources and suppliers. In the case of network industries (such as gas or electricity), the liberalisation of markets needs to be accompanied by adequate regulation of infrastructures to be effective. The EU faces a couple of shortcomings, as liberalisation is not complete yet (derogations), that regulation so far is in the national sphere and that without European regulation in energy it is doubtful that internal market synergies will be exploited.

The EU unilateral resolution to cut down on CO_2 emissions sets a signal for the European economy, to the extent that it becomes clear that efforts under the Kyoto protocol will not only not end after 2012 but have to continue thereafter and substantially increase. European firms will thereby have a more predictable and longer planning horizon for their green investments and strategy. At the same time, the more predictable evolution of the policy framework – even more if implemented through market instruments and less by means of command and control – can have a dynamic effect on the European economy, fostering innovation (of products, processes, new markets, financial instruments and markets) and hence work towards overcoming a possible trade-off between economic growth and sustainability, change production patterns and lead to the emergence of new sectors and clusters of firms.

The liberalization of energy markets in the EU exerts pressures on firms to be cost competitive and to innovate. Note that there is a two-fold approach in the EU, consisting in regulation of network industries characterized by large infrastructures (a

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for consumers and thus facilitating their choice between goods. Moreover, the legal obligation for the car industry where producers are responsible for their goods at the end of their life cycle means that life cycle assessment has already become obligatory for producers in the car industry. Another example is the European Union Technological Action Plan (ETAP), created in 2004, as to foster Research and Development in the area of environmental technologies.

natural monopoly situation, where the conditions for market functioning need to be created) and the liberalization and competition at the level of the services derived from those infrastructures.

The integrated approach taken with respect to energy policy, in the light of the link between energy and CO_2 emissions, is a new element. A European energy policy addresses three objectives, namely security of supplies (lower import dependency), prices compatible with the competitiveness objective of the European economy, and environmental sustainability. Governance of energy has to address possible trade-offs between these objectives, at least in the short run (see below). The 20 per cent target of renewable energies for the EU, like in the case of the implementation of the Kyoto target, applies to the EU as a whole and goes together with different national objectives and burden sharing. Energy mixes are member state business, provided that a minimum share of biofuels[12] is respected. The innovation in terms of governance here is that compliance with mandatory country targets for the production of energy from renewable resources is to be reinforced by sanctions. As to the need to raise energy efficiency by 20 per cent, the member states did not adopt mandatory targets against the background of different energy mixes and different endowments and mix of renewable energies. Moreover, the unrealized potential for energy saving in the EU is rather large and needs to be tackled.

Globalization implies increased economic opportunities but also exposes the EU to increased global competition for scarce energy resources (for instance from countries like China) and thus reinforces the need for secure, reliable and cost-effective sources of energy. At the same time, energy is the major contributor to CO_2 emissions and climate change. The question then is whether security of supply can be achieved at the same time as environmental sustainability and competition and competitiveness and which trade-offs governance is facing. The case for a European energy policy is reinforced and implementation facilitated to the extent that it contributes to solving or reducing national trade-offs, so that a European approach has the potential to bring about an improvement for all member states (see Roeller et al., 2007, for a detailed analysis).

To the extent that a well-functioning single European market promotes long-run efficiency, it is a precondition for achieving all three objectives. A well-functioning market in turn requires liberalisation and competition between energy suppliers and also European-level regulation over access to infrastructures, given that gas and electricity are network industries and given the need for interconnectivity to create a European energy market. The pricing of environmental damage and consumer preferences may then contribute to a shift towards cleaner energy sources. Also, one should expect national specialization in accordance with comparative advantage (for instance in solar, wind and wave- energies).

There seems also to be evidence for an increasing decentralization potential of production and of energy sources as well as trans-European networks based on direct current (DC). As energy loss in transport is minimized in DC networks (as opposed to the existing AC networks), the question is much more than the present interconnectivity of trans-European networks. DC networks instead of AC allow for the exploitation of comparative advantage within the EU and reduce dependency on

[12] Transport is one of the largest environmental problems, and one that biofuels are meant to address. However, they might not be very efficient to produce (energy efficiency, fertilisers made from fossil fuels, transport) and their production might bring about significant side effects in agricultural product and land prices. Moreover, first generation biofuels are polemic because of their ethical implications (food production and prices). The EU is thus promoting 2nd and 3rd generation biofuels.

external suppliers. The construction of DC links seems to have been already initiated by private sources (Werner, 2007).

4 Technology

4.1 Energy and technology

Promoting energy efficiency in the different economic sectors of activity could promote an economy's competitiveness, reducing both cost and negative environmental impacts. Technological solutions might entail more efficient technologies and/or those using cleaner energy sources. This calls for creating the conditions for the development and application of cleaner technologies using fossil fuels and a switch to those that raise the share of renewable resources.[13] In the longer run, it calls for developing radically new technological solutions that allow for a drastic reduction of CO_2 emissions.[14]

With respect to energy technology perspectives, the International Energy Agency (IEA, 2006a), in support of the G8 Plan of Action of 2006, analyzed the energy technology potential and best practice as to reduce energy demand and lower carbon emissions by means of the diversification of energy sources. Those policies that the International Energy Agency considered as making a difference regard the increased support for R&D for technological breakthroughs, incentives for enhancing technology deployment and deployment policies for those technologies that are not yet cost-competitive, incentives for carbon-emission reductions to promote the diffusion and adoption of less carbon-intensive technologies, and policy instruments to overcome non-economic commercialization barriers. The study suggests that within an accelerated technology pattern scenario, existing technologies in conjunction with the expected outcomes of those currently being developed could bring the level of emissions in 2050 to today's levels of global energy-related CO_2 emissions. It also indicates the large potential for energy efficiency in particular sectors (notably transport, buildings, industry).[15]

These findings suggest that technology can play an important role in responding to the needs of a sustainable energy future, but that the objectives of drastically reducing CO_2 emissions on a global scale might require technological breakthroughs. Short and medium-term solutions can be implemented by adequate deployment policies and incentives; however, long-term radical changes involve a high degree of uncertainty and large investments. While there has been progress at the level of technology development both in fossil and renewable energy, technological breakthroughs that can change profoundly the way energy is produced and consumed

[13] Needless to say, energy policy needs to consider environmental impacts associated with energy production in a narrow sense (against the need to decrease the level of greenhouse gases emissions, among others) but also issues such as waste disposal by means of energy valorisation. The Portuguese national strategy has to take into account commitments (Kyoto Protocol, the related European directives, namely regarding the use of renewable energy sources in power generation, energy efficiency and biofuels for transportation, as well as bilateral ones like in the context of the MIBEL for the power sector).

[14] The EU is committed to increase the contribution of renewable energy sources in electricity generation. The Portuguese government established higher goals (45 per cent) for 2010 which could lead to a more focused development in this area.

[15] In the case of transports, the use of biofuels is expected to contribute to decarbonisation. In industry, coal utilization is foreseen as a credible alternative provided that it is combined with CO_2 capture and storage (still needs to be demonstrated on a large scale). Diversification in the power generation sector will lead to a technological mix with nuclear power, renewables and natural gas.

are required in the longer run, making available and using new generation high-efficient and 'zero-emission' technologies as to effect the drastic CO_2 reductions required in light of the carrying capacity of the earth's atmosphere on the one hand and population and economic growth on the other.[16] The likely failure of markets to supply this kind of investments despite the high social benefits calls for appropriate research programmes and funding to be established today to develop the new and emergent energy technologies needed for in the future.

In conclusion, a secure, environmentally friendly and cost competitive energy supply calls for appropriate investment to ensure that the transformation of the existing energy system is made in a timely fashion. Governments need to adopt policies with a view to fossil energy consumption (such as promoting energy efficiency and technological diversity). The role of public research and funding is critical due to the high uncertainty and necessary large investments required for technology breakthroughs. Also, changes at the level of infrastructures need to be considered and measures should allow for adequate time frames for investments to be effected.

International cooperation is also important, bringing together research teams from different countries with specific objectives as to target the utilization of know-how and development activities of more sustainable and advanced energy technologies and rationalize scarce R&D resources. This could also help to overcome barriers for the rapid deployment of new technologies, even more so if industry is involved in the demonstration and application phase. A more active involvement of industry in the process could thereby contribute to the transition to an economy based on a new and sustainable energy mix.

Another reason for the market to fail, justifying government intervention to remedy it, resides in the fact that economic agents might not possess all relevant information to take decisions in the market place. Therefore, communication instruments are important for the acceptance of new technologies by the general public. The involvement of society in the definition of new paths in the construction of a new energy future is the crucial to ensure the success of new technology diffusion and the transfer of associated know-how.

It is very important that R&D budgets are not subjected to reductions once approved. These cuts can be quite harmful, as they might mean a move away from the objective of transforming the energy system into a sustainable one for the future, to the extent that they lead most of the time to a re-scheduling of actions programmed together with elimination of certain studies, namely the higher cost ones.

4.2 The need for technological breakthroughs and public research

The future is associated with the 'zero emissions' concept and technology development has to respond to this challenge that state-of-the-art of energy research and technologies are not going to meet. In economic terms, the intervention of governments is justified to remedy market failure such as in the case of basic research. There is a need for strategic basic research to achieve significant breakthroughs in emerging energy technologies, to provide required breakthroughs in areas like nano-sciences, genomics, superconductivity, electrochemistry and electrophysics, catalysis, biophysics and biochemistry, advanced computation and complex, adaptive systems.[17]

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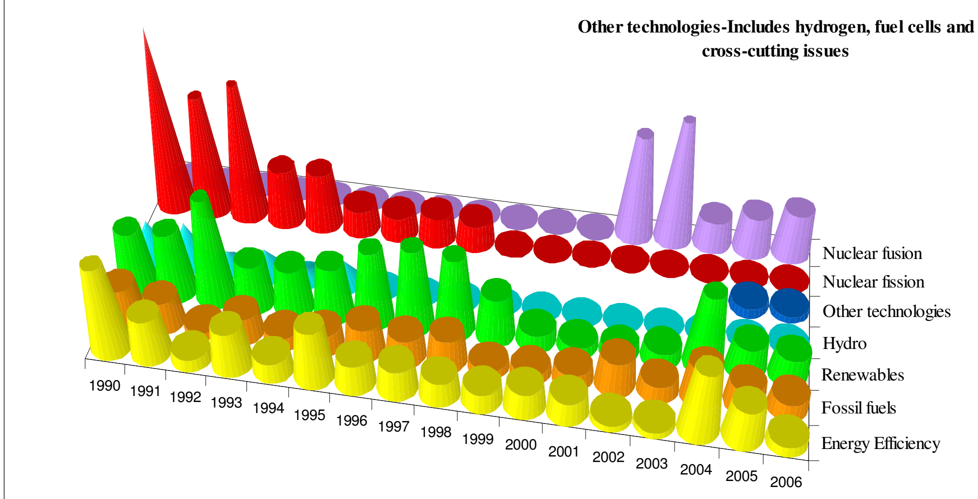
[16] To illustrate that point, while there has been progress on CO_2 emission of vehicles due to more efficient technologies, the increase in the number of cars has led to an increase in CO_2 emissions.
[17] As identified as opportunities for basic research in the Oak Ridge Workshop of the International Energy Agency (IEA, 2006c).

In the light of scarce resources, governments need to consider priorities and roadmaps of targeted technology or on a mix of technologies, and promote integrated multi-disciplinary teams, both of domestic expertise and integrating those ones abroad with relevant knowledge and specific competences. Approved R&D budgets should also be executed in accordance with long-term time horizons of fundamental research on sustainable energy solutions. National Laboratories could have an important role in pursuing specific needs in regard to technology advances, focusing on clusters and creating opportunities for new companies to emerge.

Bridging the gap between basic science and technology applications is crucial[18], and here governments should also promote partnerships to promote both the applicability and adoption of new technologies. As a response to short and medium-term needs, centres of competence are usually important on the technology push side and ought to collaborate with the private sector to deploy technologies. Such competences should be associated with standards and actions leading to the certification of appliances as well as know-how transfer and training. In addition, technology transfer and the cooperation between more advanced countries and developing ones could be useful to promote cleaner technologies.

Figure 5 – Portuguese public energy R&D funding in euro, by research area, in accordance with IEA classification



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy Efficiency	1.442.10	713.411	205.365	711.570	314.527	908.750	468.945	479.799	384.184	308.531	401.247	362.665	100.000	91.012	1113480	625.600	167.800
Fossil fuels	615.467	498.474	109.736	413.214	205.959	327.715	522.725	443.197	534.422	136.915	164.644	251.464	541.695	259.029	618737	380.000	273.000
Renewables	1.033.26	1.098.39	1.718.13	759.654	780.275	892.414	1.232.36	1.345.77	1.292.16	767.301	278.117	172.844	174.820	253.846	1241535	514.500	428.000
Hydro	621.702	681.557	245.678	378.837	130.934	377.430	0	0	0	0	0	0	0	0	0	0	0
Other technologies																147800	107710
Nuclear fission	2.877.92	1.910.38	2.173.38	913.493	933.560	428.827	393.212	467.872	430.961	0	0	0	0	0	0	0	0
Nuclear fusion	0	0	0	0	0	0	0	0	0	0	0	0	1.695.91	1.999.76	497375	650.000	780.000

Source: National Institute of Engineering Technology and Innovation (2007)

However, decreasing public R&D budgets in many countries have meant a shift towards a more immediate use of results from applied research rather than on

[18] See Cabrita, Bongardt, Guyurtly and Joyce (2007) for a discussion.

innovative emerging technologies in various domains of energy that still require scientific breakthroughs. Governments need to become aware and adequately address those needs in order to provide solutions to challenges with a view to a sustainable future. Yet, public R&D funding has also declined in Portugal (figure 5) and the items "renewables" and "energy efficiency" do not emerge as absolute priorities with a view to the future.

5 Conclusion

The EU goal – a kind of industrial strategy – of transforming itself into a competitive low-carbon economy implies the need to decouple economic growth and greenhouse gas emissions. In order to grow differently it is necessary to change unsustainable present production and growth patterns. On the basis of the Kyoto obligations, these changes have so far been rather gradual and small, but EU unilateral goals until 2020 and projections of the global reductions required for sustainability announce the need to effect significant changes within the next decade or so and drastic ones until the middle of the decade.

The carrying capacity of the earth's atmosphere and the objective to limit global warming impose limits on the use of fossil energy sources. A country's energy mix and energy intensity condition CO_2 emissions. Note that total environmental impact is conditioned by the size of the population, the level of economic development and by technology. Knowing that the world population is growing and that people and countries aspire to higher levels of well-being through economic growth clearly illustrates the need to grow differently and with a lesser environmental impact.

On the other hand, EU firms compete in the internal market and in the global market place and thus need to be competitive on a global scale. The EU internal market provides a business environment and institutional framework that pushes firms to be cost competitive and innovate. Consumers also tend to become more environmentally conscious as environmental impacts become associated with quality of life. Moreover, the Lisbon goal of transforming the EU economy into the most competitive and dynamic knowledge economy by 2010, emphasizing competition and innovation, implies the opportunity to effect a shift towards a less resource and more knowledge-intensive economy and different types of products, services and technologies. Adequate policies need to do the rest.

The discussion in this paper has shown that CO_2 reductions might imply a short-run trade-off between growth and pollution abatement but that does not need to be the case. The reduction of emissions emerges not necessarily as a cost-aggravating factor but as a new competitiveness factor. Eco-efficiency implies that firms gain competitiveness when they manage to improve their resource utilization and thereby lower environmental damage. Alternatively, changing consumer preferences also open up new business opportunities for innovative firms. As a matter of fact, the EU already starts to specialize in environmentally-friendly products and technologies in the global marketplace.

Environmental policy is critical to promote both efficiency and sustainability. The pricing of environmental damage (taxes, marketable emission quotas) prompts economic agents – producers and consumers- to change the behaviour that gave rise to those impacts. The magnitude and time horizon within which that happens depends on the existence of close substitutes and alternative technologies.

EU environmental policy emphasizes the need for market-based instruments that promote efficiency and innovation. Unlike command-and-control type instruments (such as quotas, standards, prohibitions) that have a one-off effect, economic instruments work with the market mechanism and lead agents to look for the cheapest ways to reduce pollution in order to avoid the payment of taxes or charges or to sell off unused emission quotas with a gain. The adoption of least-cost solutions of emission reductions has obvious ramifications for the competitiveness of firms and economies. In addition, the availability of technical solutions influences an economy's capacity to modify production and consumption patterns.

On the energy front, there is a large potential for energy efficiency, calling for adequate policies to prompt economic agents to put them in practice. With a view to new technological solutions, industry is more likely to invest with shorter time horizons and in more applied R&D. Market incentives are decisive for progress also in energy. The creation of an internal market in energy is associated with increased competition (and lower cost), more supply security and the potential to diversify national energy mixes. EU member countries could then specialize in energy production on the basis of comparative advantage (notably cleaner energy sources or renewable energies such as wind, waves, solar energy), provided that there is substantial investment in new infrastructures (private or public) that allows for the transport of energy in the European space (direct current). Moreover, there are ever more decentralised solutions to energy production. Regulation with a European dimension is called for to take into account the Community dimensions of creating the conditions for the good functioning of the market in network industries such as electricity or gas, where infrastructures are key.

Despite improvements, state-of-the art solutions are unlikely to meet the challenge of drastically altering production and consumption patterns over the next decades in order to cut down on total CO_2 emissions. Basic research into emerging energy technologies is however likely to meet with market failure, calling for publicly funded research in that area with a view to future sustainable energy technologies and systems. The development of radically new technologies might open up new markets and lead to new sectors and specializations. To that extent future competitiveness of EU firms will be conditioned by adequate public investment in innovative emerging energy technologies and their successful transfer and assimilation.

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