Towards a sustainable European energy model: Investment for sustainablity

Ignacio Pérez-Arriaga*, Julián Barquín

Pontificia Comillas University

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Abstract

This chapter addresses long-term policy issues in the electricity sector that are related to the sustainability of the European energy model. The basic features of a sustainable energy system are described first. Then the sustainability problems of the present energy model are identified and discussed. Most of the chapter is devoted to the analysis of the suitability and potential of different mechanisms of response to this challenge. The following issues have been addressed in some detail: Demand-side measures, such as energy saving and energy efficiency; increased penetration of renewable energy sources; research and development in the energy sector; the future role of nuclear energy and measures to achieve universal access to electricity.

Keywords: Energy, regulation, investment, sustainability, environment, long-tem energy policy, security of supply, renewables, energy efficiency.

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1. Introduction

European energy policy confronts a number of main concerns: security of energy supply, presently and in the future; guarantee of the freedom of choice by consumers at affordable prices; efficiency in energy production and consumption; acceptable environmental impact; and maintenance of the competitive position of the EU, while fixing, when needed, possible market failures.

But all these objectives only make sense in the long-term if obtained in a sustainable manner. That means that there should be a lasting and dependable access to primary energy sources; adequate infrastructure to generate and transport the required amount of electricity in a reliable way; energy-related activities performed so that no irreparable environmental damage is caused; compatibility with an adequate economic development; and finally a guarantee that fair universal access to modern forms of energy supply will take place, in Europe and also worldwide.

Environmental care and human development are two inextricably linked concepts, and no durable advances are possible in one front without proper consideration of the other one. Sustainability subsumes both kinds of considerations under a single name.

This chapter is divided into two parts. The first one is diagnosis. The sustainability problems of the current energy model are addressed, and recent results on prospective analysis are introduced. Specifically, long-term scenarios for the future of electricity supply in Europe, the impact of adopting different energy policy strategies, estimates on the European dependency on energy, the availability and price of energy resources, and the potential role of renewable generation and demand side management activities are discussed.

The second part is devoted to the analysis of the mechanisms of response that are available to build a sustainable future. The major approaches to address the problem of the lack of sustainability of our energy model are studied: demand-side measures addressed to improve efficiency and to save energy, contribution of renewable energy sources, long-term R&D in energy, and the international cooperation to address universal access to modern energy forms. The future role of nuclear energy is also examined. Information and education of public opinion, as well as advanced regulatory approaches, are essential to achieve successful results in all of them.

All these issues were covered in the presentations and papers that were put forward at the conference *Investment for sustainability*, corresponding to SESSA Work Package 7, held in Madrid, Spain, on 19-20 May 2005 [SESSA, 2005]. The objective was to identify the challenges to the sustainability of the European energy model and to examine the potential of the main solution approaches that have been proposed. This chapter reviews the material that was presented at this conference and summarizes the conclusions as recommendations for future lines of action.

2. The sustainability problems of the current energy model

Prospective analysis

Prospective studies provide highly valuable insights into the workings and the future of the European energy model, see [Capros, 2005], [IEA/OECD, 2004] or [EC, 2003]. In [Capros, 2005] the reference situation is provided by a "Business As Usual" scenario –a continuation of current trends and policies into the future-, characterized by current and expected demand growth without especial measures of energy savings and efficiency, inequitable world distribution of energy resources, inadequate effort in R&D in energy, continued rate of depletion of fossil fuel resources, risk of insufficient investment in generation and network capacity and no major effort to curb climate change. Both positive and negative features can be identified in this reference scenario.

On the positive side, it should be expected an increasing decoupling between economic growth and energy consumption. Energy intensity[1] in the European Union of 25 Member States (EU-25) is expected to decrease at a rate of 1.7% per year. The main reasons that justify this significant gain include improvements in energy efficiency (both on the demand and the supply sides), changes in the structure of EU industry, saturation in demand for some important energy needs, and the policies already in place, see [Capros 2005].

However, total energy consumption in EU-25 is expected to grow at around 0.7% per year. Renewable energy sources would expand at a moderate rate, from a share of 5.8% of primary energy demand in 2000 to reach 8.6% in 2030. This relative lack of penetration, which is below EU objectives, is obtained in spite of considerable support schemes[2]. Overall, decreased price elasticity of energy should also be expected.

Also on the positive side, no pressing energy resources limitation during the next 20 years is forecasted. However, the situation in later dates is debatable, as there are uncertainties on the magnitude of fossil fuels reserves. In the specific case of oil, peak production forecasts range from roughly now to 2030 or even beyond that date. Gas and coal reserves are more abundant, coal in particular. However most of the consumption growth will be met by increasing imports from outside the EU. Therefore, energy dependence will increase from 47.2% in 2000 to a forecasted value of 67.3% in 2030. Concerns about security of supply have been expressed, specially taking into account that oil and, to a lesser measure gas production, are increasingly concentrated in a small number of countries that are subject to considerable political risk.

In the long run, only 25% of final energy demand will be required by industry in EU-25. As efficiency in industrial uses is already high, there is a limited potential for further improvements in this sector. On the other hand, 40% of final demand is "buildings" (that is, households, tertiary sector, space heating, etc.) and 35% is consumed in transportation. There is considerable scope for efficiency improvements in these sectors, although the effectiveness of regulations and incentives is made difficult because they have to be applied to a very high number of users. Transportation is a particularly difficult case, as there are no easy substitutes to oil in the short and medium terms. Biofuels have some potential for significant penetration. The economy and technology of hydrogen production are still at a very incipient stage and its potential has still to be proved. The extraordinary growth in transportation demand is a major source of traffic congestion and air quality problems worldwide.

Electricity demand is forecasted to grow about twice as fast as the average energy demand. So, massive investments in new generation capacity will be needed (about 500-600 GW in EU-25 during the next 30 years, in order to reach a generation capacity twice as large as today's). Together with the forecasted increase in primary energy prices, this fact implies that electricity prices are likely to rise in the foreseeable future. Most of the new investments will take place as gas-fuelled plants, which will contribute to increased import dependence, especially when taking into account the decline in domestic EU gas production. British, Dutch and Norwegian gas will be also unable to meet the required

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[1] Consumed primary energy per real Gross Domestic Product (GDP).

[2] The reference case does not impose the indicative targets of the EU renewables electricity Directive for each Member State, but continuation of individual policy measures in individual countries.

demand increase, so growing gas imports from Russia, Northern Africa and other regions are anticipated.

Most environmental pressures show an improving trend, with the important exception of carbon emissions. In this case, transportation and electricity generation are the critical sectors. Carbon intensity[3] is expected to decrease until 2015 and to rise afterwards, mainly because of the end of carbon intensity improvements by fuel switching (i.e., substitution of coal by gas), and because of the electricity generation gap caused by the forecasted phase-out of nuclear stations, that would be mostly filled by advanced technology coal plants. Therefore, total EU-25 carbon emissions are expected to rise at a short-term rate of 0.3% per year, accelerating from 2015 onwards to a long-term rate of 0.5% per year. Post-Kyoto policies are, in any case, a critical issue. In this regard, it should be taken into account the decreasing share of Europe in the world economy, which makes unilateral actions unlikely to have significant effects.

In short, the main challenges of EU energy policy are:

- Security of energy supply, in relation both to dependence on imports of natural gas and oil (high volumes of imports from unstable regions) and to the required investment in infrastructures to ensure adequacy of electricity supply.
- Increasing carbon emissions, in contrast with climate change policy objectives.
- Poor performance of policies supporting penetration of renewable energies.
- Continuous growth of road and air transport, and the need to improve energy efficiency in the transport and buildings sectors.
- High uncertainty about the future of nuclear energy after 2020, and the concomitant lack of a strategic choice on a sustainable base-load generation of electricity.

Alternative scenarios can be devised by assuming implementation of measures related to further promotion of renewable energy sources, higher efficiency in final uses, increased availability and public acceptance of nuclear energy, higher taxation on carbon, increased carbon trading, support to specific transportation technologies, and development of new technologies (such as carbon sequestration or hydrogen based devices). A policy package that combines extensive support for acceleration of renewables, standards and measures for high energy efficiency, advanced nuclear technology and new standards and fuels for transportation delivers high performance in all objectives, except regarding investment expenditures, stranded costs and higher energy prices. According to [Capros, 2005], carbon emissions would drop by more than 25% in 2030 with respect to 1990, one third of energy would come from carbon free sources in 2030, import dependency would be restored to 55% in 2030, instead of 70% or more in the business-as-usual scenario. All indicators related to transport, air quality and congestion would show spectacular improvement. However, energy prices would experience a significant increase as well and the scheme would require an abundant and inexpensive gas supply, since by 2030 the gas consumption would be 2,5 times higher than in 2000. In any case, given the very large inertia of the present energy system, the actions in this policy package must be simultaneously and strongly pursued in order to have a significant effect.

Impact on competitiveness

Given the expected influence that a package of public measures, such as the one described above, may have on electricity prices it is not surprising that a debate on how sustainability

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[3] CO2 emissions over GDP.

objectives may affect economic competitiveness has already started. Sustainability impacts competitiveness by affecting economic growth, foreign investment, export markets and creation of employment. Industry is concerned about potential higher-than-average energy costs, lack of convergence of prices in the EU, stringent environmental legislation and lack of harmonisation of energy and environmental policies at European level. There is fear that energy intensive companies may be forced to relocate their activities outside the EU.

However, the precise relationship between environmental policy and economic performance remains a matter of debate. On one hand, negative economic impact on certain sectors (e.g. iron and steel, refineries, cement, chemicals) is hard to deny. Leakages[4] may also cause problems that could be possibly corrected with border taxes, which would be justified because global externalities such as global warming. On the other hand, the impact on competitiveness may have been overstated. Many studies suggest that such effects are minimal or entirely absent, finding that for most industries the expenditure required to meet environmental regulations constitutes an insignificant proportion of overall production costs, often below the limit of 1%. These studies further suggest that environmentally concerned countries do not incur economic losses from decreased trade or industrial relocation, nor do dirty countries gain competitive trade advantages and attract foreign investment by acting as pollution havens. It is even argued that strict discipline in energy and environment may provide for competitive advantages in the long term, although the case is yet to be proven, see [Golub, 1998].

Moreover, some of the measures that are required to advance the competitiveness of the European economy also provide sustainability improvements. Among then, further energy market integration, better regulation of natural monopolies and market power, and integration of environmental considerations through market mechanisms should be actively pursued. See [Comillas, 2004] for a recent review of the major issues involved.

The role of regulation

Unlike governments, individual companies carry little or no obligation to address long-term energy security or environmental challenges. It is the responsibility of governments to ensure, through market pricing and legislative frameworks, that the market responds to these concerns. Most of the mechanisms of response to be proposed in the next section have to be implemented by means of regulatory instruments, as they typically consist of additional incentives or limitations to the behaviour of market agents. These are generally necessary since markets rarely internalize long-term public policy objectives or they miss the environmental externalities associated to electricity production or consumption.

One particular issue of concern is the response of electricity markets to security of supply considerations in the short and medium term. Energy market liberalisation and privatisation have led to lower energy prices, greater price volatility and increased commercial risk for new capacity investment across all fuel types. Energy planners have begun to voice concerns over current limited levels of private sector investment in new generation and transmission capacity to meet the projected energy demand growth. This chapter will not deal with these shorter-term worries on security of supply, as they belong to market design and regulation and they are treated in the chapter of this report corresponding to Work Package 3 of the SESSA project.

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[4] If measures to mitigate climate change are implemented in a subset of countries (the EU countries) and the environmentally damaging activities are moved to other countries outside the EU, the beneficial effects of emissions reduction in the EU may be offset by higher emissions in other countries, i.e., there is leakage. The higher such leakage, the less efficient is the emission policy under a global perspective.

3. Mechanisms of response

In order to address the problem of the lack of sustainability of our energy model, the major categories of approaches that have been identified at the *Investment for sustainability* Conference will be presented here. The analysis includes: demand-side measures, renewable energy sources, long-term R&D in energy, improved approaches to regulation and international cooperation to address universal access to modern energy forms.

Demand-side measures

Total primary energy consumption of EU-25 is 1725 Mtoe (million tons of oil equivalent) per year -with a total cost of about € 500.000 million- half of which has to be imported. The annual cost per capita is more than € 1000, and it includes the direct consumption of electricity, gas and fuel for private cars, as well as the energy embedded in diverse products and services. Energy looks expensive this way. On the contrary, direct consumption of electricity –the most refined and versatile form of energy- is inexpensive for the end domestic consumer (for instance, the average daily cost of electricity for a family of four in Spain is less than € 1,4). This is one of the reasons that so much energy is wasted.

Most efforts in efficiency and cost saving have been devoted to the energy supply side. Only in the year 2000 the Green Paper on security of energy supply by the European Commission [EC, 2000] emphasized the importance of demand-side management. The Green Paper concluded that most of the margin for improvement of the EU energy situation was in the demand side. Consequently, the Commission has put forward a Directive on the energy performance of buildings and other on cogeneration and has also prepared a proposal of a Directive on energy efficiency.

A new Green Paper has been recently issued by the EC on energy efficiency [EC, 2005]. This Green Paper intends to open a discussion on how the EU promotes an overall policy in order to encourage widespread use of new technology to improve energy efficiency and to stimulate a change in European consumer behaviour. The Green Paper makes a good diagnosis of the main obstacles presently preventing the capture of cost-efficient measures: lack of appropriate incentives, lack of information and lack of available financing mechanisms, among others. Then, the Green Paper seeks to identify options on how these bottlenecks can be overcome, suggesting a number of key actions that might be taken.

Demand-side measures include both energy efficiency measures (e.g. substitution of incandescent lamps by high-efficiency fluorescent lamps) as well as energy saving measures (e.g. increased use of public transportation instead of private cars). In 20 to 30 years it is expected that about 40% of energy consumption will be spent in buildings, 35% in transportation and only 25% in industry. Therefore, appropriate regulation of the right sectors (i.e. building codes or car efficiency standards) looks very promising, as the margins for improvement are large. The Green Paper is starting a debate on how the EU could achieve a reduction on a cost effective basis of the energy consumption of the EU by 20%, compared to the current projections for 2020, i.e. average annual savings of 1,5%. This would result in 1520 Mtoe, the same consumption level as in 1990.

It makes no sense to repeat here the sound assessment of the situation and the proposals for action that are contained in the EC Green Paper. This section will just provide some reflections on specific issues that were treated at the SESSA conference in Madrid, see [SESSA, 2005].

Usefulness of price signals

The difficulties inherent in implementation of energy efficiency measures when consumption is very disperse, -as it is the case in the building and transportation sectors- should be stressed. The obvious regulatory instrument for dispersed consumption is the application of price signals. However, the effectiveness of prices in reducing consumption is scarce at the current level of energy prices –of electricity in particular-, since these prices do not internalize most of the associated impacts (environmental impacts and depletion of natural resources). A complete internalization is presently out of reach, because of its effect on inflation and the unbearable economic distortions that would result unless some kind of agreement is reached at international level. Since price signals in the price ranges we are used to are not enough, other mechanisms have been designed to pass to the consumers the need to save energy. This is the justification for the multiple activities of electricity demand side management that are taking place in some European countries. Some recent examples are a) improved metering devices -such as the ones that have just been implemented in Italy- make it possible to send hourly cost reflective prices and to create some consciousness in the public via improved information; they can also be used to implement advanced interruptibility schemes; b) since cost-reflective pricing is useful but may be insufficient to contain consumption, it may be appropriate to impose targets of energy saving to suppliers or to distributors, coupled with a market for energy efficiency certificates which creates an incentive for new energy-saving companies (ESCos).

Price measures can be effective in the case of energy-intensive industries, but here we are facing a competitiveness problem. Therefore, harmonization (at least at EU level) is necessary. This is a difficult practical regulatory problem. In some countries of the EU (for example in Portugal, UK, Scandinavian countries, The Netherlands) either there are no tariffs, or not for the large consumers, or the tariffs are just default tariffs that have been correctly computed, so that they do not compete with the market. These well designed tariffs are additive (integral tariff = access tariff + energy tariff), where the components of the tariff are computed without discrimination among consumer types. However, other countries in Europe protect their large industrial consumers in different ways: subsidized tariffs (difficult to prove if tariffs are not computed in a fully transparent way), priority access to advantageous contracts, priority in importing energy from other countries, etc. Therefore, it is needed a coordinated regulatory position from the EU because, otherwise, those countries that protect their industries may find some justification for their conduct. But, even if there is complete harmonization at EU level, the problem for most European industries still would remain, because of competition from other countries outside the EU. A similar problem happens because of the rise of electricity prices in the EU due to the market of CO2 emission allowances. With increasing CO2 allowance prices some industrial sectors will incur competitive disadvantages in Europe relative to countries that do not implement similar mechanisms. It should be further investigated to what extent border tax adjustment is an effective and WTO compatible instrument to restore a level playing field. These are instances where "environmental diplomacy" will be needed.

Final effectiveness of energy efficiency measures

It has to be noticed that the efforts to improve the energy efficiency of devices employed in dispersed energy consumption –such as cars or domestic electric appliances- have not achieved any reduction in total energy consumption according to historical evidence, since these devices keep incorporating additional services –more power and comfort- that consume more energy. Besides, increased efficiency leads to lower prices and the economic savings can be employed in additional consumption, see [Smil, 2003] for instance. The relevance of this rebound effect is still subject to discussion. Determining long-term elasticities in this context is a challenging topic.

Improvements in energy efficiency undoubtedly increase competitiveness of the economy. The critical question is whether to reduce overall energy use we need to go or not beyond increased efficiency of energy conversion and how. Global energy reduction will be ensured if the adopted measures make explicit a deliberate purpose to reduce energy consumption, such as:

- Tax away the savings accruing from high efficiency and reinvest them in environmentally oriented projects.
- Regulate energy conservation directly (e.g. limit speed in highways).
- Conscious public choice to change behaviour and lifestyle so that a moderate level of individual energy consumption is maintained. Obviously this is irreconcilable with the commonly accepted quest for an endless and sustained economic growth that is incompatible with preservation of the integrity of the biosphere.

A different question concerns whether demand-side measures lead or not to higher utilisation of base-load, lower-cost but more-polluting generation technologies, and therefore to higher emissions[5]. From the sustainability point of view, reduction in energy consumption has positive effects in almost any front, whereas just load shifting[6] decreases investment requirements both in generation and transportation facilities and, potentially, can reduce import dependence if peak stations running on imported fuel are substituted by base-load stations running on domestic fuel. However, effects in carbon emissions depend on many factors and can be either positive or negative.

A global perspective

It is missing a global perspective showing how the proposed effort in energy efficiency fits into the complete picture of a long-term path towards a sustainable energy model. The proposed target of an annual reduction in energy consumption of 1,5% seems daring but feasible. However, there is no indication whether it fells short or not of what is actually needed in an overall plan that includes efforts in further promoting renewables, R&D in energy and gradual decarbonisation of the processes of energy conversion and utilization.

Dangers and opportunities in the EU emissions trading scheme

We coincide with the Green Paper that the EU emissions trading scheme can be an effective regulatory instrument to incentivise efficient changes in the use of existing electricity generation capacity and in the composition of the future generation mix. But this will only happen if this regulatory instrument is applied correctly. This does not appear to be the case from the available information on the procedures followed in some of the current National Allocation Plans (NAP).

The problem arises when emission allowances are awarded on the basis of historical emissions and, what is more important, when the agents expect that emission allowances for the next period might be awarded on the basis of the historical emissions from the current period. If this is the case no significant reductions are to be expected neither from appropriate fuel switching nor from inefficient plant closures or from a new trend towards a better generation capacity mix. Moreover, in many cases there is no justification to award

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[5] Details of a study that explores this issue can be found in the presentation "Review and potential of demand response measures" by Ranci P., et al. at the 5th SESSA Conference. Investment for sustainability. Universidad Pontificia Comillas. Madrid. Spain. May 19 and 20. http://sessa.eu.com/.

[6] That is, moving electricity demand from peak hours, when energy is expensive, to non-peak or valley hours, when there is cheap spare generation capacity.

allowances for free to fossil power plants when the cost of any required allowances will be fully or partly recovered from the corresponding rise in energy market prices.

Renewable energy sources

A potential transition from a society energized overwhelmingly by fossil fuels to another based predominately on conversions of renewable energies would take most of the XXI century -even longer- and a huge effort. In 2000 the share of fossil fuels in meeting the world's primary energy consumption was 82% while commercially exploited renewables supplied less than 7-8% and only 21% of electricity production, of which 96% was hydro and 4% new renewables: 65% of this was wind, 31% geothermal and 4% solar.

In a shorter time span than it will necessary to achieve this transformation, the energy prospective studies described in section 2 of this chapter already show that development and deployment of renewable energy sources must be major ingredients of all strategies aimed at achieving a sustainable energy supply. Renewable energy sources must become a very significant part of the electricity generation mix in a couple of decades if sustainability objectives are to be reached. Moreover, renewables have other advantages: they are available locally, they bring environment benefits and they contribute to employment and the competitiveness of the European industry.

Studies on the possible development of renewable energy sources very often try to quantify its potential to meet our energy needs. Usually a distinction is made between "technical potential", which ignores any economic issues, and "economic potential", which must include realistic cost forecasts and their implications. Actually, "technical potential" typically also includes some economic factors, although they may vary widely among different studies; and "economic potential" studies must include "guesstimates" of uncertain costs (i.e. CO2 emission allowances costs, other externalities, renewable targets, etc.) that also will differ in different studies. Therefore, these studies only can be expected to provide a realistic estimation of orders of magnitude, being the precise figures very contentious. The potentials that are quoted in this section are economical ones, and these caveats should be taken into account, see the material in [SESSA, 2005] for details and a more complete review.

Current EU targets and support mechanisms

The EU targets regarding renewable energy sources establish a 12% share of gross primary energy consumption and a 22% share of electricity produced from renewable energy sources by 2010, and a 5.75% share of biofuels in petrol and diesel for transport purposes by 2010 (Directives 2001/77/EC and 2003/30/EC). The regulatory instruments of support of renewable sources of energy consist of a breakdown of the global EU target into individual national targets, leaving –for the time being- the national support schemes to subsidiarity, simplification of national administrative procedures for authorisation and guaranteed access to transmission and distribution of electricity from renewable energy sources.

In a recent assessment of the share of renewable energy in the EU the Commission concludes that an important first step has been made, but extra efforts are still needed. Under the currently implemented policies the global prescribed target for 2010 will probably not be met, and it will result in a share of between 18% and 19%. It seems that this will be the case even if reductions in total electricity demand as a result of new energy efficiency measures are taken into account. There are several reasons for this: Progress in achieving the national targets differs strongly between the Member States, since not all of them have adopted complementary proactive measures geared to national conditions; biomass is lagging behind and this is not being compensated by the success of wind energy.

Wind generation of electricity is presently growing at an impressive rate in the EU. Installed wind energy capacity in EU15 grew 20% in the last 6 years, with a total installed capacity at the end of 2004 of 34 GW. In an average wind year this capacity can produce 74 TWh -around 2.4% of EU electricity consumption-. Germany, Spain and Denmark contribute 80% of total EU15 wind power capacity. This success is due to the implementation of attractive support system, the removal of administrative barriers and the guarantee of fair grid access.

Although there are discrepancies on the precise figures, there is no doubt that at present there is still ample room for additional penetration of wind generation in Europe[7], especially if off-shore wind generation is pursued[8]. There are challenges concerning massive wind generation integration in the electricity power network, although it seems than integration costs in the power system are significantly lower than investment costs. Although in general electricity transport is much cheaper than electricity generation, the current difficulties in expanding transmission networks in Europe should not be underestimated and a sound system of network locational signals is recommended. In any case, further development of this source of energy will depend on overcoming the integration problem. Factors that can help to increase the volume of wind energy (or any other intermittent or non-controllable generation) include: capacity of the interconnections with other power systems, availability of generation with fast response capability as pumped storage, controllability (e.g. fast disconnection when required) of the plants, accuracy and anticipation of production estimates or ability to withstand network disturbances without losing synchronism.

Long-range marginal costs of biowaste and biogas power generation are similar to those of wind generation, and (proper) biomass power generation slightly greater. Biomass was supposed to contribute 40% to the 2010 target, but this will only happen if the current growth rate of 7% changes to 18%. The development of biomass technologies is hampered by a lack of political coordination (agricultural policies are relevant here) and financial support. This is unfortunate because of the potential of biomass for heating, transport (biofuels) and cogeneration applications. Denmark, Finland and the United-Kingdom are the only countries in which there is steady growth in biomass electricity. Member states do not all have the same natural potential; however there is considerable capacity unexploited.

Solar photovoltaic generation of electricity is presently much more expensive than solar thermal generation. However, some important scientific and technological advances of late have motivated some optimistic long-term forecasts. Its potential is immense. In some prospective scenarios, photovoltaic generation is a major source of electricity by 2040. If these developments were to take place, there would be a reduction in needs for new transmission lines. However, there are widely apart estimates of the magnitude of the investment costs of new photovoltaic equipment, so caution must be shown on the likelihood of these new developments.

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[7] For instance, Grubb and Meyer estimate a "second-order" wind power potential (that takes into account technical, as well as social, environmental and land-use constraints) of 4,800 TWh per year in Western Europe, see *"Renewable Energy: Sources for fuels and Electricity"* ISBN 1-55963-139-2, Island Press, Chapter 4: "Wind energy: resources, systems, and regional strategies" by Grubb and Meyer. Other estimates can be found in the presentation by L. Söder in [SESSA, 2005].

[8] Although there are also discrepancies, off-shore wind potential seems to be equivalent to on-shore potential.

Future EU targets and support mechanisms

The European Parliament called in 2004 for a target of 20 % for renewable energy as a share of gross inland energy consumption by 2020. The Directorate General for Transport and Energy has established a mid-term realizable potential in EU-27 for 2020. This is 1254 TWh, in addition to the 419 TWh already achieved in 2001. 26,3% of these 1254 TWh correspond to solid biomass, 10% to biogas, and 3% to biowaste. Wind would contribute 40% (20% onshore and 20 offshore).

An assessment of the current situation and proposals for action has been presented recently by the EU Commission, see [EC, 2004]. The proposal includes a Community action plan for biomass, measures to promote offshore wind generation, research and technological development and new financial instruments. In principle no harmonization is envisioned of the regulatory measures that are presently applied in the different Member States.

Regarding the special support to offshore wind, infrastructure investments for adaptation of the grids and integration of off-shore projects will have to be made. The Commission will review the obstacles and objections that may block the development of off-shore wind, the environmental requirements that need to be met and will develop guidelines for Member States.

In order to develop the use of biomass to generate electricity and heating and as transport fuel, the Commission will bring forward a specific plan. First, the biomass potential in the various Member States needs further assessment in terms of land availability and different renewable biomass applications. Second, effective use of biomass for energy purposes depends on interactions between public policy in the fields of energy, agriculture, rural development, environment and trade. The Commission will focus on the coordination of Community policies and financial mechanisms to secure adequate supplies of biomass. Finally, specific attention will be paid to the new Member States taking into account the high and unexploited biomass potential that many of them have.

Comments

For the time being, harmonization of mechanisms of promotion of renewables is not a priority of EU regulation, as no clear guidelines on the preferred regulatory instruments have been identified as yet. Most specific renewable energy support measures can be left to subsidiarity, but a modicum of coordination among the State Members must be established in order to avoid conflicting measures and improper accounting, such as the compatibility of a priori fixed feed-in tariffs on top of a market price that is affected by CO_2 emission trading. It should be remembered that many of the benefits of most renewable sources accrue at the locations where the facilities are physically located.

With the exception of large hydro-electric power, renewable energy represents a non mature industry with arguably greater need for technological and market support to enable full commercial development. There is some evidence to suggest that, in historical terms, renewable energy subsidies in the EU 15 are relatively low in comparison with other forms of energy during periods of fuel transition and technology development, see [EEA, 2004]. More mature fuels, such as natural gas, continue to benefit from the technological and industrial infrastructure built up during previous decades. As with other technologies, it can be expected that subsidies for renewable industry will fall as costs decline and the technologies mature.

Much R&D effort in renewables is needed. An area that should receive increasing attention is whatever changes are necessary to connect large amounts of wind and solar generation to the electricity networks. Notwithstanding the technological changes that will be required from the intermittent generators themselves, system operators have to make a serious effort to look at intermittent non controllable energy sources not as a threat to security but as an important future component of the generation mix that eventually may occupy a predominant position. Whatever necessary changes in operation, monitoring, control and security procedures will have to be designed and eventually implemented.

Experience has shown that meeting the EC targets for 2010 is a challenging task, not to mention the one proposed for 2020. However, much more is probably needed from a sustainability viewpoint, according to the indications of the long-term prospective studies. A precautionary principle would advise to make an extra effort so that electricity generation with renewable energy resources could take off seriously as soon as possible. The pace of progress of renewables will be determined more by perceived and actual concerns about global environmental problems (climate change in particular) rather than by any supply shortages. And an open question is how much society is willing to pay extra to support renewables in such large amounts.

It has to be acknowledged the importance of providing a long-term perspective. This is not only good because it reduces uncertainty for the industry and the market agents. It is necessary to establish a sound strategy towards a sustainable energy model. The same observation that was made regarding energy efficiency is pertinent here: there is need for a comprehensive perspective that could show how any prescribed target of renewables penetration contributes to the global picture.

Nuclear energy

The future of nuclear energy is a controversial issue and somewhat divergent opinions were expressed during the presentation on this topic at the 5th SESSA conference; see also [Romerio, 2005] and [NEA, 2000]. The fast development of the nuclear sector during the 70's and early 80's was halted by the antinuclear opposition as well as security and economic problems of the nuclear sector itself. However, nuclear energy has received recently a new impetus, mostly because of its potential to reduce CO2 emissions, which are held responsible to contribute to climate change, but also because of rising fossil fuels prices and concerns on security of supply [EC, 2000].

On the positive side, the lack of carbon emissions[9] and the existence of widespread and abundant resources are significant advantages[10]. However, concerns regarding security of nuclear operation, high overall costs -plus financial risks derived from long construction times, regulatory uncertainty and adverse public opinion-, waste disposal and nuclear proliferation issues weight heavily against further development.

Safety of nuclear operation requires estimation of very low probability accidents, albeit of potentially very serious consequences. Doubts on the robustness of these computations have been expressed, given the lack of direct empirical confirmation of the computed probabilities, and the inherent difficulties in modelling human behaviour and other critical factors.

Disposal of high-level radioactive waste is a very conflictive issue, given the extreme requirements for waste containment, of the order of the tenths of thousands of years or longer. This issue not only involves social, technical and economic factors, but also some

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[9] A certain amount of carbon emissions happen because of uranium mining and fuel processing.

[10] IEA estimated reserves are sufficient for 200 years (at the current rate of use, which is not what is needed to mitigate the climate change problem), and ultimate reserves may last much longer, especially if burnt in fast reactors.

other ones of ethical nature, as the level of risk that it is admissible to expose future generations.

New nuclear technologies can contribute to the solution of these problems. "Inherently safe" nuclear reactors, that cannot sustain uncontrolled nuclear reactions, and fast reactors, that generate vastly reduced amounts of radioactive waste, have been designed. Ultimately, fusion reactors could also avoid these drawbacks.

Some of the new kinds of reactors could also facilitate the control of nuclear proliferation. However, it could be expected that increased development of nuclear energy in Europe and other advanced economies could spread to other less developed countries, following the usual pattern. The creation of a nuclear civil sector in these countries could conceivably contribute to further nuclear proliferation, maybe increasing the likelihood of terrorist organizations getting access to these technologies. Again, this is an issue with a high political content where a lasting solution cannot be reached without a broad international consensus, which will require a favourable negotiation atmosphere that presently does not exist.

The economics of nuclear energy is also a controversial issue. Competitiveness improves with higher fossil fuel prices and worsens with higher interest rates, as capital cost is the main economic cost of a nuclear station. Fuel on the other hand represents a comparative advantage in nuclear favour. In fact, the price of uranium has little impact on the cost of electricity. According to recent estimations [MIT, 2003], nuclear energy seems to have been more expensive than gas-fuelled plants (although there are discordant voices), but this situation may change in the future, aided by rising prices of fossil fuels and stringent requirements to limit CO2 emissions. The opening of electricity markets to competition penalises investment projects that are capital intensive, have long payback periods, have little flexibility and entail relatively high risks. The life expectancy of nuclear power plants, as well as the cost of plant decommissioning, represent a considerable source of uncertainty.

Does nuclear fission represent an option for sustainable development? Undoubtedly the threat of climate change places the nuclear option under a new light despite widespread adverse public opinion. As stated by the MIT study [MIT, 2003], "We have not found and, based on current knowledge, do not believe it is realistic to expect that there are new reactor and fuel cycle technologies that simultaneously overcome the problems of cost, safety, waste, and proliferation". Public concern on this subject cannot be dismissed as irrational. But there are also serious risks associated to the use of other technologies, such as climate change, fossil fuel depletion and several forms of contamination.

One has to realize the dimension of what could be termed "the nuclear option". In 2000, less than 450 nuclear power plants provided 17% of world electricity. According to the MIT study, the deployment of 1.000 new nuclear reactors of 1.000 MW each worldwide by 2050 would represent about 19% of the electricity generation (assuming an electricity production growth rate of 2%) and they would displace just 5-15% of the yearly anthropogenic carbon emissions by that date. Therefore a huge investment in nuclear power plants worldwide would be needed to make a non negligible impact.

On the other hand, it would not be easy to bring nuclear power to a close in the short or medium term. Nuclear energy presently contributes 24% to electricity generation in OECD countries, ranging from near 80% in France to 0% in Italy. A short-term phase-out of nuclear energy would face enormous difficulties since there is simply no immediate generation alternative to replace this significant amount of electricity production.

The financial difficulties facing investments in nuclear power under a competitive regime in generation have been mentioned already. However, this is not an actual difficulty since, if it is considered necessary, the market could be oriented towards the desired direction using appropriate regulatory instruments. One concern should not be ignored: a purely market-based remuneration of nuclear plants would put an excessive pressure to maintain plant output at the highest level, an incentive at odds with meeting the most stringent security standards.

Confidence in nuclear energy cannot be re-established without guaranties of transparency and the implication of truly independent experts, open to different movements of opinions expressed by academic and civil societies. This is an issue where fanaticism of some environmentally-oriented groups should be avoided, but much care has to be also exerted to be aware of the multiple forms of pressure that industrial lobbies may exert. This lobbying pressure of industry does not seem to be commensurate with the scarce effort that has been put forward during the last decade to overcome the major problems of nuclear power that have been mentioned before.

Given the relevance of the risks involved, a minimum regret choice could be to try to make use of other options -such as demand-side actions or deployment of renewables- as much as possible, so that use of nuclear energy is minimized in the medium-term or even avoided in the long-term, but only while other risks –like accelerated climate change- are kept at bay. In this way nuclear power would at least provide a bridge, while actively exploring other options, as we need diversification and flexibility

At the end of the day the choice will be political, and it should not be based on a priori ideological positions, but on impartial expert information on all the risks involved and the implications of the possible choices. Ultimately, the vectors for decision will come down to the extent of acceptable energy frugality by society, the cost of energy with its economic consequences, the confidence in non-yet-available technological fixes, the risks associated to the use of nuclear technology and the risks derived from abandoning it and maintaining a larger share of fossil fuels consumption. A new EC project with the same SESSA format could be started to help in objectively and rigorously defining the contours of the space for decision making with regard to nuclear power.

Research and development

It is not an exaggeration to assert that the future of the high-energy civilization that is enjoyed in affluent countries hinges on the possibility of achieving a sustainable energy system, and any route to a sustainable energy system will have to resort to new or improved energy technologies that will have to be found through R&D. Therefore our effort in R&D effort should be commensurate with its critical role.

Unfortunately, this is not the case. EU-funded -as well as Member State and private industry funded- R&D has decreased dramatically over the last 25 years[11], see the 5th SESSA conference documentation [SESSA, 2005]. Presently, European subsidies for the energy sector total € 29.200 million per year, including 13.000 million euros in coal subsidies. But the total R&D effort in the EU-15 -which in the long-term should possibly have a larger effect than subsidies to declining industries-, amounts to only € 700 million.

It is expected that some technologies, such as photovoltaic, high temperature solar concentration, marine technologies and advanced biomass might become cost competitive

[11] Commission-funded energy R&D expenditure has decreased in real terms by almost a factor of four over the past 25 years.

and capture significant market shares by 2020. This is the same time scale envisaged for large-scale application of carbon sequestration and maybe slightly ahead of next generation nuclear projects. This suggests that the current paradigm of bridging technologies, e.g. priority financing of carbon sequestration to fill the gap before renewables are available, does not hold. Uncertainty in all technologies suggests that a parallel development of these technologies should proceed. We do not know which one of the present technological options can be brought to actuality, and even less at what cost. In any case, breakthroughs cannot be delivered quickly on command. Thus, the energy R&D effort must be carried on across a wide range of options, and the present 25 years long trend of decreasing investment must be reversed.

Technology specific support mechanisms may be required to provide a scale of production that would reduce the generation costs to competitive levels. To increase the market size for these technologies (particularly photovoltaic), a large number of countries need to participate in strategic deployment programs.

Energy research efforts in Europe remain fragmented. It is necessary a well-coordinated approach across Europe, and a pooling of the resources available at regional and national levels. The renewed energy R&D effort should start now and continue for an extensive period of time. Selected topics must be those where a technical breakthrough would dramatically improve our chances of making our energy system sustainable. A plausible long list of research topics -no priorities are indicated- and the sectors where they could have an impact would include[12]:

- Biomass energy (heat, electricity, transport). Development of processes for production of bioethanol from lignocellulosic material, new energy crops for solid and liquid biofuels and gasification of biomass.
- Fuel cells (heat, electricity, transport). It is needed to pursue R&D on improved PEFC fuel cell stacks (proton exchange fuel cells) with the aim of demonstration in vehicles, and SOFCs (solid oxide fuel cells) and MCFCs (molten carbonate fuel cells) for stationary applications.
- Cleaner use of coal (electricity). Efforts should be focused on improving the efficiency of the current methods of using fossil fuels, high-temperature materials, super-critical and ultra-super-critical steam generation; development of pressurised-fluidised bedcombustion (PFBC), integrated gasification combined cycle (IGCC) systems, coal gasification, including hot-gas-clean-up techniques; new processes which can separate and capture CO2; and long-term CO2 storage.
- Geothermal (heat, electricity). There are some interesting experiences in the exploitation of geothermal sources for heating purposes.
- Hydrogen-related technologies (heat, electricity, transport). It is needed to improve cost-effective production: water or high-temperature steam electrolysis, exploration of schemes to generate H2 biologically, photo-biologically and via high temperature thermal splitting of water. Development of lightweight, compact hydrogen storage systems.

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[12] An inventory of potential contributions of R&D to the development of improved and new energy technologies, -both for energy transformation and end-uses-, as well as the estimated economic resources that are necessary, can be found in two reports by the World Energy Council, see [WEC, 2001 and 2004].

- Nuclear fission (electricity). Efforts should concentrate on safety and security of nuclear power facilities, safe final disposal of the radioactive waste, R&D on innovative reactor design and advanced fuel cycles.
- Nuclear fusion (electricity). The priority is building the International Thermonuclear Experimental Reactor (ITER) and the International Fusion Materials Irradiation Facility (IFMIF).
- Ocean energy: waves and sea current (electricity). Several devices for electricity generation from wave energy have been proposed and prototypes built. Research is needed for the development of pre-industrial and later industrial devices.
- Solar photovoltaic (electricity). Research is needed for the development of new processes for solar grade silicon feedstock, novel thin-film modules and production techniques, exploration of novel PV materials, including organics and new production technologies.
- Solar thermal (heat). Research is needed to overcome difficulties in integrating these sources in buildings.
- Solar thermoelectric (electricity). Presently, pre-industrial plants are been built and tested, but further research and development is needed.
- Wind energy (electricity). It is required a better understanding of wind resources, particularly in complex terrain and offshore, and power output forecasts. Development of the 'Fourth-generation' wind turbine technology, offshore installation technologies and developments in grid integration.

The priorities that have been established for the EU 7th Framework Program for research and Technological Development are the following ones: Hydrogen and fuel cells, energy savings and energy efficiency, renewable electricity generation, CO2 capture and storage technologies for zero power emission generation, renewable fuel production, clean coal technologies, renewables for heating and cooling, smart energy networks and knowledge for energy policy making.

Universal access to electricity

Today 1.6 billion people lack access to modern energy forms, severely hindering their efforts in search of a better lot. Most forecasts predict a negligible decrease of this figure by 2030, see for instance [UNDP, 2002]. To be able to correct this situation and to provide sustainable access to energy for all mankind requires us to re-think the current supply system.

There is a strong link between electricity access and economic development, although electricity supply appears to have low priority in the agenda of international cooperation of the governments. This is unfortunate, since it is generally acknowledged that extending energy access to rural areas only requires moderate amounts of funds when compared to global energy expenses. It is estimated that the minimum required annual investment to provide universal electricity access could amount to less than 25.000 million € during 30 years[13], meaning about 7% of increment about the estimated level of investment in the reference –business-as-usual- situation, while the required electricity demand per year would amount to 5% of the world annual electricity consumption.

[13] Agricultural subsidies in developed countries are estimated at € 300.000 million.

Energy access is a mean, not an end in itself. This is why it is not explicitly included in the Millennium Development Goals of the United Nations. However, access to modern forms of energy is required to reach these goals, see [GNESD, 2004]. This elementary access should not be confused with full industrial access; neither to consider it contradictory with the pursuing of global climate change correction measures[14]. Numerous experiences show that, from an institutional point of view, good government, market reform and stable investment climate are essential requirements to extend energy access to the poorest sectors of population.

Market-oriented reforms have had neutral or adverse impacts on the poor, with a few exceptions, regarding expanded access to electric energy. Power sector reforms need an explicit pro-poor dimension; otherwise electrification of the poor is forgotten. Recommendations in this respect are: a) need to protect (ring-fence) financing for electrification of the poor; b) sequencing of reforms: preferably electrify the poor first, then privatize (or at least in parallel); c) if possible, ensure that the poor are represented in key decision making bodies.

A coherent strategy for the promotion of electricity access has to be embedded in a broader sustainable energy policy strategy and should: a) consider country characteristics that influence the effectiveness and the desirability of policy instruments and the responsibility for global climate change; b) follow an approach that includes an array of effective instruments in which promotion of access is integrated with other local development actions. Examples of these instruments are: a) price regulation to reflect economic costs and ensure fiscal stability and financially sound sector companies; b) improve sector governance so that energy markets are fair and incorrupt; c) redirect subsidies to the poor to ensure social equity; d) implement subsidies that facilitate investment and not ones that subsidize consumption.

Strategies should be tailored to the specific needs of each society. For instance, priorities in Sub-Saharan Africa should be focused on achieving an enabling environment by providing sound laws and institutions, concessional funding and private / public partnerships to foster national modern energy access programs. This can better be done through adjustable program loans rather than via intermittent project retail approaches. On the other hand, Latin American priorities should be, for low and middle income countries, to support rural and periurban electrification through general investments in infrastructure, whereas middle income countries, with high levels of electrification, require interventions to provide off-grid service to poorest areas and the creation of an appropriate framework to revitalize private sector investments, see [GNESD, 2004].

More economically advanced societies, as the EU, should remember in any case that a long-term engagement is sought, and therefore patience is required. Persistence, not perfection, is the key to success.

In conclusion, aid programmes for developing countries related to energy should be thought over again. Stronger, more sustained and more imaginative actions are needed, directly focused on attaining a global sustainable energy model. Social and environmental issues have to be looked at since the very beginning of the process. The promotion of universal access to electricity, the use of market mechanisms to internalise the use of natural resources, and the massive use, whenever possible, of renewable technologies

[14] "Thus, there is not a major need for transmission lines, central station generation and major gas developments for poverty alleviation. These will be needed for overall economic growth but not to advance the poorest of the poor." Reaching the Millennium Development Goals and Beyond: Access to Modern Forms of Energy as a Pre-requisite. [GNESD, 2004] www.gnesd.org.

should be part of this new approach. Optimal use of climate change finance and clean development mechanisms should also be sought.

4. Conclusions

A sustainable energy model for the EU must include some essential features: lasting and dependable access to primary energy sources, adequate infrastructures to generate and transport the required amount of electricity reliably, non irreparable environmental consequences, compatibility with an adequate economic development and equitable universal access to modern forms of energy supply.

According to this definition, on a time scale adequate for civilizations (e.g. 1000 years or more) our fossil-fuel-based civilization is inherently unsustainable if its benefits have to be extended to the 10.000 million people that might populate the Earth by the end of the XXI century. Our pursuit of high rates of economic growth cannot continue for yet another century if this is leading to increased energy consumption, despite continuous technical innovations resulting in gains in conversion efficiency and lower losses. As energy uses are responsible for a large share of the continuing degradation and modification of the environment, it is imperative to begin the process of limiting their environmental impacts in general, and climate change in particular.

General recommendations

There is a need to reverse the unsustainable trend of our energy model and to make it more sustainable at national, European and worldwide levels. Our general recommendations for action to achieve this end follow. This action must be quick, strong and capable of ensuring sustainability, while maintaining at the same time industry competitiveness, security of supply, and access to modern energy sources for the entire world population. However, current public policies are not strong enough, and they lack the internal consistency required to achieve such an ambitious objective.

1. Therefore, the first recommendation is to **move up energy in the political agenda**, to produce strong policies that are based on a solid institutional framework, and to integrate them as much as possible into the European and national legislative framework. Public debates and other informative activities must be held in order to educate the population and set the guidelines to be followed in the most controversial issues and the strategic choices to be made.

2. Under a pragmatic viewpoint it is convenient to **rally public opinion around one major issue**. The strong policies that will be needed require the involvement of all sectors of the society, and they also require a sense of direction. To that extent, a clear goal is required on which to concentrate efforts and wills. Currently this goal cannot be other than the fight against **climate change**, within which other partial goals may be incorporated, related to other factors that limit the sustainability of our model, such as the depletion of natural resources, security of supply, or lack of universal access to modern forms of energy. The concern about climate change must be one of the key formative factors of energy decision-making during the 21st century.

3. Anticipating the future of the EU energy model is a very difficult task. Long-term forecasts based on realistic simulations of the energy model under a variety of circumstances (predefined scenarios) provide insights on possible future outcomes, although little certainty on what is really going to happen. In this uncertain context it is particularly advisable a more **normative approach**, whereby a set of desirable realities is outlined and then complemented by a short wish-list of actions, attitudes and commitments that we should take to get there. This is basically what the "targeted

scenarios" in [Capros, 2005] try to achieve. But we have to reach the prescribed targets allowing flexibility to adapt to changing and unexpected conditions and leaving room to markets to act. In summary, based on the insights that the analysis of multiple scenarios may provide, **specific long-term targets** have to be established by the corresponding regulatory authorities.

4. The elements comprised by this normative approach –the prescribed targets and the list of actions- must be consistent with one another. The quantitative validation of the **consistency of any proposed package** has to be done by simulation with an appropriate energy model. This comprehensive view appears to be missing presently in the approach to energy sustainability by the European Commission. There are European Commission targets for reduction of CO2 emissions, targets to improve energy efficiency, targets for further penetration of renewables, targets for energy R&D and targets for international cooperation in energy matters with non EU countries. However –and this is an ambitious request- it is missing a **comprehensive vision on how all these pieces fit together and an assessment of how far any proposed energy model is from a sustainable path**.

5. Given the multiple threats to the sustainability of our energy model that have been identified and the limitations to respond, based on our present knowledge of energy technologies and resources, the application of a **precautionary strategy** seems inevitable when trying to attain the proposed long-term targets. Infrastructural problems preclude any rapid shifts, even if there were an unprecedented political will and a social compact to act. On the other hand, it is important to start now, and to work without delay and with persistent commitment. A first ingredient of the precautionary strategy should be adoption of lines of action that try to **minimize the regret**: Favor a multitude of approaches rather than relaying on a single solution. Promote minimal inputs compatible with the highest achievable targets. Be flexible, eclectic but discriminating. Avoid categorical exclusions of certain ingredients as well as an inflexible insistence on what is deemed to be best.

6. There is a gap between long-term public policy aspirations and current market trends. Public policy attempts to pursue objectives mainly through state-driven support, such as regulated support for renewables -exempted from market competition-, protection of domestic fuels, the imposition of ecological taxes or environmental constraints, various forms of state-aid for the development of nuclear energy or state-made assignment of allowances for emission trading. Markets seek to invest in technologies with minimum capital cost and quick returns, they have no reason by themselves to internalise long term public policy objectives and they consider public policy as one important source of uncertainty. **Reconciliation of markets and public policy** requires **clear strategic choices, removal of uncertainties** and the **use of market mechanisms** whenever possible.

7. Regarding the practical implementation of these policies, **liberalisation should be considered a powerful instrument** rather than a hindrance: liberalisation has opened up technology choices, supply opportunities, better linked gas and electricity markets, it has given more choice to consumers and it has increased transparency in the market. Liberalisation helps to achieve sustainability objectives at a lower cost by providing market mechanisms for implementing energy and environmental policies. These market mechanisms, and especially the price system, have proved much more powerful than other public policies for technology changes and energy savings. They should therefore

be used extensively, according to the guidelines established in another chapter of this report (Work Package 3).

8. In order not to affect competitiveness and to avoid economic distortions, this regulation should be as uniform as possible across Europe. To that end, those **policies affecting the energy sector should be made consistent and harmonised at EU level**. We need a common policy on energy and environment. Legislation should be harmonized across Europe in some key topics (emission limits, support to renewables, biofuels, strategies for acquisition of gas, etc.), while trying to find the right equilibrium between regulatory measures adopted at both the Member State and the European Union levels. Other chapter in this report deals with regulatory harmonization (WP6).

9. A key precondition for the successful contribution of market forces to public policy strategies is the **reduction of regulatory uncertainty** to a reasonable level. This can be achieved by a **credible commitment of governments and regulators to long-term guidelines and targets**. Moreover, given the global nature of the most relevant threats to energy sustainability, it is also necessary to incorporate all countries to the solution process, that is, to actively engage in "**environmental diplomacy**". It is required to incorporate explicitly the energy and global sustainability issues in the relevant international forums, and to create an adequate discussion platform from which advances may be made on the proposal of measures and on the collaboration for their implementation. We need to find ways to bring the different countries aboard in a manner that benefits them. This diplomacy has to act in three simultaneous directions:

   - Despite the current position of leadership of the EU in these global sustainability issues, it is obvious that nothing substantial may be achieved without the positive cooperation of the US and other major players. Perhaps the participation of large international companies might help in this respect. The EU, the US and other major actors in the energy scene have to find the terms for a fruitful cooperation in this topic.

   - The EU should maintain permanently a strong multidimensional energy cooperation with fuel supplying countries. Protection of key sensitive infrastructures is certainly one of the dimensions, as well as construction of new interconnections, the development of new fields and facilities as required, integration in the Kyoto market mechanisms whenever possible, participation in multinational energy markets or the facilitation of credits for the national companies to invest in new oil and gas projects, for instance.

   - New aid strategies related to the facilitation of energy access for developing countries. Developing countries are faced with the double challenge of ensuring economic growth to improve living conditions for their population (facilitating among others a reasonable and dependable access to modern energy forms) and preserving the environment. Developed countries may contribute in several ways:

     - Facilitating funds and political and regulatory support for eradication of poverty and the increase of access to modern energy forms.

     - Facilitating trade and investments to foster economic growth, in particular the expansion of energy production facilities.

     - Translating the climate change prevention strategies into concrete actions to promote the availability of appropriate technologies and specific projects to facilitate sustainable development in those countries where there is more need for it.

- Transferring energy efficient techniques to less developed countries so their rising energy use can be accommodated with high efficiency.

10. With our present knowledge of the available responses to the unsustainability threat of our energy model, if the economic growth to bring universal access to energy at a level compatible with human dignity is considered an indisputable target, a **radical change in attitudes** regarding the material consumption and the care for the biosphere appears to be indispensable, see [Smil, 2005]. This may seem an unrealistic goal at the present moment. But we should start pondering seriously how much total energy consumption –as we envision it now- is compatible with the perpetuation of vital services of the biosphere and what is the per capita energy use that is needed for a satisfactory quality of life. These concerns are expressed rarely, not only because they are difficult to address, but also because they compel us to adopt attitudes incompatible with the prevailing ethos of growth and because they demand clear moral commitments. Formulation of the goals must be aided by science, but the challenge has to be understood as a moral obligation (and implemented in actual regulatory measures).[15]

Specific guidelines

Specific guidelines for action have to be set within the scope of the general recommendations that have been just presented. Each one of these specific guidelines for European energy and environmental policy must be associated to one or more of the major approaches to address the problem of the lack of sustainability of our energy model that have been examined here: **demand-side measures** to improve efficiency and to save energy, contribution of **renewable energy sources**, long-term **R&D in energy** and the **international cooperation** to address universal access to modern energy forms. And, permeating all four, **education** -which will allow people to internalize all the other four approaches in their personal attitudes- and **advanced regulatory instruments** –to implement all this in practice-. A detailed presentation of these guidelines has been provided in the corresponding sections of this chapter their conclusions will not be repeated here.

In all these actions, governments should act as facilitators, setting clear goals and the appropriate institutional frameworks, bringing stakeholders together and helping them to organise. Then the market should be left to its own through a regulation which internalises social and environmental costs adequately, thus correcting market failures and reconciling liberalisation and sustainability.

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[15] The following excerpt from the book *"Energy at the crossroads"* by Vaclav Smil [Smil, 2005], succinctly conveys the sense of urgency and seriousness of the task that decision makers are facing when designing our energy model for the 21st century: "None of us knows what lies ahead. What we know is that our uses of energy that define and sustain our physical well-being and allow for an unprecedented exercise of our mental capacities will be the key ingredients in shaping that unknown feature. ...As we were building the edifice of the first high-energy society many things got unravelled in the process, but one key reality made the task easier: during the twentieth century we were largely on a comfortable, and a fairly predictable, energy path of a mature fossil-fuelled civilization. Things are different now: the world's energy use is at the epochal crossroads. The new century cannot be an energetic replica of the old one and reshaping the old practices and putting in place new energy foundations is bound to redefine our connection to the universe."

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