Editorial

At present it is widely recognized that the only way to respond to the formidable challenge of climate change is to move swiftly towards an economy with a drastically lower level of GHG emissions. And this can only be achieved by developing and deploying new low-carbon energy technologies massively and as soon as possible. In the short and medium term, perhaps one or at most two decades, some of the existing technologies -with moderate improvements, presumably- will have to be used, but it is inescapable that a portfolio of new and/or still unproven technologies will be needed in the longer term. Then the key question now is how to achieve the prompt development and substantial generalized utilization of these new low carbon technologies.

This special issue of the European Review of Energy Markets brings together an ensemble of contributions that explore different regulatory approaches to attain a low-carbon energy future, preferably making these clean technologies happen at a global level, possibly in the context of a comprehensive climate regime. Most of the papers in this special issue were presented at the BP Forum on Energy and Sustainability "Promoting investment in low-carbon energy technologies" (http://www.upcomillas.es/catedras/bp/Foro_08.asp), organized by the BP Chair on Sustainable Development of Comillas University, as well as in the ECP High-Level Seminar on Positive Incentives for Climate Action, see http://www.ceps.eu/Article.php?article_id=588, which took place back-to-back with the BP Forum in Madrid on April 2008.

When trying to design regulatory instruments to promote low-carbon technologies one needs to address a number of significant issues: The volume of effort -global & for each technology-, the adequate timing for massive deployment of any given technology, the specific format of the regulatory scheme to be used to minimize the cost of meeting some objective, how to encourage cost reduction, how to harmonize regulatory schemes in different neighbouring markets and, finally, how to account for potential side-effects. The first paper, *Promoting investment in low-carbon energy technologies,* addresses these open questions and discusses the preferred regulatory approaches to foster low-carbon energy technologies, within a global climate change regime, both from an academic and industrial point of view. It also provides practical recommendations for policy makers on the design of these policies. Specific promotion policies for energy efficiency and conservation, renewable energy, carbon capture and sequestration, and nuclear technology are examined, as well as the interactions between technology policies and climate change policies. The paper acknowledges the present limitations of purely carbon pricing approaches, because prices or taxes of the right strength to meet the above mentioned long-term carbon reductions are presently considered politically unacceptable, and therefore the signal provided by the current carbon prices for reducing emissions may be too low to incentivise investment in low-carbon technologies. This first paper introduces the main topics that are developed in more depth in the remaining contributions to this special issue.

The second paper, *Plugging the gap in energy efficiency policies: the emergence of the UK 'carbon reduction commitment',* examines the critical issue of the reasons for the lack of success of measures that aim at improving energy efficiency and conservation and the adequate measures to overcome these limitations. This is of critical importance, since it is widely acknowledged that this is the cheapest and quickest route to reduce CO2 emissions. Current estimations indicate that many of these measures would result in 'negative costs', i.e. a value of energy savings, discounted at a market rate of return, which exceed –sometimes very significantly– the up-front additional investment cost. The paper investigates a number of instruments already in place that aim at improving energy efficiency in the UK, as part of wider UK climate change policies, with particular reference to the business and public sectors. These instruments have failed to overcome key barriers that are specific to large, less-energy-intensive companies and public sector organisations, such as light manufacturing and the "service sector". This paper focuses on the adequacy of existing policy instruments to exploit the potential for energy efficiency, and the resulting policy implications. Besides, the paper introduces an entirely new proposal – the Carbon Reduction Commitment - which is the main new policy instrument in the UK's 2007 Energy White Paper and is due to commence in 2010.

A subset of the approaches to promote energy efficiency and conservation are those that aim at increasing the capability of the demand of electricity to respond to a diversity of signals, which may range from spot market prices to direct requests from the system operator to reduce load under emergency conditions. There is a long tradition of the so-called demand response programs. The third paper *Electricity demand response tools: Current status and outstanding issues* is the result of a thorough review of existing and planned international experiences in electricity systems, with the objective of reflecting on those still open issues that will necessarily have to be addressed to make progress in this field. Technological advances in electronics and telecommunications enable both consumers and system operators to manage demand in a diversity of forms. Smart meters will be the key elements in advanced demand management systems, together with other devices such as smart thermostats, lighting control systems or under voltage or under frequency relays. Economic incentives include a great diversity of cost-reflective tariffs, as well as incentives to participate in the spot market or to reduce demand, as for instance the recent experiences with white certificates. Numerous studies have been performed to evaluate the actual impact of these measures on the behaviour of electrical demand. The regulatory decisions on the responsibilities of retailers and distributors, or the unbundling and standardization of the metering service happen to be of critical importance for the success of measures to enhance demand response.

A massive utilization of renewable energy sources for electricity generation (RES-E) is undoubtedly an essential ingredient of the future low carbon energy model. Since diverse market failures may prevent RES-E to compete on a level playing field with other more established technologies, some regulatory support is justified. Several economic, institutional, political, legislative, social and environmental barriers have to be overcome. The fourth paper *Regulatory instruments to deliver the full potential of renewable energy sources efficiently* identifies which regulatory issues are of major relevance with respect to promotion and grid integration of RES-E, critically reviews alternative schemes and makes proposals in the context of a massive penetration of these technologies. In particular the paper explores two major issues. First, the adoption and implementation of adequate regulatory financial support systems: Here the most controversial issue is whether quantity-based instruments (e.g. guarantee-of-origin trade, tradable green certificates or renewable portfolio standards) or price-driven instruments (e.g. feed-in tariffs or investment support systems) are preferable under a societal point of view. Second, the design of a clear regulatory framework for network cost allocation policies to integrate RES-E in the electricity grids. At present these policies are very heterogeneous among different EU Member States. The most prominent open regulatory topics in this regard are: the adoption of a deep, shallow or super-shallow approach in the implementation of network charges, and the creation of market mechanisms for system balancing and operation to manage the variability and intermittency risk of the dominant RES-E generation technologies.

The search for a lower carbon future has to contemplate also how to best deal with the supply to those 1.5 billion people, about 30% of the world population, still without access to electricity. There is an emerging consensus that electric energy is a necessary, although not sufficient condition, for economic growth, especially when addressing rural development. In the least developed countries, as in Sub Saharan Africa (SSA), climate change mitigation is not the first priority, so least-cost options should be pursued, although still with a concern for a cleaner development. The fifth paper, *Compatibility of rural electrification and promotion of low-carbon technologies in development countries: the case of Solar PV for Sub-Saharan Africa*, revises actual electrification experiences, analyzes the trade-offs between climate change objectives and development objectives and examines the relevance of different possible regulatory approaches and the pros and cons of each one of them. In particular the paper concentrates on a specific technology that has proven to be useful and successful in SSA at least, Solar Home Systems (SHS), with more than half a million of systems presently installed in Africa. The paper describes and critically reviews five regulatory approaches to provide SHS in a massive way in developing countries. Different perspectives are considered: a) how to achieve the lowest fees for final consumers; b) the relevance for each method of other crosscutting elements, such as long-term political commitment, inclusion of the established financial sector and the subsidy levels; c) specific conditions that need to be fulfilled simultaneously before a market can develop: affordability, good governance, sound national economic politics and international trade politics.

It will take time to overcome the inertia of the present energy supply model regarding its high ratio of consumption of fossil fuels, despite the strong efforts that are expected in the deployment of low carbon technologies. Precious time could be gained, until these new technologies are available, if CO2 emissions from burning fossil fuels in large combustion facilities could be captured and safely stored at a reasonable cost. The sixth paper *Model-based evaluation of European carbon capture and storage policy options* investigates the prospects of carbon capture and storage (CCS) in the European energy system, as a mean of supporting the climate mitigation efforts of the EU. However, two problems have to be solved to enable the deployment of CCS. The first is to ensure that stored CO2 remains isolated from the atmosphere and biosphere, and so the technology is environmentally secure and effective as a climate change mitigation option. The second is to address commercial barriers to the deployment of CCS by appropriate regulatory interventions since, once more, if entirely left to the market, investments in CCS technology development may be insufficient because of a diversity of market failures. The paper provides an overview of the major economic, environmental and social impacts of a range of policy options aiming at internalizing the externalities related to CCS. The specific options considered in the paper are: not enabling CCS, enabling CCS under the EU-ETS, imposing obligations for mandatory CCS on new and/or existing power plants and subsidising CCS deployment. The quantitative analysis is based on a combination of a systems approach, using the large scale partial equilibrium energy systems model PRIMES, and some further ex-post analysis of the model's results.

The seventh paper, *Financing the nuclear renaissance,* examines the economic issues associated to the possible return to the building of new nuclear power plants (NPPs) in Western Europe and the US, with a focus on the key risks involved. It should be remembered that, among the several factors that contributed to the abandonment of nuclear power during the late eighties and nineties, of particular relevance for the topic investigated in this paper has been the regulatory trend towards liberalized electricity markets, with a consequent increase in the risk to obtain an adequate return on investment in generation assets. It is well known that the lifetime net-present–value of the total costs of nuclear electricity production is dominated by capital costs. Besides, between the decision to proceed with the project and the first sale of a unit of electricity with a NPP there would typically be a gap of at least ten years. It is during the interval from five to ten years when the largest costs (construction of the plant) are typically incurred and when the engineering, political and project finance risks become most acute, since a partly completed power station is almost worthless and any time delay is very expensive because of the capital sunk in the project. Those risks will affect the rates of return expected by potential private investors. The paper also factors in its analysis the claims that have been made by NPP design companies that their newer designs will be simpler, quicker and cheaper to build, the risks associated with international fuel trading in a world of evolving geopolitical risks, the price that is expected to be applied to greenhouse emissions now or in the future, as well as the price of fossil fuels, all of which contribute to provide an economic case for NPPs. The paper examines the implications of current regulatory approaches in the European Union and the US on the prospects for nuclear new build in each case.

Uncertainty in climate policy creates a barrier for investment in low carbon technologies, by introducing a potential future shock in the price of carbon, to be added to its inherent volatility. The eighth paper, *Risks and uncertainties in low-carbon energy investments,* examines the impact of uncertainty in climate change policy on the investment decisions in the power sector and, conversely, it analyzes how these policies should be shaped to facilitate investment. Potential investors may decide to postpone their decision until major regulatory uncertainties disappear. The paper uses real option theory to quantify the effect of policy uncertainty and to review the regulatory instruments that could be used to hedge against these risks, both from the potential investors and the governments' viewpoint. In the absence of adequate risk hedging instruments, the carbon price that will be required to trigger investment is expected to be significantly higher that would be expected if risks were not taken into account.

Low-carbon technologies can be furthered by climate policy instruments -such as cap and trade, carbon taxes or standards-, but also by measures directly addressed to promote technological innovation in these specific areas. However, some market failures may significantly reduce the effectiveness of innovation measures designed to complement climate policy. And, conversely, climate policy may not be able to stimulate innovation, or it may not have a sufficient effect of reduction of the GHG emissions. The ninth paper, *The interaction between carbon and technology policies*, identifies the several reasons why climate and technology policies are unlikely to be fully synergic. The WITCH model, a hybrid climate-economic model of the world economic system, is used to illustrate this point for a relevant situation of integration of carbon and technology policies: the combination of a cap-and-trade scheme with public expenditure for climate-related R&D aimed at improving energy efficiency.

All policies and approaches described in these past papers have focused on a national or regional, mostly bottom-up approach to developing cleaner technologies. But in order to become widespread, these initiatives should possibly have to be incorporated to a global agreement on climate change. The remainder of this special issue is devoted to how to address specific areas of this future agreement.

The adversary approach has been dominant in the approach to climate change by most governments. Besides, agreements at governmental level are defined in broad terms, far from the specific targets that the private sector needs to initiate any practical action. By contrast, global sectoral industry approaches are based on cooperation and specific technology-based bottom-up commitments. Sectoral approaches have received explicit support at the Bali summit in December 2007 and will be a component of the negotiations for the post 2012 agreement. The tenth paper, *Climate change: which of the different sectoral approaches can be implemented?* explains the advantages of sectoral approaches, presents a typology and describes the main categories and most relevant experiences. The paper also examines the common elements to these initiatives, as well as the main challenges that they face.

The eleventh paper *The Bali roadmap and North-South cooperation: the right to development in a climate-constrained world*, draws attention to the different level of commitment that should be expected from developing and developed countries –North and South- in meeting the very stringent emission reductions that are compatible with a long-term low carbon global economy. By means of a simple “thought experiment”, the paper shows that carbon-based growth is not an option, neither in the North nor in the South, and that any scheme of burden sharing has to recognize this and make the alternative a reality. However, while the control of emissions in the South is an undeniable scientific necessity, at the same time the South justifiably has the struggle against poverty as its first priority. Linking reductions in the South to support from the North offers the only possible solution to this dilemma. The paper presents a specific approach – the “Greenhouse Development Rights” or GDR framework – whose central principle is the right to development, rather than a right to a certain amount of emissions. Under GDR those individuals under a predefined development threshold are not expected to share the burden of mitigating the climate problem. On the other hand, above the development threshold, in any country, individuals are expected to shoulder this burden, on the basis its economic capacity and their responsibility in emitting GHG. In this way, the paper draws attention to the vast level of financial assistance and technological cooperation that the climate problem demands from each country.

The previous paper sets the scene for the twelfth one. *A bottom up approach for India,* which presents a realistic appraisal of the current close relationship between economic development and energy use in India, describes the existing policies and measures that have been adopted by the Indian Government, identifies potential mitigation opportunities in several selected sectors as well as the existing barriers to exploit these opportunities, and proposes additional measures to remove these barriers while maintaining development as the first priority. Per capita commercial energy consumption in India is still very low and it is well known that no country has significantly reduced poverty without a substantial increment in energy utilization. The challenge facing India is to meet its energy needs in a sustainable manner, and finding its own solutions to the very specific features of its energy sector. By adopting a bottom-up approach, the paper identifies numerous activities with strong GHG mitigation potential, many of which can pay for themselves, mostly in the area of energy conservation and efficiency improvement. Domestic policy actions and international support schemes are suggested to remove barriers that might impede the successful implementation of the proposed mitigation and adaptation activities.

As guest editors, we thank the authors for their brilliant contributions to shedding some light on this difficult and multifaceted topic, and to Jef Dermaut for his very effective assistance in making this special issue a reality.

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Promoting investment in low-carbon energy technologies[*]

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Abstract

Answering to the formidable challenge of climate change requires a quick transition to a future economy with a drastic reduction in GHG emissions. And this in turn requires the development and massive deployment of new low-carbon energy technologies as soon as possible. Although many of these technologies have been identified, the critical issue is how to make them happen at the global level, possibly by integrating this effort into a global climate regime. This paper discusses the preferred approaches to foster low-carbon energy technologies from a regulatory point of view, within a global climate change regime, both from an academic and industrial point of view. It also provides practical recommendations for policy makers on the design of these policies. Specific promotion policies for energy efficiency and conservation, renewable energy, carbon capture and sequestration, and nuclear are examined, as well as the interactions between technology policies and climate change policies.

1. Introduction

Technology policies are a major component of the future global climate regime, and their importance has been stressed repeatedly in past negotiations, with some countries choosing these policies as their sole approach to reducing carbon emissions. Indeed, technology policies came out as one of the four key elements of the Bali roadmap, where it was acknowledged that all possible means will be needed to cope with climate change.

In fact, climate change poses a formidable challenge to human ingenuity and consensus building capability. It is already clear that a quick transition to a future economy with a drastic reduction in GHG emissions is needed to stabilize the concentration of GHG at levels that are compatible with the objective of the UNFCC. There is an increasing consensus that the 2 degree centigrade threshold should not be trespassed.

The IPCC in its Fourth Assessment Report [1] starkly states that "… in order to achieve a stabilization level of 450 ppmv CO_2eq, emissions from Annex I parties would need to be between 25% and 40% below 1990 levels in 2020, and between 80% to 95% below 1990 levels in 2050". According to the "best estimate" of this same IPCC report, a concentration of CO_2 equivalent of 445-490 ppmv would result in a global mean temperature increase above pre-industrial level, at equilibrium, of 2.0 to 2.4 ºC. The required economic effort would result in an estimated reduction of global GDP in the range of 3% total (or 0.2% per year) to nil by 2030, and up to 5.5% total by 2050.

Although current technologies with some innovations could suffice to meet the aforementioned objectives during the first two decades, it is uncontroversial that there is the need to develop new and/or still technically unproven technologies in the longer term. Since there is no silver bullet at hand and no real prospective of having one in the mid-to-longer term, the effort should be addressed towards a portfolio of diverse promising technologies. Thus, the major issue now is how to achieve the development and the massive deployment of these new low carbon technologies as soon as possible.

This judgment has gained more momentum recently, with some authors [2] stressing the limitations of carbon pricing approaches and the need for specific technology policies to push for technology change and to achieve the reductions in emissions that are required to comply with the climate objectives. Indeed, carbon taxes (or equivalent emission trading regimes) of the right strength to meet the above mentioned long-term carbon reductions are presently considered politically unacceptable, and therefore the signal provided by the current carbon prices for reducing emissions may be too low.

Some technologies with promising potential have been identified already. The Fourth Assessment Report of the IPCC [1] makes an inventory of emissions-reducing technologies in different sectors of the economy, presently available and in the future, and also provides a preliminary evaluation of their potential and costs. The recent IEA Energy Technology Perspectives report [3] catalogues several technologies as potential major contributors to a drastic reduction in carbon emissions.

However, the critical issue is how to make the deployment of these technologies happen. In broad terms, the process should consist of three basic steps:

(a) Identification of the technical processes, costs and GHG reduction potential of existing and new promising low carbon energy technologies. Since no single energy technology on its own will provide the solution, R&D must be carried out across a wide range of technology options. The problem is that world energy research is fragmented, and private and public funding for energy R&D have been declining for nearly two decades. In addition, there are several market failures that limit the theoretical potential of innovation activities by private firms [4]: knowledge spillovers, adoption spillovers, the risk that is typically associated with innovation and also the regulatory uncertainty about the basic features of the future climate regime.

(b) Design of adequate regulatory policies to promote the required drastic technological changes. These policies should include both technology push (public support for R&D) and market pull (stable economic incentives for innovation and widespread technology development), since private firms must play the key role in this process.

(c) Make these regulatory policies fit into any global climate regime that may be agreed, which hopefully will properly integrate the development, diffusion and deployment of low-carbon technologies, [5] and [6]. Technology oriented agreements (TOAs), as complements or substitutes for carbon commitments, will surely be needed. In principle TOAs and instruments that are based on carbon prices combine well: if energy and carbon markets do not provide sufficiently strong incentives, TOAs can help in promoting technological progress. There are many types of TOAs: Knowledge sharing and coordination, RD&D programs, technology transfer, technology deployment mandates, standards or incentives, and all of them will probably be required.. TOAs can be designed according to a country interests, or applied worldwide or for any group of countries. An open issue is how to package TOAs together with mitigation measures in multilateral agreements.

When trying to design regulatory instruments to promote low-carbon technologies one needs to address the following aspects:

- The volume of effort: global & for each technology.
- The timing for massive deployment of any given technology: when & for how long.
- The specific format of the regulatory scheme to be used to minimize the cost of meeting some objective.
- How to encourage cost reduction.
- How to harmonize regulatory schemes in different neighbouring markets.
- How to account for potential side-effects.

This paper addresses these open questions and discusses the preferred approaches to foster low-carbon energy technologies from a regulatory point of view, within a global climate change regime, both from an academic and an industrial point of view. It also provides practical recommendations for policy makers on the design of these policies. Specific promotion policies for energy efficiency and conservation, renewable energy, carbon capture and sequestration, and nuclear are examined, as well as the interactions between technology policies and climate change policies.

2. Energy efficiency and conservation

Energy efficiency is the single largest prospective deliverer of GHG reductions, both due to its potential and to its low cost compared to other alternatives [1]. And it is genuinely sustainable. In Europe, for example, it represents the dominant option in the mid term (2020), followed by the massive deployment of renewable energy. The European Commission considers it economically viable to achieve reductions in energy consumption larger than 20% compared to projections for 2020 [7].

But why, if it is such a low-hanging fruit, are people not taking it? This is particularly relevant in developing countries, where energy efficiency and conservation might contribute to two thirds of all GHG emissions reductions, and in which there is a large absence of support policies for them.

There are many contributions to the discussion of the so-called energy efficiency gap, see [8] and [9]. Let us just say here that, besides market failures such as the low energy price resulting from the lack of internalization of environmental costs, and market barriers such as lack of information, there are more obstacles when designing an energy efficiency policy. First, it is very difficult to assess the real impact of energy efficiency, that is, to define the appropriate counterfactual to determine the real progress produced with and without energy efficiency programs. The rebound effect [10] only complicates such estimation. Second, and for the same reasons, it is a complex task to measure the gains and costs correctly.
Therefore, it seems that, as in other fields, the relevant discussion should not be on technology, but on how to deploy it and take into account the existing market failures or market barriers which prevent a socially efficient technology to be widespread.

There are many instruments to address market barriers/market failures regarding energy efficiency. Market pull is critical, although by no means it is the only driver. Therefore, more instruments are needed. The question is, which combination of traditional and conventional instruments to use, and how do they interact. For example, using very ambitious standards may not leave room for other instruments, and cause inefficiencies. Here an interesting idea is that, in addition to the usual carrots and sticks, companies may need tambourines, or marketing tools, to encourage them to participate in these programs.

White certificates (as cited in [7]) have recently come out as an interesting way of promoting energy efficiency measures in an economically efficient way. Italy and France are the most prominent examples.

In Italy, white certificates up to now have been oversupplied, which has required a quota upgrade (this is automatic). Here certificates are required from gas, electricity, and other fuels distributors, and may be traded among them (and also banked). The Italian market has shown some interesting features: the already mentioned oversupply; the fact that most of the actions have been carried out by energy service companies (ESCOs), not distributors or retailers; and a market split, with three different prices, one for each sector (although they are slowly converging).

The French program on white certificates in turn should be analyzed within a larger framework promoting energy efficiency, and as a complement to other instruments. There have been very effective tax credit programs in the deployment of new technologies, and many measures regarding buildings, including energy certification. The white certificate market is not an organized one, as in Italy, and in fact very few agents have gone to the market, preferring ex-ante agreements with subcontractors. So there has been no significant exchange of certificates in practice, although this was the major political lure for getting the program accepted. Companies have taken the certificates as a strategic opportunity, and as a trigger of dynamics of knowledge and capability. One of the most interesting features of the French system is the evolutionary character of the approach. Although the predictability and credibility of these regulatory instruments may be jeopardized when not fixed from the start, it has been argued that they could and even should evolve, while keeping their intended targets. That still provides stability and maintains efficiency.

The following interesting ideas may be extracted from the Italian and French experiences:

- Transaction costs should be minimized, in order to avoid discouraging the participants and to obtain savings. However, this may create some problems regarding accountability and certification of the actual savings.

– These new instruments may promote the creation of new energy service companies (and therefore jobs), and also an increased social conscience on the need to save energy, as has happened in Italy.

– Sometimes, white certificates will be attractive just because they provide flexibility to companies, even if they are not finally used, as is frequently the case in France.

– White certificates may create the contract that is missing from the market, and therefore bridge the information gap. Eventually, this may make it unnecessary to provide economic support to energy efficiency and conservation activities.

– Finally, these instruments may bring about additional benefits regarding information, market transformation and professional dynamics. Companies have taken them as a strategic opportunity, and as a trigger of dynamics of knowledge and capability.

Besides the design of the instruments themselves, it is necessary to integrate them in the overall energy market framework. And the most relevant issue here is the specification of the agent on which to impose the obligation to reduce demand. In principle, it seems that effective energy conservation policies should focus on the consumers, as it happens in Sweden, where the obligation is imposed on them. However, this may not be realistic. Therefore, the real discussion is on whether to assign the obligation to distributors (DSOs) or ESCOs. On the one hand, imposing the obligation on DSOs is easier, because they are regulated and stable firms. However, in practice, ESCOs are readier and more flexible to respond to this business opportunity. Typically, ESCOs will accompany these programs with commercial strategies, without the need to mess up with tariffs and cost-recovery systems. In Italy ESCOs are responsible for 90% of the energy efficiency actions.

3. Renewable energy

The development of renewable energy is currently a priority in most developed countries, but there is much discussion on the extent of its desirable and acceptable penetration, as well as on the specific regulatory instruments to achieve any prescribed objectives. Here the critical component of the regulation is the treatment of new investments. The diversity and different level of maturity of the different technologies has to be recognized, and the regulatory schemes should be capable of promoting a broad technological portfolio. For any given technology, the key issue is how to foster R&D and manufacturing experience so that production and installation costs can be significantly reduced, without spending too much money subsidizing large volumes of investment in technologies that still are too expensive for massive deployment.

The most important factor for the successful development and utilization of renewable energy technologies is the careful design of the corresponding regulatory policies, since most of these technologies cannot compete in present energy markets, where most externalities are not included in energy prices. Particular attention should be devoted to the improvement of the present instruments, mainly regarding the specification of targets, financial incentives, credibility for investors and costs.

Whatever the adopted scheme, the predictability of the regulatory support and the targets to be met are critical to attract the confidence of the investors. Stop-and-go approaches or the use of retroactivity in the application of the norms should be completely avoided. However, some adaptation of the level of financial support to the evolution of the costs of each technology is necessary to avoid incurring in excessive charges to consumers.

The final cost to the energy consumers of the measures to promote renewables has to be maintained within reasonable levels. Efficient schemes seek to reduce this final cost. The lower the implementation costs of any regulatory scheme, the higher will be the public acceptance, and the larger the total amount of deployed renewable energy sources (RES) for a given expenditure. The effectiveness of the regulatory measure is therefore enhanced by any improvements in efficiency.

The complexity and specific features of energy markets are at the origin of some new issues to be unraveled [11]:

(a) Carbon markets seek to internalize the costs of GHG emissions, with the result of increasing energy prices. In some cases, and depending on the specific regulation, this may result in the reception of windfall-profits by the energy suppliers (including those of RES) and extra costs for the end consumers. Whenever the revenues of RES include any regulated financial support and are also linked to energy market prices, the regulated income may need adjustments to compensate for increments in energy prices, in particular those that are related to additional regulatory measures.

(b) Regulated schemes of support to RES should contemplate the large differences in maturity and costs of the available RES technologies. Otherwise the impact on energy prices of some regulatory schemes, such as green certificates, could be disproportionably high. Banding, i.e. placement of individual objectives and instruments for each technology as currently done in feed-in tariffs, would help in alleviating this problem.

(c) Large penetration of subsidized RES will have the effect of reducing the demand that is actually subject to a competitive market, therefore also lowering the resulting energy prices. However, this may also have a dampening effect on future investments, until prices recover an attractive level and the final long-term net impact on prices is not clear.

(d) The rationale for allocation of the extra costs of promotion of RES may be subject to debate. For instance, it is questionable that the subsidies to RES for electricity production should be entirely charged to electricity consumers, when these subsidies are an instrument to meet a commitment of the complete energy system (not only electricity) to achieve a prescribed target of penetration of RES in the energy mix.

After all these considerations, the main issue remains the choosing the most adequate regulatory instrument. The choice will depend on the specific policy objectives: short *versus* long term targets, existence or not of trading systems, broad-scale deployment or not, etc. The most popular contenders are feed-in tariffs (FIT) and tradable green certificates (TGC). Conceptually, tendering seems to be very well adapted to the problem, although previous implementation failures such as the NFFO in the UK have for the most part excluded this method from practical consideration. A careful revision of tendering could be in order.

Many experts agree, see [12] and [13], that, in the real world, well-designed (dynamic) FIT systems have shown to be well suited to provide a significant deployment of RES, fastest and at the lowest costs for society (although in theoretical terms this may not be so). In addition, FIT are not prone to be subject to market power problems, and they can be easily tailored to take into account local benefits of RES -such as employment, rural development or promotion of local industry-, contrary to TGC. The strongest point of FIT is the predictability of revenues for prospective investors and, therefore, the low level of risk in a credible regulatory environment. However, this is not to say that current FIT systems are perfect: there are some difficulties regarding transparency and information, market responsiveness, and flexibility. TGCs, by contrast, are market responsive and flexible. In addition, most problems of TGC are related to implementation, not to the scheme as such. A fraction of the price risk of TGCs is due to the stability of targets, not to the mechanism as such. The use of TGCs, or trading of guarantees of origin (GO), ideally would allow to achieve a multinational commitment of RES penetration at lowest cost, since it results in the utilization of the least expensive resources within the region.

This brings the issue of the regulatory harmonization of promotion schemes of RES at supra national level, which has recently being examined in depth in the EU context (e.g. [14], [15]). On the one hand, integrated electricity markets in Europe would benefit from harmonized support schemes for RES. However, total harmonization could do away with the many benefits that deployment of RES technologies are bringing to national communities, in terms of jobs, rural development or the creation of specialized industries. It seems better that both FIT and TGE could be jointly used, so that FIT could be applied by those countries who prefer to promote any given technology locally –even if they have to incur some extra costs-, while at the same time allowing these and other countries to use TGE to trade either at country level or even at the level of individual agents.

The sheer volume and the dispersed nature of the most popular RES for electricity generation (RES-E), such as wind (both on and off-shore) and solar, are creating new challenges in the utilization and development of electricity grids. Unbundling of the transmission grid and clear connection rules for both transmission and distribution networks are a precondition for large scale RES-E integration. Existing tools, such as network connection charges, priority rules and locational signals in use-of-network charges will have to be refined and adapted to the new circumstances.

A final point to underline, however, is that this discussion has referred mostly to developed countries. A critical issue is how these considerations can be translated and adapted to the specific contexts of developing countries, in order to jumpstart renewable energy development in the larger scale required and therefore to make them contribute significantly to the reduction in global GHG emissions. Investments in clean energy in developing countries may be approached from two different sides: rural electrification, and large-scale deployment of renewable energy sources.

Progress is still low, in general, in rural electrification (RE), since it has not been explicitly considered in most electricity policies in developing countries [16]. The experience with the deployment of renewables for RE (mostly solar PV) has been frequently unsatisfactory: donor-driven agendas, scarce interest in productive use of the supply of electricity or high-failure rate because of inadequate maintenance of the equipment. The panorama may have brightened up recently for technologies such as solar-diesel hybrid systems, because of the combination of increasingly high oil prices, falling solar PV costs and technical improvements in the technology. Rural electrification programs have always needed support schemes, and a specific financial and organization model has to be established to attract private investment, such as: a donation model, a cash sales model, a program model or a fee-for-service model, see [17].

However, rural electrification with renewables will not be a key element for reducing GHG emissions, nor will mitigation be a key driver for rural electrification with renewables. Concerning a future climate regime, the key issue is large-scale, grid-connected renewable deployment in developing countries. And the critical aspects are: the acceptability of new large-hydro developments, which depends very much on the social context; how to export renewable support schemes from developed countries to other countries for large-scale deployment; and how to address the financing and infrastructure barriers, particularly in Africa.

4. Carbon capture and sequestration

There are still many good reasons for considering coal a major part of the energy picture for a long time (at least the next decades). Coal is well distributed in the world, and therefore its supply is more secure than gas and oil (not only more secure, but also less vulnerable). It has competitive costs, and essentially, there is a lot of coal to fuel the large number of power plants to be replaced in the immediate future in the OECD countries, and the large numbers to be newly built elsewhere, notably in China and India.

However, the acceptability of an extensive use of coal must be linked to the carbon capture and sequestration (CCS) technology, see [18]. As such, it might contribute about 20% of the expected carbon emissions reductions. Although there are risks, the alternative cannot be to continue sending large amounts of CO_2 to the atmosphere from non-CCS coal power plants. In fact, NGOs are now more positive towards CCS than before [19], given the scarce number of options to mitigate GHG emissions in the medium term. A growing number of prospective studies coincide on the necessity of CCS, at least as a bridging technology, see [3] for a recent one.

Achieving successful CCS projects will require answering many still open questions: Is the technology already available? What is the economic viability of CCS? Would trial plants deliver learning spillovers justifying additional support? Where best to promote investment? How best to promote it? Who should pay?

Several technical issues concerning CCS have not been solved yet: The significant loss of efficiency of CCS power plants -about 20-40%- has to be mitigated by improvements in coal burning technology. It is not possible to build a CCS-ready plant in isolation, without the corresponding systems of CO_2 transport and storage, the large scale of which is daunting.

CCS is not happening yet, not because of technological barriers, but because of its high cost, which renders it non competitive with existing technologies for electricity generation, and lack of an adequate regulatory framework, as renewable technologies have. Some studies (e.g., [20]) point out that costs should be reduced by 40-50% in order for CCS to become competitive. Or alternatively, a stable carbon price of at least 35€/t CO_2 should be attained. Since neither of these conditions is present right now, some level of public support for installing CCS equipment should be provided, at least transitionally (given that carbon prices are expected to increase if carbon targets are kept stable).

As for CO_2 transport and storage, there is widespread agreement that public support will be required for building the needed infrastructure (pipelines and storage). CO_2 transport has to be a regulated activity, and storage has to be a general interest activity. A national authority should supervise transport and storage, and the long-term liability of storage.

Another regulatory challenge is how to finance the huge investments required. Financial resources have to be mustered and the major available sources must be industrial commitments, direct involvement of individual member states and support at EU level. It has been argued that there will be a very large amount of money available from European carbon emissions allowances (EUA) auctioning, which might be used for CCS. However, there will be also a tough competition to make use of these funds, and many propose that EUA revenues should go first to sustainable sources. In fact, many people also argue that windfall profits from previous phases of ETS could have been used to promote CCS by utilities, so one wonders if the real problem is money, or rather the lack of vision and a meaningful road map.

Here the proposed EU flagship program [21] is essential to pull all possible developers together and ensure a learning process, spread results, and accelerate learning. However, the CCS effort should not be restricted to the EU or the USA. Little will be accomplished if it is not quickly extended to China, India and other large coal consuming countries.

Another major issue to be solved is the selection of adequate locations for storage, which may be complicated by the NIMBY public response. Lessons should be learnt about multiple past mistakes in the nuclear industry (although some argue that the reference should not be nuclear waste, but oil and gas extraction facilities). The public communication strategy should be transparent and timely.

5. Nuclear energy

The beginning of a nuclear renaissance is under way. Some governments have already expressed their desire to promote nuclear plants as a component of their climate strategy, and others are considering this option seriously. An interesting way to look at this renaissance is to follow second-hand nuclear plant prices. These have been increasing recently [22], what shows the increasing interest of investors in this technology. Although this may be mostly explained in terms of the large margin available for nuclear power plants in liberalized electricity markets, there may also be interest in appropriating nuclear sites, which are a major asset for building new power plants, and it also indicates the willingness to bear the risks and responsibilities associated with operating nuclear facilities.

The arguments for nuclear are basically its lower carbon emissions compared with coal, its contribution to security of supply and its possibly competitive cost. The economic argument is a contentious one, since there are several conflicting factors. Both the investment and fuel costs of most technologies, including nuclear, have increased much during the last few years. The recent sharp escalation in oil and gas prices is favourable for the nuclear case as compared to fossil fuel-based technologies. Carbon prices and, therefore, GHG emissions reduction policies will be critical for the eventual development of nuclear.

In turn, the disadvantages are also well known, and they mostly have to do with risk. Besides the long-established ones (accidents, high-level waste, and nuclear proliferation), economic risks have become larger in liberalized markets:

- High costs of capital (high discount rates and rates of return)
- Overrun of construction phase
- Future electricity prices (as for any power technology)
- Changes of safety or environmental regulation during planning and construction
- Political risk and public acceptance problems
- Risk of a low carbon price
- Poor plant reliability in the operational phase (low load factor), although this has been improved strongly recently

In fact, some argue that, although nuclear seems presently more attractive due to climate change concerns, nothing fundamental has changed about these economic risks.
Most of the economic risks apply to new plants, not to existing ones. Thus, one has to distinguish two different issues here, one regarding the extension

of life of existing power plants, or even replacing old plants with new ones at the same sites; and another one regarding increasing nuclear share (and therefore needing new sites, in general).

For developed countries, a relevant discussion concerns the business model on which to build new plants. Are liberalized electricity markets well prepared for a growing share of nuclear power? Can we leave it to the market? Is it any kind of "special regime" necessary? Regarding this latter aspect, it is controversial whether nuclear energy may be broadly deployed without difficulties in liberalised electricity markets, beyond some few particular cases which may be considered as "demonstration plants".

In the UK for example, it is expected that large utilities will be able to assume the risks and start building new nuclear power plants at old sites. The key issues here are siting (not too difficult, if old sites are used); waste; a generic design approval; financing (no merchant plants are envisaged, but rather companies will put the costs in their balance sheets); the global supply chain; the required nuclear skills (which are currently becoming undersupplied); and a stable carbon price.

In any case, what looks unavoidable is the need for a previous social and political consensus, plus some additional regulatory decisions that may reduce the aforementioned economic risks to acceptable levels. This to some extent implies a particular regulatory regime for this technology.

The final question, albeit complicated, is how to extend this model to developing countries, and the implications on the non-economic risks previously mentioned of such a massive deployment. According to the MIT study, "The Future of Nuclear Power" [23] 1,000 new nuclear power plants in the world are required to maintain the current 17% on electricity production share by 2050. From a global security perspective this offers a worrisome outlook under present and future uncertain circumstances, unless very creative solutions are found. A relevant question here is whether it is possible or not to transfer nuclear power technology indiscriminately. For example, the relationship between Western and Eastern EU in terms of technology transfer is still an unsettled issue (although this may be considered a transitional issue). Nuclear technology is not like anything else and global security risks and political issues cannot be ignored.

6. Interaction between carbon policies and technology policies

Carbon and technology policies may interact to a large extent, therefore affecting their outcome regarding emissions and technology development. Innovation in low-carbon energy technologies is the major area of interaction. In principle, high and stable carbon prices should drive the required investments in new clean technologies. In practice, this is not achieved because of low carbon price levels, price volatility and uncertainty, and other distortions. Besides, carbon pricing is a one-size-fits-all kind of support and, therefore, it leaves many technologies behind, since it results in large profit margins for some technologies and large funding gaps for others. In the end, and with the expected carbon prices, only a few companies, with deep pockets and some especial strategic interests, would invest despite the uncertainties, and never in technologies that are far from being profitable. Therefore, a sufficiently high level of carbon prices would be necessary to promote innovation in any potential new clean technology, and these prices will depend on the future climate regime and the corresponding international agreements. In addition, it should be noticed that the power sector, as well as transport or buildings are not among the most innovative industrial sectors.

These are serious limitations to the use of just carbon pricing to drive innovation in energy. As indicated, presently carbon pricing is not expected to deliver long-run technological solutions on its own. Some intermediate support will typically be needed to fill in the gap between basic R&D and carbon pricing. It becomes clear now that we need market engagement programs, strategic deployment policies, and barrier removal and internalization to move technologies through demonstration, pre-commercial and niche market stages. Even with more mature low-carbon technologies, such as on-shore wind to produce electricity, additional support in the form of feed-in tariffs, green certificates or other regulatory instruments is needed to achieve a massive deployment.

And, still, carbon pricing has a vital role to play. In such an uncertain energy environment, with very demanding targets and multiple choices to be made, it is of essence to strategically direct investment towards low-carbon rather than high-carbon technologies. Carbon prices may scare investment away from carbon-intensive paths. Carbon pricing is thus, in spite of all its shortcomings, centrally important for technology development. Besides, economic rents from carbon markets might be used to fund innovation efforts in new clean technologies. The economic resources will be available and also the political pressure to show that these revenues are committed to a good cause.

A good example of the role of carbon pricing, and of its interactions with technology policies, is the recent EU Green Package [24], where three different but interrelated objectives are addressed: carbon emission reduction, renewable energy development, and energy efficiency improvements. When dealt with separately, the marginal cost of each one of these three policies is not the same. Therefore, addressing the three of them simultaneously should profit from some synergies. Although not enough to provide "3 for the price of 2", the point is that both renewable energy and energy efficiency objectives contribute to reducing carbon emissions. In addition, the expected increase in electricity prices (25% for 2020-30 compared to the baseline, according to the background studies carried out by the European Commission), which is partly due to the price of carbon, will also help meeting some of the renewables and efficiency targets.

7. Summary and conclusions

The impacts of climate change are stronger and they are arriving sooner than anticipated. Carbon reductions will have to be more drastic than previously thought. A massive deployment of low-carbon technologies is then absolutely needed to achieve the expected reductions in GHG emissions during the next fifty years. Some of these technologies are already available, although they must be implemented at a large scale. And others must still be developed.

Support schemes for each low-carbon technology must therefore be designed accounting for these differences. When designing the strategy to be followed in any given country it must be remembered that cases of overreaction concerning environmental matters have very rarely been reported, and that we cannot respond to a crisis by using the same logic and the instruments that created it. A drastic change in mentality is thus also needed.

Carbon prices, while consistent with the GHG emission targets that nowadays are considered to be politically acceptable, will not suffice to promote the required deployment of low-carbon technologies. However, carbon prices should not be abandoned, since, for the time being, they will scare investors away from carbon-intensive prospective energy futures. Also, carbon prices, via their impact in energy prices, will help in changing patterns of energy consumption, which might prove even more difficult than developing new technologies. And with time it is expected that they will be finally able to bring technological change.

An initial avenue to meet the double objective of technological development and behavioural change is to concentrate the efforts on energy efficiency and conservation actions. Energy efficiency and conservation should be the major instrument for climate change mitigation, in developed and also especially in developing countries, for the next two decades at least. In developed countries furthermore, a specific regulatory approach, white certificates, in combination with other instruments, has shown effectiveness in generating new dynamics in firms, creating new services and jobs, and making transparent previously hidden economic savings.

Renewable energy should be promoted with more efficient instruments, since the cost reduction for the consumer will contribute positively to its larger deployment. To this extent, it is generally agreed that feed-in-tariffs have been so far, in practice, the most effective instrument, although it should be improved further. Other approaches such as green certificates or tendering schemes are promising, if lessons are learnt from past implementation mistakes. In addition to economic support, appropriate grid connection procedures and advanced schemes of system operation and demand response will be needed to minimize the barriers to substantial deployment of renewable intermittent and/or dispersed technologies for electricity generation. Biomass has the potential to make a significant contribution to the total renewable effort, but this will require no less than major changes in agricultural policy and the creation of a new industry.

Both energy efficiency and renewable energy are not only low-carbon, but sustainable technologies. Despite any strong efforts in their massive deployment, they may not suffice to achieve the demanding targets of GHG emission reduction, and other major low-carbon technologies, notably carbon capture and sequestration and nuclear, will very likely be needed.

Carbon capture and sequestration seems close to solving most of its technological problems. However, it is still too costly to compete with more traditional electricity generation options at current carbon prices. Putting together the financing is therefore a complex issue, and setting up joint demonstration programs with public support seems the right thing to do. Once the technology is available, it will be indispensable to extend it to all major coal users, also including developing countries such as China or India. Appropriate regulatory schemes will have to be developed for CO_2 transport and storage activities.

For nuclear energy to develop again in a volume that can provide a meaningful contribution to GHG emissions reduction, a very large number of plants would have to be installed worldwide. This will require a previous social and political consensus to reduce regulatory and economic risks to reasonable levels, plus the open question on how to extend this model to developing countries and the implications on the non economic risks of the quasi universal extension of the access to nuclear technologies.

While respecting the functioning of energy markets and the initiative and innovation typically associated to private entrepreneurship, it will be necessary for national governments, as well as supranational entities like the EU, to set mandatory targets regarding renewable penetration, efficiency improvements, technical standards or migration to cleaner technologies – such as CCS-. At the same time carbon markets, as widespread as possible, will introduce carbon prices that should increasingly create a more level playing field for low-carbon technologies versus conventional ones. In any case the goal is to provide a stable and attractive environment for private investment to take place.

For an effective reduction of global GHG emissions to be achieved, it is indispensable that this approach be extended to developing countries, since they will cause most of the estimated future emissions growth. But the large potential of developing countries to reduce GHG emissions will be only realized with a decided financial and technological support from developed countries. This is probably the key to the expected new global climate agreement and therefore to the future evolution of GHG emissions.

8. References

[1] IPCC, Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)], IPCC, Geneva, Switzerland, 2007.

[2] R..Pielke, T. Wigley, C. Green, Dangerous assumptions, Nature 452, 531-532, 2008.

[3] IEA Energy Technology Perspectives 2008 -- *Scenarios and Strategies to 2050,* OECD/IEA, Paris, 2008.

[4] C. Fischer, R.G. Newell, Environmental and technology policies for climate mitigation, Journal of Environmental Economics and Management, 55, 142–162, 2008.

[5] C. Fischer, C. Egenhofer, The Critical Role of Technology for International Climate Change Policy, ECP Background paper, Centre for European Policy Studies, 2007.

[6] H.C. De Coninck, C. Fischer, R. Newell, T. Ueno, International technology-oriented agreements to address climate change, Energy Policy 36: 335-356, 2008.

[7] European Commission, Doing more with less. Green paper on energy efficiency, Luxembourg: Office for Official Publications of the European Communities, 2005.

[8] G.E. Metcalf, Economics and rational conservation policy, Energy Policy 22: 819-825, 1994.

[9] A.B. Jaffe, R.G. Newell, R.N. Stavins, Economics of energy efficiency, Encyclopedia of Energy 2: 79-90, 2004.

[10] P.H.G. Berkhout, J.C. Muskens, J.W. Velthuijsen, Defining the rebound effect, Energy Policy 28: 425-432, 2000.

[11] P. Linares, F.J. Santos, M. Ventosa, Coordination of carbon reduction and renewable energy support policies, Climate Policy, forthcoming.

[12] P. Menanteau, D. Finon, M-L. Lamy, Prices versus quantities: choosing policies for promoting the development of renewable energy, Energy Policy 31: 799–812, 2003.

[13] European Commission, The support of electricity from renewable energy sources, SEC(2008) 57, Brussels 23.01.2008.

[14] M. Muñoz, V. Oschmann, J. D. Tábara, Harmonization of renewable electricity feed-in laws in the European Union, Energy Policy 35: 3104–3114, 2007.

[15] P. del Río, A European-wide harmonised tradable green certificate scheme for renewable electricity: is it really so beneficial?, Energy Policy 33: 1239–1250, 2005.

[16] GNESC (Global Network on Energy for Sustainable Development, within UNEP), Energy Access theme results. Synthesis / Compilation Report, April 2004.

[17] Nygaard, I. Compatibility of rural electrification and promotion of low-carbon technologies in development countries - the case of Solar PV for Sub-Saharan Africa. European Review of Energy Markets, this issue.

[18] Massachusetts Institute of Technology, The Future of Coal. Options for a carbon-constrained world, 2007. http://web.mit.edu/coal/

[19]. CCS - an uncomfortable but necessary option. Presentation by Dr. Stephan Singer. WWF International - European Policy Office. Brussels 8 May 2007.

[20] P. Capros, L. Mantzos, V. Papandreou, N. Tasios, A. Mantzaras, Energy systems analysis of CCS technology. PRIMES model scenarios, ICCS, NTUA, Athens, 2007.

[21] European Commission, Supporting Early Demonstration of Sustainable Power Generation from Fossil Fuels, COM(2008) 13 final, Brussels, 23.1.2008.

[22] World Nuclear Association, The New Economics of Nuclear Power, (December 2005) available at: http://www.world-nuclear.org/reference/pdf/economics.pdf - accessed April 2008.

[23] Massachusetts Institute of Technology, The Future of Nuclear Power, 2003. http://web.mit.edu/nuclearpower/

[24] European Comission, 20 20 by 2020. Europe's climate change opportunity, COM(2008) 30 final, Brussels, 23.1.2008.