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Regulatory Instruments for Deployment of Clean Energy Technologies

by
Ignacio J. Pérez-Arriaga

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Ignacio J. Pérez-Arriaga, Royal Academy of Engineering of Spain[1]

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Abstract

Answering to the formidable challenge of climate change calls for 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. Specific promotion policies for energy efficiency and conservation, renewable energy, carbon capture and sequestration, and nuclear power are examined, but the focus is on the regulatory instruments that will be needed for the deployment of enhancements to electricity grids and the associated control systems so that they are able to integrate intelligent demand response, distributed generation and storage in an efficient, reliable & environmentally responsible manner. The paper also comments on the interactions between technology and climate change policies and provides recommendations for policy makers.

[1] Member of the Spanish Royal Academy of Engineering, professor and Director of the BP Chair on Sustainable Development at Comillas University, Madrid, Spain. Presently visiting professor at MIT, Center for Energy and Environmental Policy Research (CEEPR), Boston, US.

1. Introduction

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 greenhouse gas (GHG) emissions is needed to stabilize the concentration of GHG at levels with estimated tolerable implications. There is an increasing agreement 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. More recent results lie on the pessimistic side of the range from previous predictions, see [2].

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 [3] 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 for the most part, and therefore the signal provided by the current carbon prices for reducing emissions is 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 IEA Energy Technology Perspectives report [4] 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[2], see also [5] and [6].

In the context of a global climate regime, 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's 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.

1.1. Interaction between carbon policies and technology policies

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[2] The first part of this paper draws a significant amount of material from the paper "Promoting investment in low-carbon energy technologies" by P. Linares and I.J. Pérez-Arriaga, in vol. 8, fall 2009, of the European Review of Energy Markets (EREM). This entire issue of EREM "Incentives for a low carbon energy future" is relevant for the topic being discussed in this paper.

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.

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 by itself. Some intermediate support will typically be needed to fill in the gap between basic R&D and carbon pricing. It becomes clear now that there will be a need for 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.

2. A review of regulatory approaches for different applications

2.1. 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]. 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 the relevant discussion should not be on the choice of 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, in addition to economic incentives, companies may need that marketing tools are facilitated and encouraged by regulation.

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. 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.

2.2. 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 main remaining issue is the choice of the most adequate regulatory instrument. This 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 [11] and [12], 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 the targets, not to the mechanism itself. The use of TGCs, or trading of guarantees of origin (GO), ideally would allow achieve a multinational commitment of RES penetration at lowest cost, since it results in the utilization of the least expensive resources within the region.

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 [13]. 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 [14].

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.

2.3. 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 [15]. 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. A growing number of prospective studies coincide on the necessity of CCS, at least as a bridging technology.

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?

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., [16]) 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.

2.4. Nuclear energy

The beginning of a nuclear renaissance might be 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 [17], what shows the growing 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. An escalation in oil and gas prices is favorable for the nuclear case. 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. 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 any kind of "special regime" necessary? Regarding this latter aspect, it is controversial whether nuclear energy may be broadly deployed without difficulties in liberalized electricity markets, beyond some few particular cases that may be considered as "demonstration plants".

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" [18] about 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. Nuclear technology is not like anything else and global security risks and political issues cannot be ignored.

3. The case of the "smart grids"

The case of the eventual regulatory support for the development of "smart grids" has not been subject yet to a comprehensive analysis. The remainder of this paper will be devoted to an examination of the major issues involved.

3.1. Definition and objectives

The purpose now is to examine how regulation could help to enhance the contribution of the electric grid to meeting the energy needs in an efficient, reliable and environmentally responsible manner. The term "smart grid" has been coined to name these advanced electricity networks, although a precise definition does not, and probably cannot, exist. Here, two quite long, but sort of official definitions will be provided.

The Smart Grid platform of the EU, http://www.smartgrids.eu/, defines a smart grid as *"an electricity network that can intelligently integrate the actions of all users connected to it –generators, consumers and those that do both– in order to* *efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:*

- *better facilitate the connection and operation of generators of all sizes and technologies;*
- *allow consumers to play a part in optimizing the operation of the system;*
- *provide consumers with greater information and choice of supply;*
- *significantly reduce the environmental impact of the whole electricity supply system;*
- *deliver enhanced levels of reliability and security of supply.*

Smart grids deployment must include not only technology, market and commercial considerations, environmental impact, regulatory framework, standardization usage, ICT (information & Communication Technologies) and migration strategy but also societal requirements and governmental edicts."

The US Energy Independence and Security Act of 2007 in its section 1301 states: *"It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a smart grid:*

- *Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.*
- *Dynamic optimization of grid operations and resources, with full cyber-security.*
- *Deployment and integration of distributed resources and generation, including renewable resources.*

- *Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.*
- *Deployment of `smart' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.*
- *Integration of `smart' appliances and consumer devices.*
- *Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.*
- *Provision to consumers of timely information and control options.*
- *Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.*
- *Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services."*

A multiplicity of benefits are expected from smart grids, see [19]:

- Significant reductions in residential peak demand energy consumption achieved by providing real-time price and environmental signals in conjunction with advanced in-home technologies.
- Potential carbon footprint reduction as a result of lowered residential peak demand and energy consumption, improved distribution losses and increased conservation options.

- Possible reductions in the number of customer minutes out as a result of improved abilities to predict and/or prevent potential outages, and more effective responses to outages and restoration.

- Expected deferral of capital spent for distribution and transmission projects based on improved load estimates and reduction in peak load from enhanced demand management.

- Potential utility cost savings from remote and automated disconnects/ reconnects, elimination of unneeded field trips and reduced customer outage and high-bill calls through home automation.

3.2. The impact of regulation

Although smart grids appear to be involved in a multiplicity of power system issues, this paper will focus on the impact of regulation on three major topics: i) deployment and integration of distributed generation resources; ii) development and incorporation of demand response, demand-side resources and energy-efficiency and conservation resources; and iii) enhancement of transmission grids, to allow reliable and efficient integration of significant levels of development of renewable generation resources, as well as efficient wholesale trade.

3.2.1. Distributed generation (DG)

Contrary to transmission, distribution networks originally have not been designed to accommodate generation, but now they have to be adapted to allow massive deployment of DG at different voltage levels, mostly wind, solar and cogeneration. Under passive network management, DG penetration generally results in additional costs of network investment and losses, an effect that increases with penetration levels, see [20]. The regulation of distribution networks faces here a double challenge. On one hand, the current remuneration schemes for distribution are mostly based on some sort of proportionality with the volume of distributed energy; therefore, while the costs of the distribution utility rise with the penetration of DG, its revenues fall. The second challenge lies in the lack of incentives for distribution utilities to invest in novel technologies, such as smart grids. R&D in the utility industry has long been hindered by the need for proven prudent investments. As a result, far reaching R&D happens infrequently.

An adequate regulatory response to facilitate the deployment of DG, while creating incentives for distribution utilities to cooperate, must consist of two basic dimensions. On one hand, correct economic signals to facilitate DG integration, or at least to remove any existing barriers. Measures to this purpose should include: a) regulated connection charges to avoid bargaining and discrimination; b) use of cost-reflective use-of-system network charges, with differentiation by location and time-of-use, to recover the distribution network costs (this might make sense only for larger DG facilities connected at medium and high distribution voltages); c) incentives for DG to provide ancillary and/or network services, via commercial arrangements with the System Operator.

On the other hand, and this is the most critical part, it is needed a revised regulation of the distribution activity, which should include: a) unbundling of distribution from generation and retailing to avoid incentives for discrimination; b) incentive-based regulation aimed at reducing network losses and improving quality of service, but now accounting for sizeable volumes of DG penetration; c) additional revenue drivers to compensate Distribution System Operators (DSOs) for the incremental costs due to DG penetration; d) specific incentives for innovation to achieve the needed transformation to active network management.

Upgrading the remuneration schemes of distribution to account for high levels of DG penetration is not an easy task. A computing tool that will probably prove indispensable in the new times is a network reference model (NRM), see [21] for instance. A NRM is a network that minimizes the total cost of investment, operation and maintenance costs and network energy losses, while meeting prescribed continuity of supply targets (or explicitly including the cost of non supplied energy) in the different supply areas (e.g. urban, suburban, concentrated rural, dispersed rural). NRMs may be used as an aide or benchmark, with any required adjustments, when determining the extra costs or benefits resulting from DG penetration or when designing incentive schemes for losses or quality of service. Among the European electricity regulators, OFGEM in the UK has already introduced additional revenue drivers in the existing RPI-X remuneration scheme to compensate DSOs for incremental costs due to DG penetration and for promotion of innovation towards active network management control. In the US, FERC has made the following statements (still to be followed by actions), see [22]: *"The Commission also proposes that smart grid investments that demonstrate system security and compliance with Commission-approved Reliability Standards, the ability to be upgraded, and other specified criteria will be eligible for timely rate recovery and other rate treatments (…) In other words, we propose to consider Smart Grid devices and equipment, including those used in a Smart Grid pilot program or demonstration project, to be used and useful for purposes of cost recovery if an applicant makes the certain showings, as described below (…) The Commission also proposes to permit applicants to file for recovery of the otherwise stranded costs of legacy systems that are to be replaced by smart grid equipment."*

3.2.2. <u>Demand response</u>

As with DG, technologies & economic signals resulting in energy conservation & efficiency (ECE) improvements from the consumers' side typically lead to reductions in the regulated revenue of distributors & uncompensated demand destruction for retailers. Also, as with DG penetration, these measures may not be welcomed by distributors & retailers, unless the efficiency gains are shared with distributors & retailers, the remuneration of the distribution activity is more precisely computed & made less dependent on the simplistic "distributed energy" metric.

Separate regulatory instruments have to be designed for DSOs, retailers (if unbundled from distributors, as in the EU), Energy Service Companies (ESCOs) & consumers.

Consumers need specific economic signals to promote their active integration: a) advanced meters and advanced pricing schemes (real time prices, preferably); b) advanced technologies to receive information and to facilitate demand response (e.g. to high or low prices, storage control, emergency switching) and consumer choice; c) web-enabled devices that provide the flexibility that is key to facilitate switching of retailers & to benefit from competition and innovation; and d) also with direct controls from distribution utility, which can be necessary under emergency situations.

The regulation of the distribution utility has to be revised to include: a) unbundling from generation and retailing to avoid incentives for discrimination; b) ad hoc schemes to share the benefits of increased efficiency (e.g. in network losses) with consumers; c) transparent rules (regarding sharing information or commercial strategies to win consumers) to facilitate the activity of competing retailers and ESCOs; d) more precise remuneration schemes for the distribution activity to allow an effective decoupling; e) (as with DG) specific incentives for innovation to introduce advanced technologies for consumer active participation.

The regulation of the activity of retailers (if unbundled from distribution) and energy service providers has to be revised also. Note, first, that non utility affiliated ESCOs are the natural agents to promote & perform energy efficiency and conservation activities, since they do not have any negative incentives in reducing electricity consumption, they are specialized in implementing these measures and they could become independent retailers (and conversely) using energy conservation and efficiency (ECE) as a competitive advantage. Note that "Revenue decoupled" distributors/retailers would also be interested in participating in ECE activities as any other retailer. Any regulation of the metering and retailing activity must be careful about maintaining flexibility in retailer/ESCO switching and accepting competing offers, by avoiding lock-in with hardware that later will be cumbersome and costly to upgrade.

There are other regulatory ideas worth exploring. Retailing/ESCOs activities might be integrated with distribution network management in applications such as charging multiple plug-in hybrid electric vehicles (PHEVs) in the same distribution feeder to maximize economic efficiency while meeting distribution security constraints. Or, for vertically integrated electric utilities, the design of incentive schemes that make use of the surplus of cost-effective ECE measures to achieve win-win situations for consumers & retailers/ESCOs, by improving the definition of baselines or benchmarking schemes to evaluate the performance of efficiency measures.

3.2.3. Transmission expansion and upgrade

In large interconnected power systems, like the Internal Electricity Market of the EU, despite the large dimension and open transmission access, presently there are no massive transfers of electricity, because of several reasons: a) some interconnections are weak; b) typically there are no major surpluses or deficits in the different regions and c) the generation technologies at the margin are frequently similar. However, this situation will most likely change with massive deployment of renewables and, moreover, because of their intermittent characteristics.

The existing network, both in the US and EU, is not well prepared to face this new challenge. In both cases it lacks adequate interconnection capacity among regions, a comprehensive approach to coordinated transmission expansion and the institutional capability for an effective implementation. There are several directions for improvement: a) much can still be done with state-of-the-art and new technologies to enhance the capability of the existing network; and b) present system operation is not adequate to deal with really large volumes of intermittent generation, integration of demand response and seamless coordinated congestion network management at EU or US-wide level. What is new in transmission is that the actual challenge comes from the regulation itself. This is what Paul Joskow says about the US transmission regulation, see [23]: *"We need to stop dealing with* *the electric power sector by placing band aids on the Federal Power Act of 1935. We need a comprehensive national policy for the electric power sector –a Federal Power Act of 2009– to replace the Federal Power Act of 1935. A policy that respects legitimate state rights but also reflects the contemporary attributes of electricity generation, transmission and distribution technologies, opportunities for innovation, and the public policy demands that are or will be placed on the electric power sector."* An equivalent statement could be made about the lack of a European approach to transmission expansion, leaving it to a patchwork of national regulations.

What is needed is a regulation of the transmission activity that includes all of the following features:

- A comprehensive and expert analysis of the future needs for transmission expansion that is consistent with an efficient implementation of the established policy targets, considers the global picture (the complete North America, EU-27, the Mediterranean Ring, etc.) in economic & reliability terms while respecting local policies & objectives (States in US, Member States in EU) in renewables or efficiency, considers the viewpoints of the diverse stakeholders, minimizes environmental footprint, makes use of state-of-the-art technology and promotes innovation, and pays attention to all security dimensions, including cybersecurity.

- Regulatory oversight and clear definition of the executive powers to implement the transmission expansion plan, with siting authority for transmission assets included in the plan, adequate (low risk, predictable, preferably assigned initially with market instruments) remuneration, avoiding to introduce unnecessary risks and a transparent scheme of allocation of transmission costs that is fair and efficient.

- An advanced approach to system operation that properly addresses intermittency with state-of-the-art technology, integrating demand response and storage.

- Cross-regional (federal US, EU-wide) decision making procedures on transmission planning, reliability, pricing and siting that rely on a platform of large ISO/RTOs (US) or TSOs (EU) covering the territory and who jointly prepare the expansion plans, that are authorized at cross-regional level (by FERC in the US or the new agency ACER in the EU) considering contributions from stakeholders and local goals, and with a clear allocation of responsibilities for planning, authorizing, siting & pricing.

- Adequate remuneration procedures that account for the large number of medium size projects that are required to improve, reinforce, monitor, control or enhance the capacity of the transmission network, as well as risky innovation pilot projects.

- Adequate regulatory instruments addressed to the network users (generation & demand), so that they provide effective open transmission access to the entire network with a single local transmission charge, cost reflective locational signals (energy price & transmission charge) and US or EU-wide seamless coordinated congestion management schemes.

Recent regulatory developments, both in the EU (coordination measures in the “third regulatory package” and the creation of the European energy regulatory agency ACER) and in the US (several proposed energy bills that ask for reinforcement of the powers of FERC over planning, permitting, siting and construction decisions of transmission facilities) seem to advance in the right direction, although probably not as much as necessary.

4. 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. 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.

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.

A successful development of the multitude of network enhancements using state-of-the-art technologies that are included under the broad term of “smart grid” requires the application of sound principles of economics and regulation: a) recognize the specific physical and economic characteristics of networks (mostly natural monopolies) and the potentially competitive associated activities (retailing, metering, energy services, DG); b) find adequate remuneration schemes, always maintaining economic incentives for well justified investments; c) refine the models of remuneration of distribution networks, so that the extra costs/benefits of accommodating DG & efficiency measures are recognized and negative incentives are minimized; d) find instruments to incorporate deployment of effective innovative technologies in the remuneration schemes ; e) transmission capacity expansion must be based on comprehensive planning studies and responsibilities for implementation should be clearly assigned; f) pricing and remuneration of transmission should be transparent, low risk and convey efficient locational signals; g) shortcuts and ad hoc rules that do not respect sound economic & regulatory principles will not do the job.

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