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From Current Power Markets to Hybrid Markets.

Adapting Market Design to Long Term Policy Objectives

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Abstract

Most electricity markets around the globe are 'hybrids' with a mix of varied forms of regulatory intervention and/or a significant role for the state in planning and capacity procurement. Recently, a revival of policy interventionism in electricity markets has raised questions about the ways in which market design needs to adapt to supplement markets with a number of additional mechanisms. This paper takes an institutional perspective and reviews the standard historical approach toward competitive markets. We explore the market imperfections and argue that a number of additional modules are required, which, in turn, destabilize the initial modules of the market design.. We then review international experience with hybrid market design and draw a number of policy recommendations on best practices, as well as on how to articulate the market elements with the additional modules driven by policy interventions.

Résumé

La plupart des marchés de l'électricité à travers le monde sont en fait des «hybrides de marché" articulant des marchés organisés avec des formes variées d'intervention réglementaire et un rôle important de l'État en matière de planification et d'organisation des investissments. Le regain de politiques publiques dans le secteur de l'électricité à des fins de sécurité de long terme et de décarbonisation soulèvent des questions sur la façon dont le "market design" a besoin d'être repensée en complétant les marchés par des mécanismes supplémentaires reposant sur des arrangements de long terme. Ce papier développe une perspective institutionnaliste sur la dynamique des insitutions sous-jacentes aux marchés électriques concurrentiels à partir d'une approche en termes de modules de market design. Nous observons que pour faire face aux imperfections de marché, un certain nombre de modules supplémentaires sont nécessaires, ce qui, à son tour, déstabilise les modules initiaux du "market desing".. Nous examinons ensuite l'expérience internationale d'hybridation des marchés pour tirer des recommandations politiques sur les meilleures pratiques, ainsi que sur la façon efficiente d'articuler les éléments du marché avec les modules supplémentaires relevant des politiques publiques visant le long terme.

1. Introduction

The main reasons for public intervention in power markets revolve around three drivers which recently intensified in many countries : i) determination of part of the generation mix through support for the clean technologies, in particular those based on renewable energy sources (RES); ii) the need to overcome the market failures that undermine investment in sufficient generation capacity to maintain security of supply; iii) system planning to optimize transmission and generation development.

These drivers of policy intervention resonate in the OECD countries within a context characterized by a revival of government interventions to guarantee security of supply though the introduction of capacity mechanisms, the priority given to decarbonisation by the support of clean technologies - decentralised RES as well as centralised low carbon technologies LCTs (large off shore wind, new nuclear, clean coal CCS, etc.) -, and the growing challenges of network planning in the context of variable RES generation development.

However, this revival of policy interventionism in electricity markets needs to be reconciled with the standard historical approach towards competitive markets. Twenty-five years after the start of reforms, a number of electricity markets around the globe are 'hybridised' with various forms of regulatory intervention and/or a significant role for the state in planning and capacity procurement. We are moving on an institutional path towards a hybrid regime combining planning and long-term arrangements on one side, and current energy markets on the other.

These policy and regulatory interventions can have a significant impact on electricity markets and undermine the ability of prices to provide adequate short term and long term coordination signals to market participants. This can create fundamental inconsistencies with the current market, and a number of misalignments in different parts of the market design: merit order effects on the power exchanges, limits on system balancing constrained by the rigidity of existing resources, poor market valuation of the flexibility resources which are increasingly needed, limits on transmission access rules without locational signal, etc.

This paper analyses the dynamics of change in the market regime and investigates the issues associated with such 'hybrid market models' that mix a role for the market with strong public governance. Our purpose is both:

1. to develop a dynamic approach in terms of permanent adaptation of the market design and regulation to correct the market failures by the introduction of new sets of rules in the general market design and then to correct the inconsistencies between the ancient and new elements of the market design,
2. to combine this analysis with case studies of different combinations of coordination by market and by planning, and to identify the inconsistencies introduced by the new modules introduced in the market design.

The paper begins in section 2 by a conceptualization of market design in terms of modules which are blocks of operational and transactional rules, and their dynamics across the identification of the drivers, namely market failures in the current markets in a first stage and later the inconsistencies between the initial modules and the new ones. Section 3 concentrates on the need for modules providing long term signals which leads to a new hybrid market regime, namely : Long Term Contracts module, Capacity Market module and RES-Decarbonisation module. This leads in section 4 to draw lessons from the international experiences featuring these modules providing "long term signals" on the efficient designs for the articulation of planning and market coordination principles. Section 5 concerns the inconsistencies between these new « long term » modules and the initial modules and the permanent adjustments which are needed since the market regime has been crucially altered by the intrusion of these "long term" modules.

1. Institutional dynamics of power market designs

We adopt a neo-institutional economics (NEI) perspective which allows us to extend the economic approach by focusing on economic rules and legal norms that underlie economic activity. As suggested by the different streams of the NEI (Williamson, 1996 ; North 1990), the major drivers of institutional dynamics in the power industry are: the inability to invest in specific equipment (assets) due to market failure, innovations which reduce some asset specificities (Information technologies, low upfront cost technologies such as CCGT, etc.), and new political ideas leading to new regulations (Hall, 1993) such as environmental regulation or renewables promotion policy.

If we consider reform of a formerly vertical industry which is motivated by improving its economic and environmental efficiency through industrial organisation changes, it is convenient to consider the reform as the installation of a set of different functional and institutional modules along the value chain. Glachant and Perez (2010), inspired by Baldwin and Clark (2000) on the design of industrial organisation in terms of modularity, develop such an approach for the electricity industry by differentiating the elements with competitive potential and those with permanent monopolistic characteristics after the disruptive unbundling of the electricity chain decided by the reforms.

Each module is composed of a set of concepts, parameters, tasks and rules which are consistent and interdependent . But, while Baldwin and Clark underline that the modules should ideally be independent of each other, Glachant and Perez (2010) argue that in the electricity industry, such independence is not relevant or feasible because of its technical and regulatory complexities and numerous externalities.

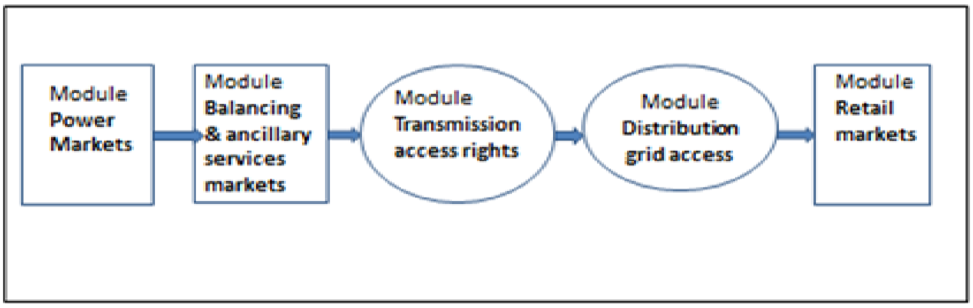

Figure 1. Chain of modules of the initial industrial organisation of unbundled electricity sector

The liberalised electricity industry is characterised by a set of modules of physical and commercial transactions: a module of energy markets (forward, day ahead, intraday) which organises short-term commercial coordination, a module of real time (balancing) and ancillary services for the system balancing by the system operator, the module of transmission rights based on regulatory access rules, and downstream, a module of distribution grid access, and a retail supply module. The entire chain of unbundled modules requires a comprehensive governance structure, under the scrutiny of new sectoral regulators.

Since the reforms, the global architecture has continued to evolve, at the beginning as a result of the learnings, and later as an answer to market failures, particularly in terms of investment orientation. Indeed, experience shows that the implementation of reforms has followed very various institutional trajectories and trial and error processes with experiments on the different elements of the market designs (see for instance, Newbery, 2002; Jamasb, Pollitt, 2005; Joskow, 2008; Pollitt, 2008, Correlje, De Vries, 2008; Borenstein, Bushnell, 2015).

Interdependencies between modules imply that the introduction of a new module generally has unexpected effects on the existing modules which in consequence have to be fixed. More importantly, interdependency also means that we need to make modules consistent between themselves[1]. A new module could be inconsistent with the functioning of another module, which could lead not only to adjustments of the latter, but also to the introduction of a new module to correct some of the unexpected effects.

A typical exemple of the effects of inconsistencies between old and new modules that is developed further is the effect of the "RES support" module on the other modules: here and there it has created important discrepancies and disalignements in the power exchange module, the system balancing one, the transmission access one and a de-optimisation of the technology mix in the matter of conventional plants for capacity adequacy.

2. The need to complete the market design with modules providing long term signals and hedging

In theory, the electricity market has two coordination functions. First, in the short-term it ensures the efficient operation of the total fleet of plants. Second, it indicates scarcity of capacity in different technologies via price signals that orient investors' long-term decisions. There is, in theory, total consistency between short- and long-term market coordination when there is pure competition, perfect information and no risk aversion.[2] The optimal technology mix that results from the investment decisions of market players would be quasi-identical to the long-term optimum of a benevolent social planner which would minimize long-term costs, apart from some differences coming from the cost of risk management and the inclusion of option values in decision criteria.

However, in practice electricity markets are incomplete and suffer from a number of imperfections, which have led policy makers and regulators to implement various reforms and additional mechanisms. In particular, decentralized electricity markets seem to have worked well to drive competition in the short-term, but their ability to deliver investment incentives that will lead to a socially optimum generation mix remains uncertain. In addition, policies to support renewables have had significant effects on electricity markets in Europe.

It is useful to use our institutional Framework to analyse the missing market modules that could be introduced to correct these issues. In the next paragraphs we introduce three such modules.

- **The Long Term Contracts module to support investment**

The restructuring of the electricity markets was based on the idea (implied in Joskow, Schmalensee, 1983) that if generators are not able to carry investment risks, vertical integration could be replaced by bilateral contracts between generators and retailers or large consumers,

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[2] Theoretical microeconomic analysis of power systems shows that, under a number of very strong conditions, the short-term price resulting from a competitive market provides efficient outcomes both in the short and long run, see Bohn et al. (1984), Caramanis et al. (1987), Vazquez et al. (2003). In this way, infra-marginal energy revenues provide the necessary income for the recovery of both operational and investment costs.

with the assistance of multilateral markets for spot trading and financial markets for hedging arrangements. This supposes also completeness of markets, including financial hedging products of long maturity. (See for instance IEA, 2007). H.P. Chao, S. Oren and R. Wilson (2008) showed that restructuring based on unbundling of activities and market exchanges are deficient in this respect and that a balanced mixture of vertical integration (long term arrangements) and liberalized markets is superior to the two extremes, with an energy-only market on one hand and vertically integrated utility monopoly on the other hand.

The problems come from the fact that the interests of generators who invest in new equipment and buyers are not aligned regarding the duration of contracts and the potential quantities involved (Chao et al, 2008; Finon, 2011). In particular retailers are hesitant to sign long-term contracts for a fixed quantity at a fixed price when their customers can just switch to an alternative provider in case of reversal of market price trend. Conversely, generators who prefer such long-term contracts cannot find credible counterparts among large consumers or suppliers (Green, 2004, 2006).

On another side, there is no financial market for long term hedging products (Gross et al., 2010). At the end of the day, producers are deeply incited to invest only in the CCGT plants with low capital expenditures, as shown by approaches in terms of the mean-variance portfolio theory (Roques et al. 2006; Roques, 2011). To overcome the obstacles to establishing risk-sharing contracts, credible counterparts should be envisaged, in particular public agencies with a protected budget financed by a specific levy, who can take on price and volumerisks , or retailers who have legally kept their service area monopoly, with the exception of a few very large consumers (Finon, 2011; Finon and Roques, 2013).

The module of “long term contracts” is a combination of programming procedures and market oriented selection of contracts with many variants. The international experience with this element of market design is analysed below.

- **The Capacity Mechanism module**

A particular problem is how to ensure that short term scarcity situations during peak load periods are reflected in wholesale prices and converted to long term signals for investment, according to the peak load pricing theory (Boîteux, 1949, Joskow, 1976). In particular peaking units which are needed for long term reliability are very capital intensive because their fixed cost can only be recovered from scarcity rents during a small number of hours in extreme peaks and other exceptional situations.

However, the growing evidence suggests that the current market cannot guarantee supply reliability in every situation in the long term for five different reasons: first a regulatory imperfection which is the price cap resulting from the political unacceptability of very high power prices, which leads to a chronic shortage of revenue for plant operators (the so-called “missing money” issue as referred to in the academic literature), second the risk aversion to investing on the basis of very uncertain revenues from scarcity rents, third the incentive of the generators to maintain a relative scarcity situation by tacit collusion, fourth the difficulty of hedging or transferring risk on a long term basis, and finally a range of administrative procedures (e.g. preventively calling reserves) (Cramton, Stoft, 2006; DE Vries, 2007; Joskow, 2008b; Keppler, 2016) .

In fact at the origin of the problem lies a market imperfection which is the absence of price-reactive demand. This calls into question the rationale of relying on market forces to determine the adequate level of installed capacity to guarantee security of supply. This issue is amplified by the development of the VRE equipment (Cramton, Ockenfelds, Stoft, 2013). Indeed, during peak periods, as they have low variable costs, their hourly production displaces the merit order curve to the detriment of peaking units during peak load, while there is a risk of wind scarcity in some years during this peak period. The solution relies on the introduction of a capacity remuneration mechanism(CRM) which combines planning and market-oriented awarding of capacity contracts.[3]

- **The RES-Decarbonisation module**

Several studies have also shown that the price signal of power markets alone can fail to fully incentivize investment in RES and LCTs via the carbon price signal for a number of reasons (Hepburn, 2006; Jaffe et al., 2005; Lehmann, Grawell, 2013). First, RES plant manufacturers and investors cannot yet reap the benefits derived from cumulative learning about new RES and low carbon technologies, which limits the incentive to invest in non-mature technologies. Second, the characteristics of large-sized technologies and the complexity of such systems (e.g. off-shore wind power, new nuclear, CCS, concentrated solar power) magnify the learning costs and associated risks, because the chain of innovations is too long, too complex and too diverse. Finally, the large investment risks inherent in immature technologies are combined with important political and regulatory risks, [4] even for the small-sized RES projects, and aggravated by the low credibility of the carbon price signal stemming from an ETS (Grubb et al., 2008; Finon and Roques, 2008).

Some conclude that it is necessary to use long term arrangements in order to decarbonize power systems and invest in low carbon technologies, in addition to the implementation of a carbon price (Neuhoff et al., 2007, Grubb et al., 2007; Boot, 2010; Grubb and Newbery, 2008; Newbery, 2011; Finon, 2011; Finon and Roques, 2013).

Presently, in view of the decarbonisation, the emphasis is mainly put on the promotion of RES, even if it is currently being extended to other low carbon technologies in some countries. The three main mechanisms of RES support, have two common characteristics: an obligation to purchase RES electricity imposed on clearly specified agents, eventually under the form of a green electricity obligation to be respected, and the establishment of long term arrangements between RES investors and credible counterparts. These traits characterise the buy-back tariffs (feed-in tariffs or FIT) which are guaranteed in the long term by the government, the auctioning for the assignment of long-term purchase contracts, and the system of renewables certificate obligations imposed on energy suppliers (combined with certificate exchanges), in which risk management constraints incite developers and obligated suppliers to establish long term contracts.

To sum up, these market failures and regulatory imperfections have led a number of countries to embark on wide ranging market reforms in order to provide better investment incentives for both RES and low carbon plants, as well as for fossil fuel plants (peaking units) through capacity mechanisms. These three « long term » modules are designed to guarantee the recovery of fixed costs and to de-risk investment, while they make it possible to subsidize production in the long-run for the new technologies.

4. Lessons from international experiences featuring modules providing long term signals

Overall, the hybrid markets comprise some form of public intervention in either security of supply, determination of the generation mix, and/or the development of transmission networks.

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[3] The respective qualities and drawbacks of the different CRM are compared in Cramton et Stoft, 2006, De Vries, 2007. Roques, 2009; Finon et Pignon, 2009; Cramton, Ockenfels, Stoft, 2013; The Brattle Group, 2012, 2014).

[4] Most importantly, the perception of market players of regulatory and policy uncertainty has had a significant effect on carbon prices. See Koch N. et al., 2014;

But these hybrid models vary widely depending on the objective and type of public intervention, as well as on the resulting allocation of risks of investment between private generators, and government or consumers. This section investigates a number of case studies of hybrid power markets from Latin and North America, and from European experiments in decarbonisation, with the use of renewables obligations in several EU member countries, the long lasting German policy based on long term feed-in tariffs and the recent Electricity Market Reform in the UK which synthetizes the different types of market "hybridization".

4.1. Adjunction of a «Long Term Contracts » module to support investment in generation

- **Reforms of the reform in Latin America**

The initial wave of electricity market reforms that started in several Latin American countries in the 1980s failed to stimulate timely investment, in particular in high sunk cost equipment like hydraulic plants. Moreover as many systems include a large share of hydraulic generation, market designs which produce volatile prices have been very vulnerable to episodes of droughts in Argentina, Brazil, Chile, Colombia, Peru, etc. with long lasting price spikes and administered rationing for consumers. This triggered a second wave of electricity market reforms in the early 2000s which introduced long-term contracts implemented to support and coordinate investment (Battle et al. 2010; Moreno et al., 2008, 2010; Rudnik et al., 2002, 2006).

These arrangements identify specific roles for the spot market and for long-term contracts:

- Short term system optimisation (dispatch) based either on variable costs (Brazil, Argentina, Chile, Peru, etc.) or on bid prices (Colombia, etc.); and
- Long term investment decision-making largely driven by auctioning of long-term contracts either on capacity as in Colombia (Harbord, Pagnozzi, 2012), on energy as in Chile and Peru, or both as in Brazil.

So this hybrid market framework ensures competition under two forms: First, there is competition "for the market" through the auctioning of long-term contracts. Second, there is competition "in the market", where existing generators compete to supply energy through the spot market.

In practice, there are significant differences in the key implementation parameters across Latin American countries, such as the degree of centralisation of the arrangements, the responsibility for load forecasting for anticipating capacity needs, the type of products procured (energy or capacity or both, delivery date, etc.) and the auction procurement approach (frequency, type of auctions, etc.). For example, the Brazilian model features centralised procurement of long-term contracts while the Chilean model features a decentralised procurement model based on an obligation placed on retailers to commit to long term contracts to cover their future loads.

But beyond these differences, a common condition for the feasibility of these different market designs is the remaining retail monopoly of the distributors (with an exception for the supply of very large consumers). As is discussed further, this allows a credible long term commitment on the side of the retailers and an efficient risk sharing between the investors and their counterparts in the contractual structure.

These 'hybrid markets' have attracted significant interest from investors in a range of technologies, including large hydro projects through the LTC auctions. One key benefit of long-term contracts is that they support an efficient allocation of risks and enable project financing with reasonable hurdle rates, thereby reducing financing costs. They have allowed the development of large renewables projects first in technology specific auctioning and later in the normal technology neutral process.[5]

- **Ontario (Canada): Return to the single buyer**

The liberalization of the Ontario power industry which started in 2002, exposed consumers directly to wholesale price volatility which quickly led to public protests as wholesale prices rose sharply soon after the reform in 2003 because of a conjunction of circumstances (high demand driven by the hottest summer in 50 years drought, nuclear plant outages, limited import possibilities from other provinces). Because of a historical culture of consumer protection, politicians felt compelled to intervene. The new Ontario government that came to power shortly after the initial reform implemented quite radical modifications of this reform, re-installing retail monopolies and regulated tariffs, and introducing the Single Buyer model in 2004. An additional reason for the introduction of the Single Buyer model was the commitment taken by Ontario in 2002 to phase out coal-fired generation by 2015, to be replaced by gas generation, new independent hydro plants and after 2005, biomass and windpower.

Under this system, the administrative body Ontario Power Authority acts as the single buyer with responsibility for long term forecasting and planning of the state's future energy needs (Ontario Energy Board, 2012; Goulding, 2013). Once it determines what type and amount of capacity is needed, it runs tenders to contract power purchase agreements (PPAs) with the various generating companies. Specific calls for tenders objectives for gas plants and hydro plants result from the policy to phase-out coal plants. A FIT mechanism for decentralized small-sized RES complements the market design since 2008.[6] Aside from the contract system for generation investments, the Ontario mechanism maintains an important role for the dispatch optimisation by the remaining spot market.

4.2 - Adjunction of a capacity remuneration module in US restructured markets

The failure of the Federal Energy Regulatory Commission's (FERC) 'Standard Market Design' initiative in 2002 to harmonize power markets in the USA has led to a variety of market structures among US states. Over the last three decades, the approach to deregulation in the US has passed through different phases, featuring a pressure for deregulation in the 1990's, a slow-down of the deregulation process in the 2000's and the more recent push for the environmental policies in 2010's. Aside from the half of jurisdictions which maintain regulated utilities, the market structures in the other ones currently represent a spectrum of arrangements for investment in power generation from heavy to light administrative intervention. Amongst these, a major focus was the capacity adequacy objective to maintain security of supply. In the PJM and New England markets,[7] the capacity market initially featured a fixed market-wide short term requirement for installed capacity imposed on the retail suppliers on a daily, monthly and multi-monthly basis. In

[5] However, there are still concerns about the effectiveness of the auction mechanisms and there have been continuous improvements in the past decade (Tomasquilm, 2012).

[6] Initially, Ontario solicited renewable energy projects mainly through competitive requests for proposals from private developers managed by the OPA. In recent years, renewable energy has often been procured through standard-offer and non-competitive processes in response to ministerial directions. Prices for renewable energy, especially under the FIT program, have been between two and ten times higher than those of conventional energy sources, such as nuclear, natural gas, and coal. Generators of renewable energy will be paid guaranteed prices over the contract terms, which range from 20 years for electricity from wind, solar, and bioenergy, to 40 years for hydroelectricity.

[7] The PJM market covers the electricity systems of three states, the Pennsylvania, the New Jersey and the Maryland, but also the District of Columbia and some parts of Delaware, Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, and Virginia.

the mid-2000s, a number of flaws with that mechanism became apparent. The fixed and short term requirement for installed capacity did not provide for much competition between the existing capacity and the capacity that can be built in the near future, and it excluded demand response and cross-border participation. This resulted in a capacity price that was very volatile, being close to zero most of the time when capacity exceeded the peak demand, when it was not aligned on the penalty level: this was not propitious to investment triggering.

The PJM capacity market was reformed in 2007 to combine a resource adequacy requirement with an organised market for forward capacity products. Capacity remuneration is therefore provided through annual forward contracts which are auctioned. The PJM capacity market arrangements have evolved over the years in order, among other things, to provide a stable valuation of capacity, including through an administrate demand curve and price controls for capacity with differentiation depending on the resource location.

The US restructured markets indeed provide examples of market arrangements for locational energy and capacity price-signals contributing to generation investment and retirement decisions, allowing for the coordination between generation and network investments. In PJM, with locational marginal pricing, congestion on the transmission network results in higher energy prices in the import-constrained areas. The locational investment signals are further strengthened by the zonal structure of the capacity market, which values capacity in the import-constrained areas higher than in the export-constrained ones.

4.3 - The addition of a RES-Decarbonisation module: the UK and German cases

The UK and Germany have followed different approaches towards decarbonisation, both of which reflect a fundamental lack of confidence in the carbon price-signal emanating from the EU-ETS (emissions trading scheme). The UK , as several other EU members (Belgium, Italy, Sweden, Poland), first implemented a market-based instrument, the renewable obligation, complemented by a certificate exchange, which was supposed to be consistent with electricity market functioning. But, after 2010, the British government preferred to implement a wide ranging market reform through long term arrangements to both maintain security of supply and support clean technologies.

The German approach has been much simpler and illustrates a ”just do it” approach (Mitchell, 2007): they just add as much renewables as possible to reach an ambitious target and then make the necessary adjustments to the support mechanism and the general market design to accommodate the system balancing with the large share of VRE production and to incentivize investment in the transmission and distribution grids.

- **Renewables obligations**

This type of obligation requires electricity retailers to supply a specific amount of electricity to consumers from renewables and clean sources or else pay a penalty for their deficit related to this amount. In the US jurisdictions with restructured markets, this system it is quite similar to the renewables portfolio standard (RPS) which is currently being extended into a clean energy obligation with the inclusion of other LCTs (co-firing, new nuclear, CCS projects, etc.) (Paul et al., 2011), This enlarged obligation will receive a boost from the new Clean Power Plan launched by the Environmental Protection Agency in 2015 in which it is one of the four policy options available for choice by each jurisdiction, eventually in mixing them, a quota of emissions (namely the mass-based goal approach), an output based approach (namely the rate based goal or carbon intensity goal) and the demand-side efficiency programs (US EPA, 2015).

With this mechanism, which brings inherent risks for the investors (political risk on the defintion and the horizon of the obligation, possible discrimination between technologies in relation to their maturity, level of the buy-out price or the penalty, etc.), experience shows that, in fact, obliged suppliers hedge the acquisition of certificates on a long-term basis either by signing long-term contracts at a fixed price with developers (as in the UK, Poland, California, Texas) or if vertically integrated, by internally fixing a long-term price between the retail business subsidiary and the RES subsidiary (Woodman, Mitchell, 2014 ; Mitchell et al., 2004 ; Wiser et al, 2007). Exchanges on the certificates market serve to adjust the positions of vertically integrated suppliers or to help small retailers to respect their obligations. So the mechanism leads also to the use of long term arrangements, but in a decentralized way, as for example in Chile with the long term energy contracting obligation imposed on distributors. That being said, the experiences show that this mechanism is much less effective than the FIT mechanism (see section 4.4).

- **The German case of extensive us of FIT arrangements**

Since 2000 Germany's ambitious decarbonisation policy has been primarily driven by the implementation of FIT arrangements for RES promotion. This policy succeeds at increasing the RES share in electricity generation from 6.7 % in 2000 to 32.5 % in 2015. The FIT mechanism enshrines a long-term public commitment on a regulated tariff per technology, and combines an obligation for the grid in a given region to purchase RES electricity at these regulated fixed prices per MWh for a 15 to 20 year term. Since 2000, regulated FITs have been aligned on anticipated levelized costs[8]. After 'trial and error' learning, the German scheme evolved in 2004 to a system of decreasing FITs each year for new projects by considering the learning effects on the costs of successive projects. The structure of the arrangement also evolved with fixed tariffs for 5 years, and afterwards declined to a definitive rate depending on site quality.

However, the German experiment shows the difficult controllability of RES capacity development and its policy cost. The debate on the efficiency and side-effects of the FIT mechanism only started in Germany around 2013, when its cost for the consumers became quite high and continues to grow (in 2015, the levy reaches €63/MWh to compare to an energy price of €25-30/MWh). The increasing system costs also incited a questioning of the mechanism, as well as of the growing effects of RES production on depressing prices on the electricity market. Finally, the European Commission's State Aid guidelines published in 2014, led the German ministry to revise the mechanism to implement floating Feed-in-Premium (FIP) for small-sized units, and to allocate long term contracts with FIPs for the new projects by auctioning.

- **The UK Electricity Market Reform**

In the past five years, the UK has implemented a wide ranging reform of its electricity market arrangements (OFGEM, 2009; DECC, 2011, 2013). The 2013 Energy Act focused on reforms aimed at attracting the investment needed to achieve decarbonisation of the sector and to ensure security of supply at the same time. The Electricity Market Reform (ERM) introduced two main mechanisms based on auctioning of long term contracts:

- *Auctioning of long-term contracts for RES and LCT projects under the form of contracts for difference (CfDs)* to be established with a public agency.[9] CfDs provide a top-up payment

[8] Before this date, the FIT system installed in 1990 to pulled the RES into the power system by a niche policy based on a FIT aligned on a percentage of the household retail tariffs, with no relation to the cost-price of the different RES technologies.

[9] In power markets, a contract for difference (CfD) is a long term financial contract between two parties, typically described as "buyer" and "seller", stipulating that the seller will pay to the buyer the difference between the current value of the energy on the hourly market and its value in the contract (if the difference is negative, then the buyer pays instead to the seller). In effect CfDs integrate symmetrical option contracts that make it possible to guarantee a long term revenue for the investor.

for the energy produced by these generators with respect to the reference market price (while it leads the producer to reimburse the difference between the contractual price and the market price when it is lower). CfDs are intended to provide support to low-carbon technologies in addition to the investment signal generated by the carbon price, and to hedge the market risks between the developers and the public agency. They are complemented by feed-in tariffs for the small sized RES units.

- *A capacity market including long term capacity contracts for new equipment.* The capacity market is based around a centralised auction system held four years ahead of delivery for new and existing capacities (outside those benefiting already from the CfDs auctioning system). Unlike the US forward capacity market, new resources can secure long-term capacity contracts (up to 15 years) which are structured as a CfD, which makes it closer to Latin-American mechanisms.

These two measures have been complemented by a carbon price floor to increase the revenue of RES and low carbon equipment through the market (and reduce subsidies), and an emission standard on new fossil fuel plants to restrict the development of fossil fuel equipment**.** In parallel to the EMR, the UK is performing several other reforms of the market arrangements. The electricity balancing reform aims to provide better price signals to value scarcity and flexibility. The reform of zonal network charges aims to provide better locational incentives and coordinate network and generation development.

4.4. Lessons for the design of the « long term » modules

Interventions into power markets take very different forms depending on the market surveyed. Our review of international experiences focused on countries whose market designs keep a role for the market in operational decisions, alongside complementary mechanisms designed to support any generation investment (or almost) in different contexts of demand growth, or decarbonisation policies.

The different policy objectives of the experiences surveyed makes a comparison difficult, so our ambition is merely to evaluate the conditions under which these different complementary “long term” modules, under either their centralized or decentralized forms (planning and tendering mechanism versus increasing mandatory obligations), supplement the functioning of the market in a constructive way to compensate the failures of the long term coordination function of the market. They should drive investment towards the technologies needed either to meet environmental objectives and/or to maintain security of supply. These long term arrangements again provide a stable remuneration of the investment costs, in case of additional short term energy revenues, and tus provide the recovery of complete equipment costs.

In Table 1, we provide different elements of comparison of the long term arrangements supporting investment in the different case studies surveyed, such as the public governance, the degree of centralisation of the mechanism, the autonomy left to generators in investment, the length of contracts to guarantee a revenue over the long term, the degree of technology neutrality, and means of flexibility (exchange of certificates, secondary markets, etc.). We draw five lessons from this survey and this table of comparison.

- **The need for careful design of interfaces between market and complementary modules**

A first lesson is that experience with hybrid markets calls for caution in implementation as complementary mechanisms can be counterproductive if not carefully designed. Designing an efficient hybrid market with complementary mechanisms to support system planning and allocate risk efficiently is possible but requires a clear definition of roles and responsibilities. The experience from Latin America demonstrates for instance the complexity of designing an efficient system planning and procurement process with a residual role for the market. One key issue resides in the responsibilities and incentives of regulatory authority and/or operators in charge of these planning and coordination mechanisms. Independence from policy makers and the ability to resist potential capture by vested interests is key. But the planning process does not necessarily have to be centralized. The experience of Chile, although it highlights the complexities of a decentralized approach, demonstrates that obligations on suppliers to contract generation in the long term can avoid some of the usual pitfalls with central planning.

- **Advantages and pitfalls of strong public governance and a centralised approach**

Centralized approaches with strong public governance allow efficient monitoring of LCT capacity development, efficient contracting with effective risk sharing and lower transactions costs for new projects because of the possibility of contract standardization. It is an advantage displayed by the Brazilian centralized auctioning mechanisms for capacity and energy contracts over the Chilean mechanism of a long-term contracting obligation for distributors with quite various contractual arrangements between the retailers and the generators (Moreno et al., 2009). The British mechanisms (auctioned CfDs, capacity mechanism) present the same advantages of contract standardization related to the centralism of the hybrid market design.

Table 1: Characteristics of hybridisation of market designs by different “long term” modules

	"Long term Contracts" Module for investment			" Capacity Mechanism" Module		"RES technologies- Decarbonisation" Module		
Country	**Brazil**	**Chile**	**Ontario**	**US**	**UK**	**EU countries** **Renewable obligations**	**UK** **CfD auctioning**	**Germany** **Feed-in Tariffs**
Public governance	Strong	Light	Strong	Strong	Strong	Strong	Strong	Light: Eventual quantity cap
Degree of centralisation of mechanism	Joint auctions by a central entity before transferring contracts to distributors	Disco(s) organise and manage their auctions, possibility of joint auctions	Calls for tender for PPAs by Ontario Power Authority (OPA)	SO organises a central auction + cost sharing between suppliers	Ministry organises capacity contract auctions + payment by consumers	Decentralised decision to establish contracts	Ministry organises auctioning of CfDs + payment by consumers	Freedom of developers' decisions
Autonomy left to generators in investment	No freedom of timing Techno-neutral	Freedom of timing Techno- neutral	No freedom of timing	No freedom of timing Techno-neutral	No freedom of timing	Freedom of timing	No freedom of timing	Freedom of timing Techno-neutral
Buyers	Regulated users	Regulated users	OPA as single buyer	The SO	TSO with some parameters determined by the ministry	Obliged suppliers	TSO with some parameters determined by ministry	TSO
Sellers (existing and new capacities)	Separate auctions for existing and new capacities	Existing and new capacities in the same auction	New plants only	Existing and new plants & Demand response	New capacities and existing capacities. Interconnections & Demand response	Developers and existing RES capacities	Investors for CfDs	RES plants only
Contracts structure	Capacity and energy terms/ Energy part as an option contract	Energy contracts	PPAs with capacity and energy (pay as bid). Exposition to market price	Payment on one year	Long term CfDs for new capacities Annual forward or existing.	Payment of one-year certificate	CfDs Exposition to market price	Long term revenue guarantee (No exposition to market price /priority access)
Degree of technology neutrality	Techno neutral with some techno specific auctions	All technologies compete together	Specific calls for tender per technology	Techno-neutral (but with low capacity credit for the RES units)	Techno-neutral	Abandonment of techno neutrality (Techno. bands)	Techno-neutral for RES technologies	Techno-specific feed-in-tariffs
Exchanges			No	Yes	Yes	Yes		No

On the other hand, a key issue resides in the responsibilities and incentives of the public entities in charge of these planning and coordination mechanisms. With strong public governance, the ministry as well as the regulator and the system operator are generally risk adverse in matters of supply reliability and capacity development. So, if the definition of the capacity target for keeping capacity adequacy is in the hands of these actors, there is a risk of capacity overshooting, and of excessively favouring some specific options such as demand response programs.

However, the planning process does not necessarily have to be centralized from the beginning to the end of the decision process. The experience of Brazil shows that the long term load forecasts can be established by the distribution companies before their aggregation by the planner. The experience of Chile, although it highlights the complexities of a decentralized approach, also demonstrates that obligations on suppliers to contract generation in the long term can avoid some pitfalls of the central planning.

- **Efficiency of LTC auctioning and impact on competition**

Experience demonstrates that long-term contracts can have a pro-competitive effect and support an efficient allocation of risks between market players. An issue is the access to information and the asymmetry with market players for the authority in charge of system planning, which points towards the use of information revealing mechanisms such as auctions. The organization of competition ‘for the market’ through the tendering of long-term contracts has proven an efficient way in Latin America and in the UK to put competitive pressure on investors and drive costs of both low carbon technologies and thermal plants down, in particular in the matter of financial costs (Maurer, Barroso, 2010; Newbery, 2014, 2016).[10] This was the sense of the reform boosted in 2014 by the European Commission in the matter of renewables promotion policies in the EU in order to suppress the FITs which were considered by the latter as market- and competition distortive. The reforms of the support mechanisms which are currently introduced in the EU member states following the 2014 Guidelines on State Aid (DG Comp, 2014) are intended to induce more cost-efficiency in the RES capacity development by auctioned CfDs or floating Feed-in-Premium arrangements.

- **The issue of counterparty’s credibility**

The experience in Latin America and in the UK points towards the role of the credibility of counterparties in the establishment of long-term contracts as the only solution to facilitate financing, allow higher leverage and reduce the hurdle of rates and financing costs. They allow the use of project finance or hybrid financing approaches, with a clear allocation of risks between the different stakeholders. Similarly, in the UK, long-term contracts in the capacity mechanism (which contrast with the one year contracts in the US forward capacity markets), have an impact on the financing arrangements.

In Europe the difficulty of hedging generation risks without a ‘sticky customer base’ is a barrier to entry for new investors who develop equipment with high upfront costs. In contrast, in Latin America, tenders for long-term contracts which are established with distributors who legally retain their retail monopolies have driven intense competition for investment in the market, and a number of new entrants have successfully entered into the generation market without having a prior established consumer base in the past decade. In the present European context, the role of long-term contracts in supporting risk transfers and investment is disqualified by the general retail competition required by the EU directives. Long-term contracts needed to develop any new plant should be driven by regulation, more precisely by long term arrangements established with

[10] D.Newbery (2016) shows that the first CfDs for RES were initially priced by bureaucrats at DECC, on the advice of consultants and after discussions with investors, using a high WACC of 7.9% with a CfD, but when DECC decided to adopt auctions for allocating specified volumes of RES (mature, less mature – off-shore wind – and immature technologies – tidal stream, etc.), the resulting clearing prices for on-shore wind lowered the WACC by 3% real.

a public agency which shares price and volume risks with investors, as in the UK electricity market after the reform. In fact in Europe a state counterparty appears to be the easiest way to hedge the risks of investors and to facilitate financing and reduce the cost of capital. But, a body grouping solidary suppliers could also act as the counterparty of long-term contracts, as envisaged in the UK for CfDs.

- **Decentralized obligations *vs* premium mechanism for clean technologies**

Renewables certificate obligations are supposed to be superior in terms of incentives to efficiency for investing but are in fact more costly for the obliged purchasers and consumers than a feed-in tariff mechanism, because of the risks borne by investors and the higher risk premium in the capital cost (Butler and Neuhoff, 2004; Mitchell et al., 2006). A second issue with the RO mechanism is the foreseeability of revenues: there is a dependency of the revenue value to the timeframe of the mechanism (the horizon of the obligation) and the regulatory changes of the design (adaptation of technology bands, buy-out price, etc.). Moreover the price presents a strong dependency on the situation of the ROC market with frequent flip-flop changes from zero to the buy-out price, while the hourly revenue depends also on the volatility of the wholesale electricity price. With a regime of fixed price fixed revenue (FIT or assimilated), the compensations are "customized" for each hour of production. This case leads us to conclude that the mmechanisms with minimal intervention which avoid regulatory risks should be seen with 'a better eye' , all other things being equal.

5. Inconsistencies between old and new market modules: the need for permanent adjustments

In the hybrid market regime resulting from the adjunction of some of the three modules of long term, a number of issues arise from the interraction of the market and supplementary modules.

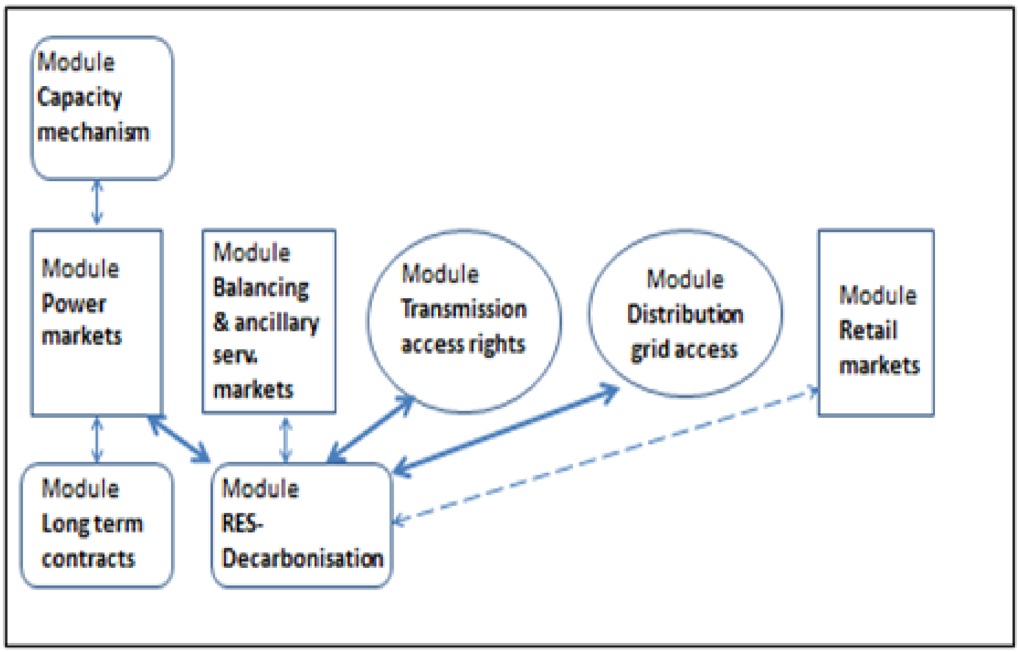

Figure 2. Interactions between initial modules and « long term » modules

- **Tension between the Long Term Contracts module and the Power Market module**

In the market designs which include a "long term contracts" module for every generation investment (Latin American countries, Ontario, UK) or for a major part of the new investment (EU countries with auctioning for FiP contracts of RES projects, etc.), the power market has no function of long term coordination. It has only an economic dispatch function. Besides, as the investment in various technologies which are incited by the long term arrangements could be in low SRMC technologies (hydro plants, other RES, low carbon technologies), these investments would tend to lower the prices on the hourly energy markets where prices are aligned on the SRMC of the marginal technologies.[11] So this reinforces the role of the long term risk-sharing arrangements.

- **Tensions between the RES-Decarbonisation module and the Power Market module**

In the short term the variable production of RES units comes on to the detriment of existing equipment on the day-ahead market. The potential for dispatch distortion from the VRE support depends on the RES support scheme. Most supports incite VRE plants to produce in hours where power prices are below the avoidable costs by conventional units, creating distortions in the merit order in the electricity market, and therefore increasing total generation costs to meet demand. These distortions can create artificial (and inefficient) negative prices for the revenues of non-RES equipment. This issue is clearly revealed in the EU countries by episodes of negative prices which reflect the non-adaptation of the existing fleet of conventional generators to the new flexible needs when the VRE production can occasionally reach a very high share while the existing system with few flexible resources presents limits to the adaptation to "fast ramping" needs.[12]

In the long term, the price signal to trigger investment in conventional technologies is distorted. The production by RES capacities displaces thermal plants in the merit order, and therefore has a significant effect on the revenue dynamics of thermal plants. Indeed there are two significant merit order effects: a decrease in the wholesale prices and the yearly production of existing plants, each effect being also uncertain in the future year. Revenues of any new plant are made risky, by the uncertain result of the policies in terms of shares in the energy production. New low short run marginal cost plants based on RES or LCTs displace more SRMC expensive thermal plants and reduce average power prices.[13]

Another consequence concerns the future of existing base-load and peak-load units, while they tend to be operated with much smaller and uncertain annual load factors and to have lower

[11] It is the case, whatever the design of the energy market, bid price based, or cost based as in several Latin American countries where the market operators refer to the SRMC of the different plants which declare to be available. Indeed the economic dispatching is based on a pseudo market which refers to the variable costs of the plants in Argentina, Brazil, Chile, etc. In Brazil, for instance, the prices are calculated by the computational model used for system operation: Every week the computational model computes short-run marginal costs ($/MWh) in each region and for 3 load blocks. (Tomasquilm, 2012).

[12] An answer to the problem raised by the negative prices (before the development of flexible means) is in the reform of the support mechanisms like those currently implemented in the EU countries. The potential of flexible FiP per MWh and Contracts for Difference (CfD) (which are in fact a flexible FiP)to distort dispatch and make prices negative is less important than with FiT. The FiP per MW (adopted in Spain) and the Renewable Obligation do not have such distortive effects.

[13] An example is the increase of the average electricity price reduction from 5 € in 2010 to around 13 €/MWh in 2015 in Germany while the share of RES in the energy production increases from 10 % to around 30% (Öko Institute, 2013; Praktiknio, Erdmann, 2015).

revenues when they are called by the hourly market, because of the effects of RES production. A number of existing conventional plants cannot even cover their operational fixed costs, without mentioning asset depreciation. This leads to decisions of 'early retirement' and definitively deters investment in thermal plants in the EU countries, while they are needed as back-up of the variable RES production (NEA-OECD, 2012). Said in other words, the market fails to fully compensate for both generation investment and depreciation adjustments resulting from the RES and low carbon policies. The use of « out-of-market » arrangements for promoting RES and LCTs of the RES-decarbonsation module is likely self-reinforcing, because, even with commercially mature technologies which moreover would be made more profitable with a high carbon price, investment in these capital intensive plants would not be financially viable if these mechanisms were removed.

- **Tension between the RES-Decarbonisation module and the Balancing Services module**

The development of variable RES production by plants entered in the system by "out of market" incentives generates an important need for flexibility services. In the European market design, existing modules of balancing and ancillary services, which are less detailed in terms of products than in the US market designs (Saguan, 2009), are poorly adapted to value flexibility and so to indirectly orient investment towards flexible resources. The development of VRE reinforces the need to reward operational flexibility as well as dependability over short time frames, both for flexible power plants and demand side response. The value of operating flexibility is typically captured through price variations in day ahead or intraday markets, balancing mechanisms and ancillary service contracting. So in the European countries, there are growing concerns that such short term price signals do not convey the proper scarcity value of operating flexibility in many countries, leading to calls for a revisiting of the current arrangements for intraday trading and ancillary service procurement to orient investment towards flexible resources, but also to lower the operational costs of the system.

For that reason, the RES-Decarbonisation module should evolve on one side by making the VRE responsible for their imbalance in order to ease the market valuation of flexibility services. Indeed for developing exchanges of flexibility products, it is important that VRE producers become balancing responsible in order that these markets become liquid by creating a vast demand on intraday and real time (balancing) markets.[14] Flexible units with fast ramping should find more value on these markets with more granular products.

So, because of the priority given to the development of variable RES in many decarbonisation policies, the sequence of day-ahead, intraday, real-time (balancing) and ancillary services markets should be improved to reflect scarcities over time. This should be the place where prices optimise the system in the short run, reveal the value of electricity related products hour by hour and thus orient investments in the long run (IEA, 2016). This should also be accompanied by the improvement of transmission pricing to reflect scarcities over space.

- **Tension between the RES-Decarbonisation module and the Transmission Access module**

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[14] Improvement could be made in different directions: first by the development of 'ancillary services' products and improvement of intraday energy markets on one side, market-based mechanisms for reserves and (ancillary) system services on the other side. It could be usefully made by moving trading on system service markets closer to real-time. Market operators should facilitate trading as close as possible to real time (for instance by the introduction of power delivery contracts that allow trading electricity in 15-minute blocks rather than one full hour, as before) and up to 45 minutes before real-time (rather than one day before real time).

Indeed the VRE units which are mainly decentralised are connected to the distribution grids, without any price signal to indicate the districts behind congested transmission lines. The locations of these units could generate new congestions. This issue of optimisation throughout network and generation is made increasingly complex by the growth of variable generation, as well as the need for flexible resources (demand response services, different types of storage plants, etc.). In this perspective, it is not only important that electricity prices, and transmission charges convey locational signals to optimise the operation of networks, production and load in different nodes of the network, but also to provide incentives to effectively locate new production assets, and build new transmission and distribution lines (Li Fi et al., 2009; Glachant et al., 2013; EISPC, 2013). The absence of locational price signals and locational transmission charges does not allow for economically optimal development of network and generation.

- **Tension with the Retail Market module**

While the price signal of the power market steadily becomes more ineffective for triggering investment decisions in conventional technologies, there is an increasing discrepancy between the energy market prices paid by consumers, and the total costs of production, resulting from the higher cost of MWhs produced by RES which have entered under a specific regime of long term arrangements and the system costs they generate.[15] To fill the gap, the money for subsidies should come from somewhere, generally from a specific charge paid by the consumers. The rules of the cost reimbursement process and its accountability are totally at the discretion of the government, far from the ideal textbook model of cost-reflective pricing. Indeed governments are tempted to reduce the burden for energy intensive industries for reasons of competitiveness and to overcharge medium and small consumers. This inequitable burden sharing has two consequences. First it distorts the price signal of electricity to the large industrial consumers, which are not incited to adapt their consumptions and their equipment to higher electricity costs. Second it raises an important distributional issue, as underlined in the German case (Okö Institut, 2013).

Table 2: Key issues associated with hybridisation of market designs by the “long term” modules

[15] To be complete, it should be added that, at the same time the variability of RES has caused an increase in system costs (ancillary and balancing services), which contributes to increasing a bit more the energy bills of final consumers, via the tariffs for transmission and distribution.

Interface with initial market modules	"Long term Contracts" Module for generation investment			"Capacity Mechanism" Module	"RES technologies- Decarbonisation" Module		
Country	**Brazil**	**Chile**	**Ontario**	**US and UK**	**EU countries' RE Obligation**	**UK (CfDs)**	**Germany (FIT)**
Power Market Module	Small role for market (Dispatch organised based on hydro optimisation)	Well-developed spot market	CFD design	Depending on product definition (availability or production). Risk of bidding distortions Long term effect on generation mix	Merit order effect	Merit order effect Possible distortions depending on reference price for CfDs	Merit order effect Distortions dealing to negative prices
Balancing & Ancillary Services Module	Introduction of flexible service payment in the pricing mechanism			Interference with complementary payment to flexible resources	Need of flexibility Eligibility of RES in balancing and ancillary services	Need of flexibility Eligibility of RES in balancing and ancillary services	Need of flexibility Eligibility of RES in balancing and ancillary services
Transmission Access Module	Planning and eligibility of transmission assets in LTC auctions. Coordination of market revenues with network charges revenues	Idem	Idem	Possibility of locational capacity price	Need of locational pricing	Idem	Idem
Distribution Grid Access Module	Regulation Tariff design	Idem	Idem	Participation of demand response	Need for active grids	Idem	Idem
Retail market Module	Policies cost passthrough in regulated tariffs	Idem	Idem	Capacity cost passthrough in transmission tariffs	Cost control by target definition and opt-out	Cost containment procedure	Cost control by quantity cap

4.2. Experience with correction of distortive effects of new "Long Term" modules

It is mainly in Europe where the low carbon policies based on variable renewables have led to various attempts to reform power markets in order to address some of the issues and distortions introduced by the additional modules.

- **Improving the design of the support mechanism for clean technologies**

The introduction of more market-based mechanisms to support RES development could help to control the policy cost and make RES producers responsible for their system costs (Ragwitz et al., 2014). So the reforms of the support mechanisms introduced in the EU member states following the 2014 Guidelines on state aid (DG Comp, 2014) are supposed to induce more cost-efficiency in the RES capacity development and operation, by new mechanisms: adoption of Feed-in premium, auctioning of CfDs and FIP contracts for new projects. These contractual arrangements expose RES producers to energy prices, make them responsible for their imbalance, while auctioning is supposed to reveal the cost of the projects. But, if some efficiency gains are to be expected from these market-based reforms, the control of the RES policy cost will be first brought by the control of the capacity to be auctioned on a per technology basis and the speed of deployment. Such control of quantity by auctioning or by a cap typically relies on a programming approach.

- **The need for a comprehensive approach**

The UK case shows that effective development of RES and LCT technologies accelerates the need for a comprehensive reform of the market. Indeed, the implementation of ambitious climate objectives and clean technology support policies went hand in hand in the UK Energy market review with the implementation of market reforms to improve scarcity pricing, and the introduction of a capacity market. As discussed above, one explanation is the decreasing economic value of non-RES plants when the share of renewables grows, despite the fact that they are needed as back-up of the VRE. To be made attractive to investors, they would need complementary revenues, but not only from new ways to remunerate flexibility products. Indeed proper scarcity pricing and efficient remuneration of flexibility products and system services introduces such volatility in revenue streams that they are hardly credible as a long term price signal to invest in conventional back-up plants.[16]

- **Developing the role of DSOs**

To complement the adaptation of the balancing and transmission modules and because the VRE are mid- and small-size plants which are generally connected at the level of the distribution grids, the supply reliability problem is first raised by the VREs at the decentralised level. The role of DSOs is changing and distribution grid regulation is evolving in different EU member-states.

The development of small-scale generation, distributed demand-side response and electric vehicles is affecting distribution system operation and will transform it as they scale up. It is a powerful incentive to make distribution grids "active". Indeed, as these changes become more widespread, distribution system operators (DSO) will have to take a more active role in the optimisation of the electricity system. More efficient regulation would be valuable if it gave the right incentives to DSOs and allowed them to optimise between CAPEX and OPEX: for example by using local flexibility – in coordination with TSOs – to facilitate RES integration and possibly limiting or postponing costly network investment (Brandstätt et al, 2011; Florence School of Regulation, 2013), eventually by some VRE production curtailment (Anaya, Pollitt, 2014)).

The distribution grids could become 'active' and decide to turn off renewables at times of excess generation, which is now the case in Ireland, under different forms of compensation ; to make the

[16] The limited scope of this paper does not allow us to develop this issue, while some argue that flexibility services remuneration would be sufficient to trigger investment in flexibility resources and by this path, to solve the problem of 'missing money' for investment in capacity for the reliability of the system in any situation (Hogan, 2014).

VREs and other distributed generators participate in ancillary services (frequency and voltage regulation), at the local level and to program load shedding or load shifting with the aggregators.

- **Protecting consumers by controlling investment policy cost[17]**

Formal or informal cost containment procedures are being adopted, through the definition of a cap either on yearly capacity to be installed by technology or on annual expenditures per technology or for the total policy.[18] Such control of quantity through auctioning or by a cap typically relies on a programming approach. This procedure is quite hard to manage. Indeed it imposes a limit on the policy cost -- which is the difference between the FiT (or equivalent) and the market price times the RES/LCT productions of MWh--, which means that when the limit is reached, the regulator adjusts the level of FITs or caps the installed capacities per year (National Audit Office, 2013). But the market price is highly dependent on fuel prices and the ETS price, which means that the limit is rapidly reached if fuel price decreases are as since 2013, or if the ETS price is systematically depressed because of poor design which does not take into account the effects of parallel climate policies by low carbon technologies promotion, or energy efficiency measures.

6. Conclusion and policy implications

Most electricity markets around the globe are 'hybrids' with a mix of regulatory interventions and/or a significant role for the state in planning and capacity procurement. Recently, a revival of policy interventionism in electricity markets has raised questions about the ways in which market design needs to adapt to supplement markets with a programming process (Pérez-Arriaga, Linares, 2008) and a number of additional mechanisms.

In this paper we used an institutional perspective to review and identify the key modules or building blocks of the standard historical approach toward competitive markets. We argued that a number of additional modules are required to address market imperfections and achieve policy makers' objectives. We conclude that, in order to meet decarbonisation and supply security objectives, electricity markets need to be supplemented by different forms of long term public coordination of investment that enhance investment through risk sharing arrangements. In particular, there is a need for risk sharing contracts and coordination mechanisms in order to support investment and maintain security of supply.

We then reviewed international experience with hybrid market design and drew a number of policy recommendations on best practice. We highlighted the need for a careful design of the interface between the market and complementary modules in order to minimize distortions and unintended effects. We also highlighted the advantages and pitfalls of strong public governance and a centralized approach versus decentralized approach for the procurement of capacity.

[17] The price-signal for RES entries ignores the market and there is no optimisation of the share of renewables in the electricity system, as would be the case in a power market where a credible and significant carbon price was the only incentive to invest in VREs. Indeed there is no direct effect on slowing down RES entries when the demand growth is slower or even negative. There is no market signal for the sharp decline of the market value of the marginal MW of windpower or PV capacity, after a threshold of 30-40% share (see for instance Hirt, 2014). There is no adjustment of the long term investment in these technologies, the only solution being a regulatory decision to cap annual installations by technology in order to control the policy cost.

[18] In Italy there is a cap on annual expenses for solar PV and windpower since 2013 with € 12.5 billion per year for each technology. In Germany the cap is on the annual quantity per technology. They are respectively 2.5 GW per year for onshore wind and for PV, 100 MW per year for biomass, and 6.5 GW in the 2015-2020 period for off-shore wind (given its very high capital cost and the long leadtime of the projects). In the UK, there is a formalized cost containment procedure for the overall expenses associated to CFDs, FIT and the renewables obligation (it limits the expenses to a cap of £ 7.6 billion in 2020 with a 30% RES share target).

Finally, the impact on completion of long term contracts was discussed, as well as the pros and cons of a decentralized obligation vs a premium mechanism for clean technologies.

Overall, the evolution towards a hybrid market regime should be recognized as the only way forward if governments want to remain involved in determining the generation mix and security of supply. This recognition would have profound implications in the EU where market design and policy interventions are scrutinized under the competition policy and state aid rules. These considerations also illuminate the institutional and regulatory evolutions expected to arise in the United States with the implementation of the EPA's Clean Power Plan in the jurisdictions with restructured electricity markets.

Finally, policy makers and regulators need to recognize the need for periodic adjustments in the market and regulatory framework, which requires a sound governance process in order to minimize regulatory risk and in order not to have an adverse effect on investment. To do this it would probably be best to anticipate the need for adaptation of the original market design to the large-scale development of VRE and low carbon technologies, rather than patch up the system after an uncontrolled penetration of renewables under a "just do it" VRE policy.

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