IIT Working Paper IIT-10-017A. First version: April 2010. This version: July 2010.

Accepted for publication in Energy Policy

A CRITICAL ASSESSMENT OF THE DIFFERENT APPROACHES AIMED TO SECURE ELECTRICITY GENERATION SUPPLY

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Since the very beginning of the power systems reform process, one of the key questions posed has been whether the market, of its own accord, is able to provide satisfactory security of supply at the power generation level or if some additional regulatory mechanism needs to be introduced, and in the latter case, which is the most suitable approach to tackle the problem. This matter is undoubtedly gaining importance and it has taken a key role in the energy regulators' agendas.

In this paper, we critically review and categorize the different approaches regulators can opt for to deal with the problem of guaranteeing (or at least enhancing) security of supply in a market-oriented environment. We analyze the most relevant regulatory design elements throughout an updated assessment of the broad range of international experiences, highlighting the lessons we have learned so far in a variety of contexts. Based on the analysis, we conclude by providing a set of principles and criteria that should be considered by the regulator when designing a security of supply mechanism.

1 INTRODUCTION

Since the very beginning of the power systems reform process, one of the key questions posed has been whether the market, of its own accord, is able to provide satisfactory security of supply at the power generation level, see for instance (Pérez-Arriaga, 2001), (Stoft, 2002), (Hogan, 2005), (Joskow, 2007) or (Finon & Pignon, 2008), or if some additional regulatory mechanism needs to be introduced, and in the latter case, which is

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the most suitable approach to tackle the problem. The previous authors have contributed to this debate by claiming that, in a number of different contexts, and for a variety of reasons, there is a market failure[1]. This market failure poses the regulatory need to provide the incentives the market is not providing so as to ensure an efficient security of supply level[2]. This translates in practice into providing generators with an extra income and/or hedge instruments in exchange for a product (e.g. installed capacity or long-term energy contracts) aimed to enhance security of supply.

When the so-called "market reform" started, the expectation was that little by little market agents, especially demand, would be able to learn the market game and therefore no additional mechanism would be needed. But, the reality nowadays is that security of electricity supply is more and more turning into a priority in the agendas of electricity regulators. In this respect, (Ofgem, 2010) and (CEER, 2009) are two of the consultation processes opened at the time of this writing that represent two good illustrative examples of the importance of this concern at the present time. Both initiatives are aimed at receiving feedback from the different stakeholders on how to ensure security of supply at

[1] The inefficient allocation of risk plays a key role, but it is not the only issue hampering long-term security of supply in electricity markets. Some flawed regulatory rules which cap short-term signals (the source of the so-called missing money problem), coupled with the lumpiness investment problem, economies of scale or the lack of short-term demand elasticity, result in a security of supply level that is far from being perfectly optimal (i. e. efficient from the net social benefit point of view).

[2] Provided that a suitable implementation of the market design is already in place (it makes no sense to correct with an additional mechanism a flawed market design).

all levels[3]. Another clear example is the number of systems worldwide (as it is for instance the case in Ireland, Panama, Peru, etc.) that have been recently or are currently in the process of revisiting their long-term mechanisms design.

From the time dimension perspective, the security of supply at the generation level can be decoupled into four major components. Breaking down the central problem into its sub-problems facilitates not only its understanding but also the design of a regulatory mechanism (if required). These components (or dimensions) are the following:

- Security, a very short-term issue, defined by the North American Electric Reliability Council as the "ability of the electrical system to support unexpected disturbances such as electrical short circuits or unexpected loss of components of the system" (NERC 1997).

- Firmness, a short- to medium-term issue, defined in (Batlle et al., 2008) as the ability of the already installed facilities to supply electricity efficiently. This dimension is conditioned by the characteristics of the existing generation portfolio and the medium-term resource-management decisions of the generators (fuel provision, water reservoir management, maintenance scheduling, etc.).

- Adequacy, a long-term issue, defined as the existence of enough available generation capability, both installed and/or expected to be installed, to meet efficiently demand in the long term.

[3] In the case of Ofgem the consultation process was motivated by a previous analysis (Ofgem, 2009), which highlighted the possibility of a future shortage on supply in the UK in the near future (around 2015).

- Strategic Expansion Policy, which concerns the very long-term availability of energy resources and infrastructures. This dimension usually entails the diversification of the fuel provision and the technology mix of generation.

There is a certain consensus around the idea that, on one extreme, the security dimension can be tackled by means of operation reserves markets[4], where the requirements are prescribed by the System Operator, and that, on the other, the Strategic Expansion Policy has to be solved through the implementation of additional "out-of-the-market" mechanisms (e.g. feed-in tariffs or cap and trade mechanisms). But in between these two dimensions, the debate on the necessity of intervening to ensure firmness and adequacy (particularly this latter) has always been, and still is, quite intense. Analyzing the different approaches to tackle the potential problems at these two dimensions represents the major objective of this paper.

Security of supply mechanisms in deregulated electricity markets

As a first essential step, the regulator has to decide whether or not fully relying on the market to solve the security of supply problem. In this sense, the regulator can adopt one of the two opposed strategies:

- Do nothing; in the belief that the market will provide the efficient long-term outcome. The regulator's lack of intervention would be mainly supported by the expectation that demand will (or will learn in the end to) manage the long-term risk involved in electricity markets (for example, by hedging and guaranteeing their future needs). This is often known as the "energy-only market" approach.

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[4] Nevertheless, some more attention should be devoted to the interaction between reserves requirement and long term signals, see for instance (Stoft, 2002) or (Hogan, 2005).

- Do something on behalf of the demand; in the opposite belief. In this case, the regulator designs a security of supply mechanism which entails the definition of a certain reliability-oriented product (the "reliability product", as we will call it hereafter) aimed to ensure system security of supply (i.e. avoid scarcities). This reliability product is provided by the generators, who receive in exchange the extra income or the hedging instruments they require to both proceed with efficient investments (adequacy) and make resources available when most needed (firmness). The other counterparty is either directly the demand, compelled to purchase the product by the regulator, or the regulator itself (i.e. the system, the tariff) acting on behalf of the demand. If the regulator opts for this alternative, as we analyze in this work, there are several key elements of the mechanism that have to be carefully designed to avoid inefficiencies.

Traditionally these two opposed strategies have been termed the "energy-only" approach and the "capacity mechanism" approach. We rather avoid using the term capacity mechanism for in our point of view it can create confusion. The reason is that, as we later discuss, there are some security of supply oriented mechanisms that are not usually represented by this denomination (e.g. long-term energy auctions).

Classifying security of supply mechanisms

The different mechanisms can be classified based on the classic discussion on whether to use price-based approaches or quantity-based approaches. In this particular context, this translates into determining whether the regulator's main objective has been to ensure a certain quantity of the "reliability product" or to administratively set a price for the product itself[5].

- Price mechanisms: an administratively determined payment, often known as the "capacity payment", additional to the income derived from the energy (spot) market, is provided in exchange of the reliability product. In this scheme, the reliability product is in practice the so-called "firm capacity".
- Quantity mechanisms: the regulator imposes on (or buys itself on behalf of) the demand the purchase of a specific quantity of the reliability product. In this context, this product takes a variety of formats, e.g. an energy long-term forward, a capacity credit, etc. Depending on the system, the product may be traded bilaterally, within an auction (centralized or not) or by means of additional and organized short-term markets.

A good number of analyses from different points of view can be found in the literature, see for instance (Wolak, 2004), (Roques et al, 2005), (Cramton & Stoft, 2005) (Joskow, 2007) or (Finon & Pignon, 2008). In this paper we take the taxonomy we just outlined as a guide to review and categorize the whole scope of approaches. We detail and critically evaluate the broad range of international experiences throughout the years up to the present moment, emphasizing the lessons we have learned so far in each particular context.

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[5] Generally speaking, all mechanisms require the definition of a price-quantity offer curve for the reliability product purchasing process. For the sake of simplicity, we will classify here the different experiences around the two extreme approaches (quantity-based and price-based).

The role of demand

It can be considered the possibility of allowing consumers to participate in security of supply oriented mechanism (in some of them is more straightforward than in others) by offering a kind-of-symmetric product to the one required to generating units. Although this paper is focused on the generation side, it is important to note that there is a growing trend on integrating demand in the security of electricity supply mechanisms. Indeed many of the problems regarding security of supply will be more suitably tackled thanks to the efficient demand participation.

Paper structure

First we consider necessary to call into question the so-called "energy-only market" approach, which in principle consists in relinquishing any way of directly or indirectly intervening. In other words, this "energy-only market" approach consists in leaving the market exclusively to its own devices. We next show that in practice it is very difficult to find electricity markets in which the regulator does not resort to any explicit (or implicit) safety measure to ensure security of electricity supply. This way, although we pointed out that the regulator can adopt two opposed strategies, in practice it can be observed that the pure "energy-only market" approach is not a real alternative.

Then we discuss the complementary approaches which entail the implementation of an explicit regulatory mechanism, beginning with the price-based mechanisms and ending with the quantity-based ones.

Although the lessons learned have led to a certain convergence in long-term security of supply mechanisms design criteria worldwide, we are still far from obtaining a definite consensus on the subject. In fact, international experience has largely demonstrated that no solution fits perfectly in all systems. The reason lies on the fact that each market's particularities make it very difficult, for what could have been considered as a successful mechanism in one system, to be directly exported with guarantees to another.

The different experiences are presented in a rather chronological way, so as to allow the reader to understand why the first approaches failed, and therefore the reason behind the design features of the new ones. We have devoted more attention to the mechanisms offering new design features or remarkable design errors at the time they were introduced. This way, we analyze in more depth the former ICAP than the mechanism in Western Australia, or the Colombian design[6] than for instance the mechanism introduced in New England or PJM.

Finally we examine the key elements and put forward the criteria the regulator should take into account when designing this sort of regulatory mechanisms.

2 DO NOTHING: THE SO-CALLED ENERGY-ONLY MARKETS

The first alternative is doing nothing. By doing nothing we mean a regulator's long-term commitment to refrain from intervening in securing the supply. The regulator's lack of intervention would be mainly supported by the expectation that demand will (or will learn in the end to) manage the risk involved in electricity markets (for example, by signing long-term contracts). The regulator's position will have to remain unchanged even though things may not have turned out as initially expected.

Theoretical microeconomic analysis of power systems shows that, under a number of strong ideal conditions, the short-term price resulting from a competitive market provides efficient outcomes both in the short and long run, see (Caramanis et al., 1982), (Bohn et al., 1984), (Caramanis, 1982), (Scheweppe et at. 1988), (Pérez-Arriaga, 1994) or (Vázquez, 2003). In this way, inframarginal energy revenues (the so-called scarcity rents

[6] The proposal of the last Colombian mechanism was developed back in 1999.

being particularly important[7]) provide the necessary income for the recovery of both operational and investment costs.

Using this argument (amongst others), some experts (less and less as time passes) suggest that only purely market-based approaches would provide an efficient outcome regarding long-term security of supply.

This approach, focused on not interfering with the market and leaving the demand with the responsibility of deciding its own level of security of supply, has often been termed the "energy-only market" approach, see for instance (Hogan, 2005). However, among regulators and academics, it is not always clear what is and what is not considered to be market intervention. As a consequence, what it is meant by the term "energy-only market" usually depends on the system, the context or the point of view of the author.

When using the term "energy-only market", some authors simply make reference to the absence of the some kind of "capacity-based mechanism" (like the well-known capacity markets or capacity payments), while countenancing the possibility of many other types of regulator's actions/interventions regarding long-term security of supply. Some examples of these actions include, for instance:

- The long-term contracting of energy and/or reserves (not only operational but also "strategic reserves" to be used in scarce situations and described later in deeper detail) by the regulator or the System Operator.
- Giving the System Operator full control of the operation in those cases in which a scarcity period is bound to happen[8].

[7] That is, the income perceived when the generation resources are not sufficient to supply the demand, and so, the price is set by the demand above the variable cost of any of the generators.

- Allowing the regulator to call an auction to encourage new investments as a backstop mechanism to ensure security of supply, etc.

From our point of view, these actions have to be included among the mechanisms to ensure long-term security of supply, since it is obvious that any of them is a clear indication that the regulator does not fully rely on the market to naturally do all that is required. In order to avoid confusion, we rather prefer to use the term "energy-only market" to make reference to the strict "do-nothing" alternative.

But from this perspective, it is very difficult in practice to find a market in which the regulator is really able and committed to just "waiting and seeing", having renounced the possibility of resorting to any explicit (or implicit) form of intervention, especially when the system is already suffering (or it is expected to suffer) a period with a tight or even scarce reserve margin. This form of intervention is sometimes subtle, especially in those cases where the regulator allows a third party to intervene or just suggest that this third party should do so. Such a third party might be the SO or even the incumbent.

While, in several (particularly European) markets, no security-of-supply mechanism has been explicitly implemented, it may be safely asserted that no system lacks at least an implicit regulatory safeguard regarding security of supply. In some systems the incumbent (now in a market-like context but still under partial, and sufficient, public control) "shares

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[8] In other cases, when operating reserves fall below a certain level, the SO take actions, such as voltage reductions and non-price rationing of demand (rolling blackouts), to reduce demand administratively while avoiding prices to reflect the scarcity situation, see (Joskow, 2007). Another similar example is the Maximum Generation Service contracted by the SO in UK (NGET, 2010). These types of "out-of-the-market" measures complicate the price formation process in conditions of scarcity, and affect the proper and expected recovery of generation investments.

the regulator's concern" about system reliability[9] (France[10], Italy or Portugal are some examples).

Indeed, in the European case there are "latent" security of supply mechanisms thanks to Directive 2005/89/EC[11], which states that 'The guarantee of a high level of security of electricity supply is a key objective for the successful operation of the internal market and that Directive gives the Member States the possibility of imposing public service obligations on electricity undertakings, inter alia, in relation to security of supply', and also that the possible measures could include capacity options, capacity obligations or capacity payments.

In some cases, another (not always confessable) reason why certain regulators do not implement an explicit security-of-supply mechanism is the existence of horizontal

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[9] In this sense, one of the arguments presented by the Spanish authorities to stop the German E.ON's takeover bid for Endesa was the nation's need to guarantee its own security of supply (paradoxically the process ended with the successful takeover bid by the Italian company Enel). In some other systems it is the retailer who it is still publicly controlled in some way (by municipalities in many cases) and is therefore the agent that seeks to protect its customers from unexpected annoyance through long-term contracting.

[10] Indeed, on April 2010, in the preamble of the (NOME, 2010), to justify the proposal of creating a capacity market, it is said: 'It is about ensuring that all suppliers assume all their industrial and energy responsibilities on behalf of their customers and do not rely on an implicit guarantee of delivery of the incumbent'.

[11] Directive 2005/89/EC of the European Parliament and of the Council of 18 January 2006 concerning measures to safeguard security of electricity supply and infrastructure investment. Official Journal of the European Union, 4.2.2006.

concentration. A concentrated market allows generators to ensure the recovery of a "reasonable" rate of return.

Thus, strictly speaking, it is not clear that purely energy-only (competitive) markets do exist. That said, it has to be acknowledged that certain systems are greater "market believers" with respect to the market capability to ensure long-term security of supply. Among the most representative systems that are usually included in the literature in this "energy-only" approach we find ERCOT (Texas), NEM (East Australia), Alberta, UK and the Nord Pool.

However, in our view, strictly speaking it cannot be considered that any of them has fully relied on the "left-to-its-own-devices" ideal market mechanism approach. Indeed, all of them present some kind of implicit or explicit security of supply mechanism. In the case of ERCOT, the emergency program known as EECP (Emergency Electric Curtailment Plan) allows the system operator to use reserves and out-of-the-merit units through "out-of-the-market" protocols aimed to avoid load shedding. The resulting short-term prices during these emergency interventions have been criticized for not reflecting the opportunity cost of providing the service. The System Operator may also enter into Reliability Must Run contracts with uneconomical units for many different reasons.

In the UK, under the BETTA, the TSO is responsible for the long-term purchasing of the operating reserves. It is well-known that operating reserves requirements affect both short-term prices and consequently long-term investment signals. Thus, artificially modifying these requirements, above the actual needs to face exclusively very short-term security issues[12] can therefore alter medium- to long-term market outcomes. This has been the case in some of the UK operating reserve purchasing processes[13].

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[12] Note that a scarcity in generation supply is not a very short-term issue.

In Nord Pool, the SO takes an active role resorting to a long-term contracting that it is later discussed in the quantity-based mechanisms.

Moreover, ERCOT, NEM, Alberta and the Nord Pool present a considerable degree of public ownership (either in the generation- and/or the retailer-side). In the NEM in particular, around 63 % of generation capacity is government-owned or controlled (AER, 2007).

3 PRICE MECHANISMS: CAPACITY PAYMENTS

Roughly speaking, capacity payments are a price-based incentive that seeks to achieve both an efficient resource management (firmness) and investment (adequacy and strategy energy policy).

The mechanism entails mainly two problems: first, to properly define the reliability product, second, to fix the price (right enough to avoid falling too short or too long).

In the price-based mechanisms context, the product is usually the so-called firm capacity. Each unit's firm capacity is aimed to represent the unit's contribution to the overall system's security of supply. In practice, depending on the system, we find many different alternative methodologies to define the firm capacity. In most of the cases it is mainly based on the (expected) availability of each generating unit when most needed, but sometimes other parameters are used in its calculation as for instance the units' variable

[13] For instance, Roques et al. (2005) state that under the Supplemental Standing Reserve Tender (SSRT) called on October 2003 to increase the reserve capacity, there was evidence that the role of this supplementary tender (requiring a much larger quantity than it usually deems necessary to hold system frequency, so as to bring back some mothballed units) caused an immediate increase in forward market prices (i.e. in longer-term signals).

costs (e.g. the smaller the variable costs, the larger the firm capacity assigned, as for example it is the case in Guatemala, Ireland or Brazil).

Next we delve into the analysis of the different capacity payment experiences.

Chile

Administratively determined capacity payments were first introduced in Chile back in 1982. The payment design was aimed to provide an extra payment to ensure the full recovery of generators' investments and production costs. This payment was provided to each unit based on its firm capacity. The firm capacity was calculated using probabilistic models, and it represented each unit contribution to overall system reliability.

UK (1990-2001)

Capacity payments were paid to all generating plants declared available in each half hour, and the value was equal to the Loss of Load Probability (LOLP)[14] of the period considered, multiplied by the difference between the Value of Lost Load (VOLL, i.e. the regulator estimate of the cost of non-served energy) and the plants' bid price (if not dispatched) or the system marginal price (if dispatched)

This mechanism was criticized for many different reasons; for instance, Newbery (1995) pointed out that some companies artificially increased the LOLP, and thus capacity payments, by declaring unavailable certain units. Green (2004) highlighted that most of

[14]The LOLP value represents the probability of rationing. Another relevant measure that can be calculated straightforwardly from the LOLP value is the expected amount of hours of rationing in a given period of time. Many systems define their reliability standards using this latter measure; for example, US power systems usually establish a maximum accumulated rationing period of one day in ten years.

these abnormal payments were rather the result of a deficient definition of the method used to determine the new units' availability factors. In (Roques et al, 2005) a thorough analysis of the major shortcomings of the mechanism is carried out.

These capacity payments disappeared with the introduction of the decentralized NETA model in 2001 (BETTA, since 2005).

Argentina

When the market started in Argentina back in 1995, two different capacity payments were implemented: one for dispatched capacity and another focused on remunerating those plants which did not produce on a regular basis but whose availability was essential for system reliability during dry years. A plant could not receive both payments during the same dispatch period.

The formula determining the first of the abovementioned payments was similar to the one already presented in the former UK mechanism, that is, the higher the expected value of loss of load the higher the payment received by the generators. The difference lay in the fact that it was only provided to those generators producing in each hourly interval. The problem that rapidly appeared was that the size of this payment was large enough to severely affect the system dispatch. As remuneration was linked to production, the optimum strategy for generators was to internalize the payment in the bid sent to the market, what induced generators to bid below marginal costs in order to receive the extra payment.

Due to these inefficiencies, it was decided to introduce certain modifications in the design, guided to eliminate dependence on the actual dispatch and on the expected value of the non served energy. The new scheme remunerates not just the plants producing but also the ones available during hours of higher demand (CAMMESA, 2005).

Spain

The original "capacity guarantee mechanism" implemented in Spain when the market started in 1998 provided an extra remuneration based on average availability rate in the case of thermal plants (plus a minimum annually production requirement[15]) and based on the average historical production in the case of hydro units. This scheme was largely criticized, see for instance (Pérez-Arriaga et al, 2006), for being too simplified on the firmness side, lacking of effective incentives for generators to be (or penalties for not being) available when needed and on the adequacy side for being extremely unstable.

After a two-years period of discussions, see (Batlle et al., 2007) and (Batlle et al., 2008), the Ministry of Industry came up with a redesign consisting of two differentiated services (MITyC, 2007):

- The availability service, aimed at allowing the system operator to enter into bilateral contracts, lasting no longer than one year, with peaking.
- The investment service, for units larger than 50 MW and during their first 10 years of operation[16] an annually capacity payment (expressed in euros) per installed megawatt.

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[15] Plants had to produce at least 480 equivalent hours every year to be entitled to receive the capacity payment. The measure was designed in an attempt to prove a minimum reliability of the plant. But the inefficiencies that resulted from such a rule were obvious, since it led high-cost peaking units to uneconomically force being committed to receive the payment.

[16] This 10-years condition is aimed to reward only CCGTs, which have entered the system after the market started in 1998. This design is clearly "contaminated" by the windfall profits discussion that puts into question the income mainly nuclear and hydro plants (installed under the former regulated context) are receiving in the new market scheme.

This investment incentive depends on the value of a so-called ''reserve margin index'' ("*índice de cobertura*" in Spanish, or IC) that has to be calculated by the system operator.

Italy

In Italy, an administratively determined fixed capacity payment is in place. This mechanism was initially conceived as transitory, but after almost ten years it is still in force. The payment is focused on providing additional remuneration to the power plants whose production can be considered to be manageable (thus, wind for instance is excluded). The associated remuneration depends on the availability during the "critical" days, which are identified by the Transmission System Operator.

The payment consists of two different components (Benini, 2006):

- A capacity remuneration component which is calculated by the TSO on the basis of the units' estimated power capacity available (Terna, 2008).
- An additional amount that only applies in the event that the unit's revenues obtained from the energy sold on "critical" days are lower than those that would have been obtained on the basis of the administrated tariffs

The mechanism has been criticized for not ensuring the recovery of the investment fixed cost (Benini, 2006), but it seems that for the time being, the main objective of this transitory measure is to avoid mothballing, and not to foster new investments.

Others

In Ireland, the capacity payments are updated every year[17] based on a complex set of rules that determine the remuneration each unit is entitled to receive. The payments

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[17] Due to the continuous yearly updating, this mechanism does not provide a stable source of income to generators, and thus, it may not be helping to significantly reduce their risk exposure

depend on the unit's declared availability in each of the hours, and each of the hours is weighted depending on the ex-ante expected LoLP and the ex-post calculated LoLP. The payments also depend on the price bid. For further details on the (long) formula that determines the payments' distribution see (SEM, 2009).

In South Korea there two different capacity payments (one defined for base-load units and another for peaking units).

Besides the ones mentioned, capacity payments were implemented in some other electricity systems, mainly Latin American ones, which reformed their regulatory scheme to introduce a market-based design: in Colombia they were replaced by the Reliability Charge mechanism described later, and they are still in force in others (Peru, Chile, Dominican Republic, etc.). In some cases, these capacity payments coexist with other long-term security of supply mechanism (as mandatory long-term energy contracting).

4 QUANTITY MECHANISMS

The security of supply mechanisms we include in this category of "quantity mechanisms" differ from the previous ones in the fact that the regulator relies on a market-based mechanism to set the price for the reliability product. This approach in principle solves one of the main problems of the price mechanisms just described: instead of setting administratively a price and then expect (hope) for the right amount to come into the system, the regulator declares the quantity expected and lets the market mechanism reveal the right price.

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problem. It would be much more appropriate to stabilize the payment for a minimum number of years for those units entering the system.

We next review the different quantity-based experiences, beginning by reviewing the initial mechanisms, the so-called "capacity markets", and highlighting their flaws. Then we delve into the discussion of the current re-designs, aimed to solve these problems.

4.1 Capacity markets[18]

The former ICAP in the Eastern USA (PJM, NYISO and ISO-NE)

ICAP markets have been the most debated case in terms of capacity markets. Nowadays, they are still an inevitable reference, mainly due to the poor results obtained.

These mechanisms consisted in having every Load Serving Entity (LSE) to back up its expected peak-load capacity requirements (plus a reserve margin) with capacity credits. At first, all generating units received credit for all their installed capacity (that is what ICAP stands for: Installed CAPacity). Hence, each LSE had to purchase a certain amount of the product (the credits), that was supposed to serve to guarantee that there would be

[18] The term "capacity markets" was originally used to denote the market to trade a (reliability) product "artificially" created by the regulator. This way demand had the obligation to contract the power capacity (expressed in MW) required to supply its future consumption. This solution was born in the context of a fully thermal (thus capacity-constrained) power system. The problem that rapidly arose when trying to implement this approach in other non-fully-thermal power system was obvious. In fully-thermal (non-fuel constrained) systems, it can be assumed that the availability of a thermal plant is uncorrelated from the availability of the rest of the plants in the system and also (sufficiently) uncorrelated from the peak demand. But this is not the case at all of hydrothermal systems, which are mostly energy constrained. The direct consequence is that defining "capacity", as the ability to produce energy when needed, is not so obvious. Thus, under this "capacity markets" category, we will include experiences in which under the term capacity it is not understood just MW but "MW in certain hours, season, etc." (i.e. in those periods in which the regulator considers the risk of scarcity is higher).

enough installed capacity to satisfy their expected peak demand (plus the mentioned margin) at peak hours.

However, capacity is not always available, and soon the different ISOs, beginning with PJM, became aware of the firmness problem and developed the concept of UCAP (Unforced Capacity). By using this new UCAP concept, each ISO was able to discount, depending on each unit's actual historical availability, the capacity for which it was given credit (that is, the quantity of the product that the generator was entitled to sell).

Nevertheless, this UCAP was calculated as an average of the available capacity over long periods of time (typically a season or even a whole year) irrespective of whether the unavailability did or did not occur during a scarcity period. Thus, the incentive to be available during tight reserve periods was exactly the same as for any other given hour of the year.

The different ISOs, in their attempt to encourage generators to make their installed capacity available, looked for additional rules. As a consequence an additional condition was introduced for those generators willing to participate in the ICAP mechanism: a must-offer requirement in the day-ahead market. Unfortunately, this did not solve the problem, the reason is that it is difficult to find a means to measure availability that does not entail fully relying on self reporting by generators (the must-offer requirement is not effective, since unavailabilities can be hidden behind high-priced bids)[19].

[19] Although some sort of monitoring is possible, the only alternative implies making *in situ* random tests on a unit by unit basis, as it is the common methodology in Latin American designs, as for instance in Guatemala.

The controversial performance of the mechanism

In (PJM, 2006) the PJM Market Monitor conducted an analysis in an attempt to assess whether the fixed costs of the different units were covered by the prices received by generators from the PJM markets plus the ICAP payments, and concluded that investments costs were not being recovered.

In addition to this lack of investment cost recovery, there was another relevant problem linked to the design of these capacity markets: the extreme volatility of prices. Capacity market prices tended to alternate between very low prices, during the large periods where the system's reserve margin was large, and extreme high prices when not enough capacity resources were available (Chandley, 2005).

Capacity demand inelasticity was pointed out as the main reason behind this price volatility, and soon some proposals were made with the objective of determining a downward-sloping demand curve that could better represent demand interests. Nowadays, each of these capacity markets has defined the so-called Variable Resource Requirement demand curve (a price-quantity elastic curve).

But demand inelasticity was neither the only reason behind these market results nor probably the most important. These results were the inevitable consequence of other design flaws that we review next.

Why prices bounced from near-zero to extreme high values?

If the capacity auction is called a short period in advance of the delivery date, only the units already installed can participate. Since these units cannot internalize their investment costs in their bids, the generators have to bid the cost associated with the provision of the reliability product being purchased by the regulator. But, what is the additional cost of keeping an already installed capacity (ICAP) of a unit operational? Obviously near-zero in most cases. This was the reason why prices tended to fall dramatically during long periods. Conversely, when the capacity reserve margin becomes tight, there is a reliability product scarcity, and prices do reflect this.

This was the case in the early ICAP markets, and therefore, the price that served to complement investors' remuneration in the energy markets presented either near zero or very high peak values. Thus, instead of providing the stable price signal sought by investors, in the end, another (even more) volatile short-term market was created. The feared energy scarcity periods were replaced by the installed capacity scarcity periods[20].

In the end generators received an extra income that complemented the income received via their sales of energy, but this remuneration was neither certain nor capable of guaranteeing in advance the recovery of investment fixed costs.

Was this volatility unavoidable?

This volatility might have been reduced if the auctions' time terms had been increased so as to allow potential new entrants to participate in the auctions. As pointed out in (Vázquez, 2002) in a general context, and also in (Chandley, 2005) within the PJM ICAP framework, the solution entails allowing for a longer time interval between the moment the commitment of deliverability is signed and the moment it has to be delivered (the so-called "lag period", so as to allow the new entrants to build the generating project). It is also recommended to make some other additional changes: for instance, allowing for longer contract durations, since generation investments usually require long contract durations to ease their project finance.

[20] Although the consequences of a scarcity period in this new market also had an undesired economic impact, since a certain reserve margin with respect to expected peak consumption was defined by the regulator, it did not imply energy rationing.

Lack of locational signals for capacity

In all these Eastern US markets, the effect of network congestions is important, and consequently, reflecting the different value of energy at the different consumption locations has been considered to be a necessary market design characteristic. In this context, locational signals should be provided by these capacity markets mechanisms so as to acknowledge the different values of capacity at the different locations.

Guatemala

In the electricity market design in Guatemala the regulator imposes on demand the obligation to hedge their future energy consumption (linked to a profile) plus their "firm offer" needs (a sort of capacity credits).

In the initial design, the firm offer the regulator assigned to each generating unit was in principle based on the theoretical availability of the unit in the dry periods[21]. But providing a payment based on availability may attract the undesired type of generator. The reason is that highly inefficient "junk" generation can take advantage of such a definition of the reliability product. Plants with very low investment costs, although presenting extremely high production costs (and even high failure rates) may become the most competitive units in this context.

Years later, the regulator came up with a new design aimed to solve the matter. The "firm offer" was replaced by the "efficient firm offer", with the idea of rewarding only the so-called efficient plants (i.e. the cheapest).

[21] For hydro units, this value was based on the production that the plant was able to theoretically assure in 95% of the cases (according to historical series) in the "peak blocks" (the four peak hours of each of the working days), from December to May (corresponding to the dry season). On the other hand, for thermal units, the "firm offer" depended on the historical average failure rate.

France

On March 2010, the "New Organization of the Electricity Market Bill" (NOME, 2010), proposes the implementation of a capacity market. Thus, it imposes the obligation on retailers to acquire "guarantee certificates" (*certification de garantie*). The SO will allocate this certificates among generating units (and also "elastic demands") according to the "total technically available capacity", and the CRE (*Commission de Régulation de l'Energie*) will calculate annually the penalties to be paid by market agents in case on non-fulfillment 'to provide agents with incentives to invest on new capacities of demand response or generation'.

At the time of this writing this mechanism is still a preliminary proposal, and thus lacks of the final development details.

Western Australia: The Reserve Capacity mechanism

All the demand is required to buy capacity credits to cover their share of the system future capacity requirements. Both the system requirements and the capacity credits assigned to the generating facilities (and also to some demand side management resources) are determined by the Independent Market Operator (IMO) on a yearly basis.

4.2 Auctions for long-term and lagged reliability products

This renewed approach consists in (often centralized) auctions for longer-term contracts, with the additional feature of postponing the moment to start delivery (the so-called lag period, a number of years) so as to allow the winners of the auction to build the plant.

Colombia: the Reliability Charge

The Colombian power system experience pioneered the major wave of changes regarding regulatory design of security-of-supply mechanism, and directly or indirectly influenced heavily some other redesigns reviewed afterwards here (for instance, among others, the mechanism of New England).

The Colombian electricity system is dominated by hydro-generation, and it is significantly sensitive to the cyclical climate period known as El Niño-Southern Oscillation, which implies suffering one severely dry year once out of five to eight years.

The first scheme, in force during the period 1996-2006, was an administratively determined capacity payment known as "Capacity Charge". The effectiveness of the scheme was called into question almost from the very beginning. A consultation process on the different flaws of the mechanism was launched in 1999, and as a result some alternatives were proposed. The approach that finally was chosen consisted in replacing the capacity payment by a quantity mechanism, but correcting the already observed flaws of the mechanisms already implemented (mainly PJM, discussed previously). The original proposal was put forward back in 1999 in response to a requirement of ACOLGEN (the generators association) later on described by the consulting team that developed it in (Vázquez et al., 2002). The two major features of this proposal were the introduction of the so-called "reliability option" as the new reliability product and its acquisition through a centralized auction.

The reliability option

The reliability option[22] is a call option contract with the particularity that the strike price is calculated so as to serve as a threshold for determining scarcity situations[23]. In other words, every time the spot price goes above the defined "scarcity price", all the sellers of

[22] Denoted as Firm Energy Obligation in the Colombian regulation.

[23] In practice, this results in a strike price that is set at a level slightly higher than the most expensive unit's marginal costs.

the option (the generating units) have to sell the committed energy at the strike price instead of selling it at the spot market price. The main objective followed with this design was to get to a better way to identify when the security of the system is in danger, since the best and indisputably most market-oriented indicator of an impending scarcity episode is an abnormally high market price. This design also provides demand with a price hedge in extreme situations.

The other key design parameters of the reliability option were the time terms: both a lag period (denoted as planning period in the Colombian regulation) and a contract duration long enough. The first to give new entrants enough time to build the project (and thus, allowing them to participate in the mechanisms before carrying out the investment), and the latter to reduce risk exposure (thus easing the project finance).

These time terms critically condition the type of generators that will enter the system. For instance, a lag period of three or four years can ease the entry of thermal generation but it is completely irrelevant for large hydro plants, whose construction period exceeds this term. Analogously, a very long contract duration (e.g. fifteen years) matches better the project financing needs of a large hydro than a thermal low-capital-intensive peaking unit. In this sense, the finally implemented design (Cramton & Stoft, 2007) includes special rules to cope with this reality: the regulator defines different contract duration for the different generation technologies (e.g. shorter for thermal plants than for large hydro ones). Also, as detailed in (CREG, 2006a) and (CREG, 2006b), for large hydro projects the regulator allows the investor to lock-in the auction price from the 4-year ahead auction up to seven years ahead.

The auction

The other main feature introduced in the original proposal was to centralize the acquisition of the reliability product by means of an auction. The objectives are to increase competition, to benefit from economies of scale (gathering together the different sometimes small and numerous regulated retailers, so as to make possible for large investments to participate) and to enhance transparency (to avoid vertical integrated companies taking advantage of obscure agreements).

The proposal also established that the regulator should acquire the reliability product on behalf of the whole demand desiring a higher level of security of supply. It is important to note that if the whole demand is not represented in the mechanism, which has been the case in some Latin American power markets, undesired cross-subsidizing or free riding issues may arise (see section 5).

The final auction design (Cramton & Stoft, 2007) also includes a downward-slopping curve to specify how the purchased quantity of the reliability product depends upon price. Also, a relevant characteristic of the process is that different rules apply to new and existing plants (e.g. existing plants are price takers in the auction).

Brazil

Electrical energy in Brazil comes mainly (80-85%) from hydro-generation plants with multi-annual reservoirs. The first market-based design, in force from 1996 to 2004 consisted in a centralized system marginal cost calculation to remunerate generating units, with added sort-of security of supply mechanism: regulated retailers were compelled to contract in the long-term 85% of their expected future energy needs and a floor price existed to overcome the fact that the market price is zero almost 80% of the time. This floor price has been also adopted in the subsequent redesign of the Brazilian market.

After the 2001 and 2002 rationing episodes, ensuring long-term security of supply became a truly vital objective. The situation led to several thorough analyses, as a result of which experts concluded that there were some imperfections regarding expansion and efficient contracting. This led to a proposal that to some extent was inspired in the abovementioned auction-based solution proposed years before for the Colombian system and that resulted in the mechanism currently in place (Barroso, 2006).

The main differences from the Colombian case are:

- Different auctions are called for existing units and new entrants. In the first ones, the lag period and the contract duration are significantly shorter (1-year lag instead of 5, up to 15 years instead of up to 30).
- There are two different reliability products: a financial forward energy contract for hydro units and an "energy call option" (which in very general terms presents the characteristics of the reliability option previously described in the context of the Colombian case) for thermal plants.
- The regulator has a backstop mechanism that allows the government to carry out specific energy auctions driven by energy policy decisions[24].

ISO New England

In ISO-NE, the so-called Forward Capacity Market (FCM) replaced the previous ICAP mechanism, see (Cramton & Stoft, 2005), (ISO New England, 2006). This new framework shares the major characteristics of the mechanism described in the Colombian context, without entering into some of Colombian complications led to cope with different generation technologies, but including locational signals, i.e. different zones are defined in which the capacity requirements and clearing prices are calculated.

[24] In 2008, for instance, a special auction for this mechanism was held for 1200 MW of co-generated power produced with sugar cane biomass), see (Batlle & Pérez-Arriaga, 2008).

We do not delve into the description of the auction-based mechanism, since as stated is very similar to the Colombian mechanism. However, as it is the case in other designs, it is remarkable the degree of integration of demand as a potential provider of the reliability product.

PJM's Reliability Pricing Model (RPM) and the new NYISO's ICAP

The poor performance of the capacity markets originally implemented in PJM and NYISO led to significant redesigns aimed to correct most of the shortcomings that have been analyzed previously. Sketchily, the new design (PJM, 2008) consists in an auction for a reliability product based on an evolution of the former UCAP: the way availability is measured is now much more detailed and sophisticated, providing a much more precise measurement of the actual contribution to the security of supply level of the system.

The time terms have been also redesigned, and now it is considered both a longer lag period and longer contract durations, thus avoiding repeating the errors from the past.

Furthermore, locational signals are provided to capacity and demand has been considered as a potential provider of the product.

Chile

In the Chilean system, distributors (in their role of retailers of the regulated demand) must commit all their consumption at all times and at least three years in advance. The relevant contracts have also to be assigned through public auctions (Ministerio de Economía, 2008). Each distributor must design its own contract characteristics as well as manage its own auction, although other distributors may join the process so as to take advantage of economies of scale. Additionally, the capacity payment is fixed over the duration of the contract.

Others

Other characteristic mechanisms that would fall in this category would be the long term auctions implemented in Peru, see Batlle et al (2009), the long term auctions of Panama, see CND (2008) and Urrutia (2008), and also the Energy Plus Program (EP,2006) in Argentina.

4.3 Strategic reserves as the reliability product

In this last category of the quantity-based mechanisms, we have included those schemes focused on purchasing the so-called "strategic reserves". The "strategic reserves" have traditionally represented a particularly controversial type of reliability-based product, since it consists in tearing apart a certain amount of generation capacity which does not take part in the energy market, unless the regulators or the SO considers that it is necessary (according to more or less objective criteria).

Different works, as the remarkable analysis carried out in (Finon el al, 2008), have shown that if both the criteria used to trigger the production of the reserves and the purchasing process are well-designed, the mechanism can provide suitable results.

Finland, Norway and Sweden

In Finland, Norway and Sweden, the SO is in charge of purchasing strategic reserves. This reserves are defined as reserves designated for times when demand is close to exceeding the available production capacity; in other words, they are called upon to supply energy when a generation scarcity scenario appears.

It is the responsibility of the SO to define the rules for offering the electricity of these reserves on the market. Obviously, this can result in a significant distortion of the price signals (since the SO may become into an irregular market agent). However, if the price at which the load reserves produce is set at a value high enough, see Finon et al (2008), there would be no price distortion (as it is the case in the following experience).

New Zealand

New Zealand is a hydro-dominated system (65% of the energy in an average year). Thus, as in most hydro-dominated systems, the concern has been to ensure enough production resources during dry years[25.] The mechanism designed to overcome energy constraints during those years consists in contracting strategic reserves, which may include either new or old equipment (MED, 2003).

The contractors are selected by means of centralized public auctions and their responsibility is only to supply energy and capacity during scarcity periods (dry years). The design of the strategic reserve mechanism includes the price at which the reserve capacity has to be offered on the wholesale market. This price is set at a high value, which ideally serves as a threshold for detecting scarcity situations[26]..

5 DESIGNING LONG-TERM REGULATORY MECHANISMS: PRINCIPLES AND CRITERIA.

No matter the type of mechanism, there are some common elements of design that the regulator should take into account when introducing a security of supply mechanism. These elements and decisions are briefly enumerated next, showing in the light of the

[25] New Zealand's Electricity Commission objective is to ensure that supply remains secure even in a 1-in-60 dry year event, that is, in a hydro drought of a severity that can be expected to occur every 60 years

[26] For instance, the Whirinaki reserve energy trigger price was set at 38.7c/kWh ($387/MWh) in its December 2008 update.

international experience which are the alternatives and in which aspect the regulator should be careful to avoid the mechanism failure.

The counterparties: buyers and sellers

The regulator has to define the part of the demand on behalf of which he will make decisions. Thus, the regulator has to decide whether to act on behalf of all the demand or just a proportion of it. Care will need to be taken so as not to create cross subsidizing.

That is, those being represented by the regulator in the mechanism are not always the only ones desiring and enjoying a higher level of reliability. For instance, on many occasions, particularly in Latin American power markets, large consumers are exempted from long-term contracting or defraying the capacity payment.

The regulator has also to define who is entitled to act as a seller in the mechanism. In some cases all types of units are allowed, in some others just new investments or some particular technologies. Depending on the case, discriminating among different units may create a market segmentation with undesired long term effects.

The product

To properly define what generating units sell in return for the additional hedge instrument or source of income the security-of-supply mechanism aims to raise. This is known as the reliability product.

Determining the product to be bought from the generation is of the utmost importance and complexity. There are many different alternatives: fixed or flexible long-term energy contracts, certificates of installed capacity, certificates of available capacity (or available energy), certificates of a certain technology installed capacity, long-term reserves requirements, physical units to be operated by the System Operator under certain conditions, energy financial contracts, etc.

Defining an adequate product can determine the success or failure of the whole mechanism. In this sense, when defining the reliability product, the regulator has to be careful with the foreseeable response on the generators side, so as to analyze whether this response leads or not to an efficient result[27].

Since the regulator acts on behalf of the demand, and it is difficult in practice to know demand preferences, it would be convenient avoiding hedging in excess. This would avoid isolating demand (and somehow also generators) from the market, what could bring undesired effects. As long as demand perceives to some extent short-term price signals, there will be a true incentive to encourage its participation in the market, which would in the end provide the most efficient outcome. This is the reason why, for instance, a reliability option would be preferred instead of locking the price of the energy with a full-requirement type of contract for the next 20 years.

In this sense, there is a certain consensus around the idea that the reliability product should remunerate the capability of producing energy at "reasonable" prices (whatever "reasonable" might mean, usually below the NSE value) when the system is suffering a scarcity. But at the same time, it is also far from being obvious how to define a scarcity. In this respect, the market price seems to be one of the most reasonable and transparent indexes, but although inferior, other possibilities have also been implemented, such as defining certain periods ex-ante, using the reserve margin measure (whatever the methodology used), etc.

[27] For instance, if the regulator decides to buy installed capacity by means of a public auction, it will probably get the capacity which presents the lowest investment costs, but maybe with low availability rates. If it decides to pay for the water reservoir level in the "dry season", it will fill reservoirs to their full capacity in that season. Sometimes the consequences of the product definition are not evaluated beforehand, and highly inefficient situations are the result.

Other relevant aspects of the contract associated to the reliability product include:

- The time parameters. There are two time parameters of the product that have to be carefully designed (especially relevant in auction-based mechanisms): the lag period and the duration of the commitment (contract).

  - The lag period is the existing time duration between the moment the commitment of deliverability is signed and the moment the product has to be delivered. The *lag period* indirectly determines whether (and which) new investments may participate in the mechanism. If the lag period is shorter that the time required for constructing and installing a new project, then this new project will not be able to participate. Thus the definition of this parameter has two major consequences. First, a proper definition gives generators the chance to bid their investment costs in the mechanism, and thus helps reducing generators' risks. Second. it also affects the competitive pressure in the process (the longer the lag period, the larger the technologies and plants that may compete in the mechanism).

  - The *contract duration* affects the generators' risk exposure. Those products which have a short contract duration do not help hedging generators' risks. They provide an additional source of income, which may help to solve some investment problems (such as the so-called missing money problem caused by price caps), but they do not help to reduce risk exposure, which is particularly relevant when large investments are evaluated. The contract duration in price-based mechanisms (capacity payments) in nothing but the stability of the additional income provided. If the payment is recalculated every year (as we have seen is the case in Ireland, for instance), generators' risk exposure may be significant.

  Both the lag period and the contract duration defined by the regulator condition the results of the mechanism (i. e. a seven-year lag period with long term contract "makes life easier" for large hydro plants, while a three-year lag period and short term contracts makes it close to impossible).

The first wave of capacity markets (e.g. PJM or NY-ISO) are a good example of mechanisms with short lag periods and short contract duration (did not ensure enough competition, did not allow generators to bid investment costs and did not reduce the risk involved).

Regarding the reliability product design, in order avoid free riding issues it is desirable to provide consumer with a price-hedging rather than with physical supply delivery hedging. Today, in a scarcity event, there is still no technical way to discriminate between the different types of consumers. Thus, if the product is based on physical delivery, there will be no way to discriminate those that have acquired it and those who did not. This would result in free riding. On the contrary, it is always possible to financially settle each consumer contract.

Other relevant characteristics to be taken into account are the penalties for non-compliance; force majeure clauses; whether the contract is indexed to reduce generators' risk exposure; or credit guarantees, which in this context are of the utmost importance.

Price versus quantity

The regulator has to decide whether a price-based, quantity-based or price-quantity based curve is going to be offered on behalf of the demand. This decision depends mainly on the regulators reliance on the market to determine the price of the product. This reliance depends on the one hand on existing market structure and the expected level of competition and on the other hand also on the agents knowledge with respect to the costs associated to the different technologies. If these conditions are adequate, a market-based solution appears as the more suitable alternative.

Resorting to a fixed-price mechanism may result in a security of supply which is either too large or too small. Analogously, resorting to a fixed quantity may result in too high a price. Elastic requirements better reflect the utility each security-of-supply level provides to the buyer (the demand). Additionally, they help to reduce market power and also provide more information about how far the system is from suffering a scarcity.

Other details

When the effect of network congestions is important, and consequently, the value of energy at the different consumption locations is significantly different, then, it could be desirable to introduce locational signals in the security of supply oriented mechanism. In this context, if enough liquidity and market competition can be ensured, locational signals could acknowledge the different values of ensuring electricity at the different locations.

The regulator has also to decide whether the product is bought in an auction or bilaterally and finally if the purchasing process is centralized or left to the retailers' initiative. The international learning process has led to the conclusion that it is desirable to use centralized auctions for different reasons, among others, to benefit from economies of scale increasing competition, to avoid vertical integrated companies taking advantage of obscure agreements, etc.

6 CONCLUSIONS

Under the market-oriented paradigm, the new regulation must make sure that the appropriate incentives exist so as to ensure an efficient long-term security of supply level.

In this context the regulator ideally has two alternatives to deal with long-term security of supply: to do nothing (in the belief that the market will provide an efficient result, hopefully sooner rather than later, given the possibility of periods of scarcity in the meantime) or to take an active role trying to represent its own view about demand's best interests by introducing a long-term mechanism.

Once the regulator has decided to undertake the task of "helping" the market to reach what it considers to be an efficient outcome, the next key question is how to introduce the necessary adjustments in the market design in place so as to achieve the objective pursued in the long term. This is particularly complicated and controversial, because in the end, all long-term planning may, directly or indirectly, fall again into the hands of a central planner, and we should not forget that avoiding the potential inefficiencies stemming from the central planner scheme was one of the principal motors behind the liberalization wave that started a few decades ago.

The exhaustive and critical review of the international experience illustrates that the design of a long-term mechanism to acquire a certain reliability product presents challenges that if not properly solved may result in the end in undesired market outcomes. Throughout the paper, we have detected and discussed several key design elements.

Be it said in summary, that although it can be observed a certain convergence in long-term security of supply mechanisms design criteria worldwide, we are still far from obtaining a definite consensus on the subject. The reason lies on the fact that each market's particularities make it very difficult, for what could have been considered as a successful mechanism in one system, to be directly exported with guarantees to another.

In the light of the evidence discussed throughout this paper, one might conclude (as is often the case) that the market resulting from the reform of the electricity carried out over recent decades is not the right alternative. The main aim of our work has been to highlight the fact that the final problem is not the market approach itself, but the lack of adequate regulatory mechanisms to deal with the complications that real life markets may present[28].

These regulatory flaws have resurrected and encouraged numerous lines of argument in favor of a step back towards the traditional centralized (even nationalized) model; for instance, in the case of Ecuador, see (Batlle & Pérez-Arriaga, 2008). However, it should not be forgotten that these unreformed markets have not escaped similar or even worse problems. In this respect, the latest news from Venezuela or Mexico illustrates the fact that the formerly traditional centralized model, if flawed regulated, also does not guarantee an "adequate and sufficient" functioning of the electricity system. Indeed, the vast majority of problems have not arisen because of the liberalization, but because of the poorly designed regulation.

Acknowledgements

We want to thank specially our colleagues Prof. Ignacio J. Pérez-Arriaga, Michel Rivier and Carlos Vázquez with whom we have had the opportunity to share the analysis of this matter throughout the years, and to whom to some extent some of the ideas developed belong. Also, we are sincerely grateful to the number of academia colleagues with whom we have shared and discussed good parts of this work and whose comments have been extremely helpful.

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