Locational market in Poland

Security of supply, costs and the impact on the energy transition

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AUTHORS:

Michael Hogan – Regulatory Assistance Project
Dr Joanna Maćkowiak Pandera – Forum Energii

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Foreword

Today's energy system works on the basis of principles that were established at the beginning of the last century. Large power plants operate at full load, the transmission system provides power to where it is needed. However, the energy system is changing rapidly and the traditional structure of electricity generation, transmission and distribution has not kept pace with the development of technology. How to change the power market so that the energy system remains reliable, low-carbon, economically and socially acceptable?

The experience of the energy transformation in Europe shows that grids will be the biggest challenge. Renewable sources are growing rapidly. They are generated where there are proper conditions (it blows and shines), where it is possible to connect to the grid or where there is a political will to build a power plant. There is no economic stimulus that would give an impulse to build transmission networks or generation sources in the place of the highest demand. Without taking into account the needs of the system, the costs of balancing and congestion removal will increase. Therefore, it is essential to improve the flexibility of the power system.

We present the concept of the locational (nodal) market, which in our opinion addresses this challenge. In the locational market model, not only the cost of the generation is priced, but also the cost of delivering electricity to a specific location in the system. In the study we analyse the experiences of other countries and the possibilities of introducing this market model in Poland. For over a dozen years, the locational market has been operating in many countries, including some of the United States, Australia and New Zealand. In the study we explain why it is worth implementing it in Europe, especially in Poland.

We encourage you to join us in discussions and polemics.

Yours sincerely,
Dr Joanna Maćkowiak-Pandera
President of Forum Energii

1. Main conclusions

- *Locational marginal pricing* (hereinafter referred to as LMP) has a positive impact on the improvement of flexibility and the use of underutilised energy system resources.
- LMP increases the use of the cheapest existing system flexibility resources, both traditional resources on the supply side and new ones on the demand side.
- The locational market stimulates new investments in generation and networks.
- In the long run, the locational market leads to lower wholesale prices.
- Implementation of the locational market in Poland, if carried out well, may bring significant benefits for the low-carbon transformation of the Polish power system.

2. Purpose of the study

Poland is considering the introduction of *locational marginal pricing* (LMP) as an alternative to the current EU-wide "copper plate" model.

The purpose of this paper is to answer questions:

1. Will the implementation of the locational market support or hinder the low-carbon transformation of the energy sector?
2. Will the energy system based on locational prices be reliable and cost-effective? How will it affect new investments in the energy sector?
3. How to ensure that the locational market will gain social acceptance?

3. Introduction

Electricity is evolving towards a system based on distributed and variable energy sources, which require higher capital expenditure but at the same time have lower production costs. These changes are driven by technological development and climate policy. They put pressure on energy markets.

The transformation of the energy sector towards low-emission and distributed sources will require significant investment in:

- generation
- transmission
- distribution

Both electricity production and consumption are characterised by increasing volatility and at the same time consumers are becoming producers. As these trends collide, the risks and costs of misallocation and underutilisation of limited resources will increase.

There is a growing need to increase the flexibility of the energy system. Energy markets must start to generate price signals that correspond to the real supply and demand situation, as well as for new ancillary services and increased amounts of existing services - this is a common international trend.
In the next five years the resources of the energy system will become :

- more local (flexible demand and dispersed energy sources)
- located independently of where the load is.

such that the locational component of the cost of energy will become increasingly important.

The current pricing system "hides" the variation in marginal costs resulting from the different costs of delivering energy to individual locations. This increases market inefficiencies and creates the wrong price incentives. Transmission system operators resolve energy market failures through congestion management (e.g. redispatching). These are not optimal methods, because it is the operator, and not the market, who decides which resources to use, how to reward them and how to recover the costs incurred. This is a method of manual control that, can be ineffective from a technical and cost standpoint.

The experience with the introduction of the locational market presented in this study will mainly, but not only, come from the Electric Reliability Council of Texas' (ERCOT) market in the United States.

We decided to analyse ERCOT because it is adequate for Europe and Poland for several reasons:

1) ERCOT is probably the best example of a competitive energy market, EOM (*Energy Only Market*).
2) ERCOT has evolved from a single-zone market by dividing it into smaller price zones to the introduction of LMP, a process that has taken the last eight years; a similar evolution can be expected on our continent.
3) A broad spectrum of independent and publicly available data is available for the ERCOT market.
4) The introduction of LMP has coincided with a rapid increase in the share of variable sources, which can also be expected in Europe.

4. The challenge - the current architecture of the electricity market

The current market structure with a single price in the European Union reflects the objectives of introducing competitive energy markets in the 1990s and early 21st century.
The fundamental challenges in the energy sector, particularly in countries where it has been liberalised, are almost the same everywhere:

1) Historically shaped structure of electricity generation with a predominance of old, inelastic resources and a negative impact on the environment.
2) An extensive power system with large units designed to meet inelastic demand.
3) The share of variable sources with minimum or zero variable costs is increasing, challenging traditional electricity systems and traditional assumptions about the way wholesale prices are set;
4) A market distorted by strategic reserve mechanisms operating in the market does not send the correct price signals.
5) Decentralisation, both in the form of distributed energy resources and digitisation of energy services.
6) Network development has not kept pace with the changing structure and distribution of generation capacity, leading to increasing network congestion or costly countermeasures. Historically, the average congestion costs have been relatively low in most markets, which was particularly evident in the strongly interconnected European network. Although it was clear in theory that market prices should take into account marginal locational costs, policymakers decided against introducing it - the choice was one of cost (start-up cost and added complexity) versus perceived benefits.

As a result, in Europe - also in Poland - prices are set without taking into account the costs associated with network congestion (or line losses). Significant differences between wholesale prices and actual marginal costs, taking into account the costs of delivering energy to a specific location, result in incorrect price signals. They lead energy market participants to make decisions that neither solve the transmission problem nor stimulate the resources most needed (e.g. cheapest or most flexible).

This leads to sub-optimal decisions on:

- energy sales
- making bilateral commitments with other market players
- energy production and transmission planning[1]
- energy consumption
- investments in new resources

Wrong price signals lead to uniformed decisions about the availability of resources and the availability of capacity and interconnectors on the market.

In many early adopters in non-European markets, it soon became clear that it was wrong to rely on the average congestion costs. Even if the average cost corresponds to reality, the biggest problem is a few hours, when it is the most difficult to overcome congestion. In some markets (e.g. Scandinavian countries and Italy), attempts are being made to alleviate the situation by dividing it into smaller zones (*market splitting*), but this leads to other problems.[2]

In an ideal power system, it would be possible to send electricity from where it is produced to where it is needed at the cheapest price ("copper plate"). In fact, it is not possible. Capacity between locations will be temporarily reduced due to network congestion. Expansion of new transmission lines and countermeasures are costly. Even with an optimally designed transmission system, we have to accept some of its limitations. In the era of the energy transition, new relatively fast-growing generation units and centres of high energy demand, new transmission congestion appears in a dynamic and less predictable manner. In Poland, as in the rest of Europe, investments in transmission networks have not kept pace with the changes, leading to increased costs and increased risks to the stability of supply.

In the current system, national borders define the scope of the market where a single wholesale price is created. In such *large price zones*, marginal congestion costs are either socialised or concealed by imposing administrative congestion on cross-border trade[3]. As a result, market prices do not reflect the marginal costs of purchasing and selling energy in different locations of the system. This may be important because the proper functioning of the market in both the short and long term is based on the assumption that prices will reflect the real marginal cost of energy.

Electricity prices that do not reflect actual demand create unwanted signals in relation to electricity production and consumption. This in turn leads to:

- increased congestion
- inefficient use of system resources
- increased uncontrolled physical electricity flows
- less flexibility in the electricity system
- suppressing incentives to improve energy efficiency
- higher operating costs of the system
- lack of investment in transmission
- wrong decisions regarding the location of the investment

1 Unlike other Member States, Poland uses a central dispatching system for generation capacity, which gives it an advantage in limiting this particular risk; unfortunately, the lack of locational marginal prices tends to neutralise this advantage.

2 See, e.g., Hirth, L. and Schlecht, I., „Redispatch Markets in Zonal Electricity Markets: INC-DEC Gaming as a Consequence of Inconsistent Power Market Design (not Market Power)" (21 March 2019)

3 The exception is the Scandinavian region and Italy, where (as needed) the market is "subdivided" into regional zones, which have been designed to reflect real system constraints. The old border areas coincide with national borders, but the zoning within the market still better reflects marginal costs.

There is no doubt that a competitive wholesale energy market is essential. It aims and will continue to deliver the energy services that consumers expect reliably and at the lowest possible cost. Moreover, increasing decentralisation can only strengthen such a market. For this to happen, market rules and practices need to change in order to reflect the rapid changes in the European energy system. One of the biggest challenges is the lack of reflection of locational marginal costs in the energy price.

5. Characteristics of the locational market

The locational market is a wholesale market which operates on the basis of *locational marginal prices*. These are prices that reflect not only the cost of production, but also the transmission costs caused by the locational of the production relative to where it is consumed.

Definition of the locational market

The locational marginal pricing (LMP) market is based on the marginal costs of purchasing and selling electricity at different nodes in the wholesale electricity markets. Each node is an entry or exit point from the transmission system (LMP can also be implemented in the distribution system, but we do not deal with it here).

Examples of markets operating with LMP are PJM, ISO New England, MISO, CAISO, ERCOT and Ontario. LMP consists of three components: energy prices, congestion costs and transmission losses.

Ideally, the wholesale market operator operates both on the day-ahead market and in real time, with marginal locational prices in both markets.

The introduction of LMP is aimed at replacing zones and instead creating wholesale prices in individual nodes of the whole market.

Each node represents:

- *source* (where electricity is supplied to the grid)
- or *off-take* (where energy is taken from the grid).

The price of energy in each node reflects its marginal share in the cost of congestion in the system.[4]

Difference

The main difference between the LMP approach and the current one is that congestion is priced and, in most cases, removed by market participants responding to economic signals and not by the administrative actions of the transmission system operator.
LMP is therefore a more cost-effective solution.

4 In many LMP markets, the price at each node also reflects the marginal cost of transmission losses. Some have assumed that only producers are accounted for at locational prices, but prices to customers are averaged in zones.

6. Rules of functioning of the locational market

The essence of wholesale energy markets is to enable cost-optimal system management and create incentives for investment. The main objective of the market is to ensure a reliable supply of electricity at a reasonable price. The theory and practice of the operation of power systems shows that this goal can be achieved by economically efficient selection of generation units. It is important to take into account system security constraints (*bid-based security-constrained economic dispatch*) using locational marginal prices.

What does it actually mean?

Marginal cost pricing

Marginal cost pricing is the essence of a liberalised market. It is about satisfying the demand for energy with the cheapest unit - one that is able to produce and deliver an additional unit of energy (e.g. 1 kWh) at the lowest price. The marginal cost of generating energy is not enough - it is necessary to take into account the costs of transmission - to deliver electricity to where the energy will be consumed.

In a competitive market, the clearing price is expected to approach marginal energy costs. The marginal cost is often presented as the cost of production in the *merit order (a ranging from resources with the lowest marginal cost)*. And this is usually the case. However, for wholesale energy prices to reflect true marginal cost in a meaningful way, not only energy production costs are important.

Transmission congestion may generate additional costs resulting from feeding energy into the grid and off-take from the grid in different locations. Even an optimally designed transmission network will from time to time be congested in certain locations. When there is no congestion, prices are the same in each location[5]. However, when congestion occurs, the most economic resources are blocked by this.

Generators that would be competitive without network congestion must reduce production in the presence of network congestion. On the other hand, other resources with higher costs have to be called to work in order to cover the demand in the system.

The cost of congestion is simply the difference between what the actual cost of meeting demand is and what it would cost without congestion.

The price reflecting the full marginal costs should be higher in congested locations and lower in places where there is no transmission problem[6]. In this way, appropriate actions are stimulated - construction of networks, new generation units, storage, energy efficiency demand-side resources (DSR).

Locational market and the energy transition

Renewable sources develop dynamically and unevenly across the country. Often, the development of the network does not keep up with them. Without changing the approach to valuating electricity, which accounts not only the cost of energy production, but also for transmission of energy to the place where there is demand for it - the costs of the system will only increase. This will be due to erroneous price signals and the increasing need for administrative balancing and congestion management activities.

5 Transmission losses are an ubiquitous locational cost factor and are reflected in prices in some markets.
6 A single constrained pathway can often affect many producers; each of the producers concerned contributes differently to congestion depending on where it is in relation to congestion, so that each producer would have different locational marginal costs.

7. Incorrect price incentives

The administrative measures necessary to bring the system closer together with existing network congestion generate high costs and the wrong incentives for market participants.

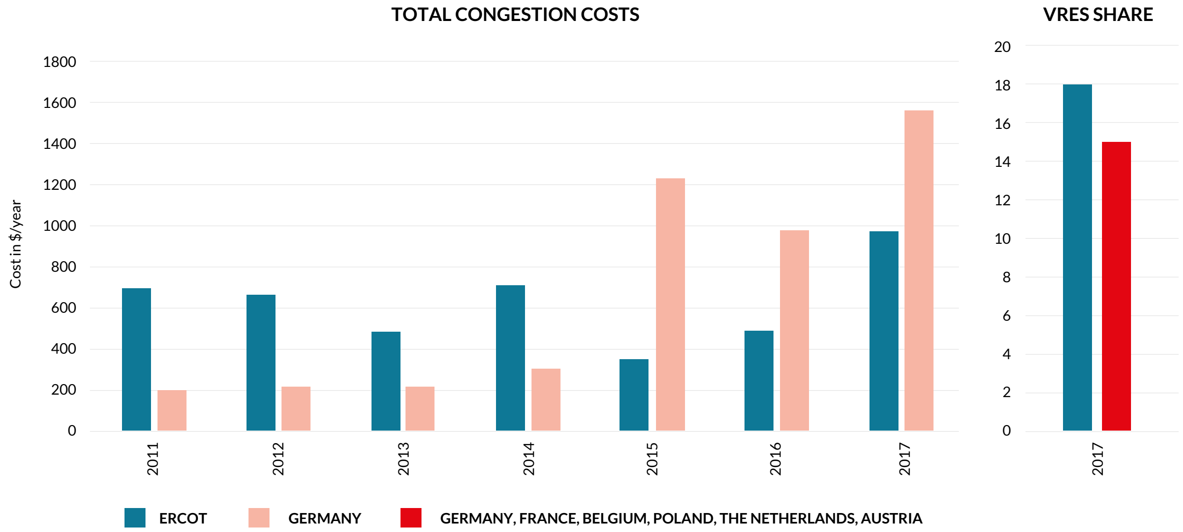
Let us now consider congestion arising in a zone where there is a single price, as in Europe. Each source that produces or consumes electricity receives the same price as all other sources in the zone. It does not matter in what part of the zone the manufacturer or customer is in, nor does it matter how the entities influence the creation of restrictions. On the other hand, the system operator - applying methods of removing transmission congestion (the so-called *redispatch* - intervention triggered units) de facto allocates these costs equally to all market participants.

Therefore, market participants do not take into account congestion and the associated costs. The system operator uses the available administrative tools - redispatching - although experience shows that, as their level of complexity increases, the transparency of these solutions decreases.

8. Rising congestion costs

With the energy transition, the share of variable generation sources is increasing, which translates into increased efforts to manage network congestion.

Figure 1. Total annual congestion costs on the ERCOT market and in Germany for the period 2011-2017



Source: ERCOT Annual State of the Market reports; BnetzA; DG Energy

Figure 1 above compares total annual congestion costs in the ERCOT market and in Germany (excluding "spillover" congestion costs shifted to neighbouring markets) from 2011 (the first full year of the LMP in ERCOT) to 2017, along with a relevant comparison of variable energy shares in the market.[7] A more granular approach to locational pricing is likely to reduce costs and increase flexibility precisely at a juncture when increased system flexibility is seen as the key to integrating these new resources reliably and at a reasonable cost.

7 The ERCOT data reflect congestion rent whereas the German data reflect re-dispatch costs; they are different ways to measure the cost of congestion, with congestion rent typically resulting in a higher number. Therefore these data most likely over-state congestion-related costs in ERCOT relative to those shown for Germany. The German also data exclude any costs incurred in neighbouring countries as a result of the congestion arising within the German single-price zone; this is not an issue in ERCOT, which is not synchronised with neighbouring regions.

Efficient use of system resources

Given the dispersed nature of renewable energy sources, transparent price formation and the inclusion of the costs of integrating sources into the system will increase in value on the energy market. Investment behind physical constraints is made less attractive, and conversely market actors are more motivated to support investment in more beneficial locations. It also makes more transparent the net benefits (or lack thereof) in supporting investment to relieve constraints. This will be especially important when considering the significant increase in capital investment going forward, where more efficient and flexible pricing has been shown to increase the utilization of hard-won system assets.

Example

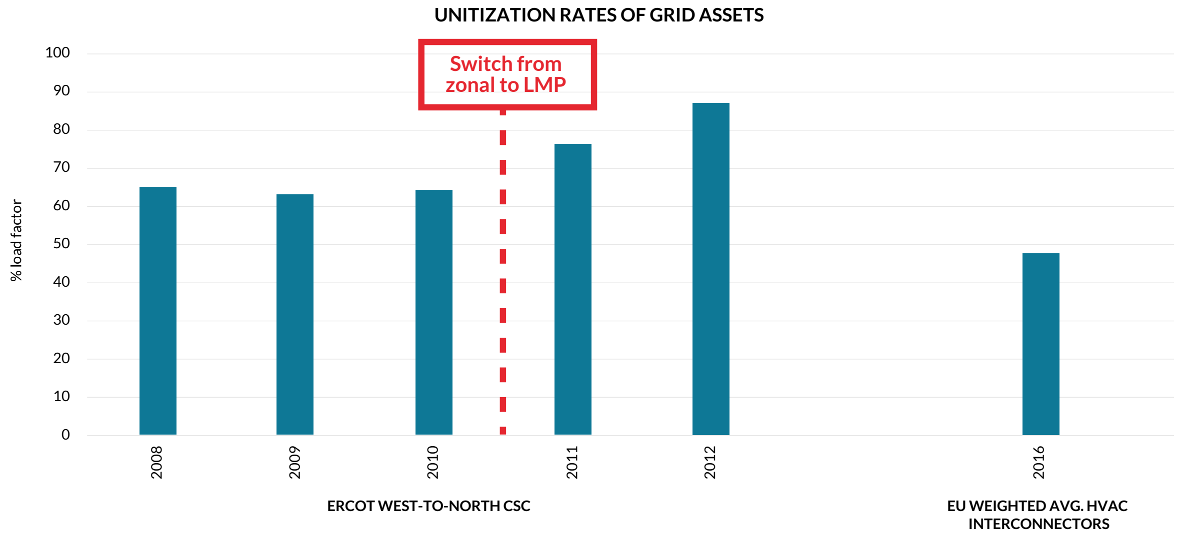
After the introduction of the locational market in ERCOT, use of one of the sections of the network with the greatest limitations increased in the first year from 64% to 78%, and in the next year to 87%.[8]

Figure 2 shows a comparison of the use of interconnectors between European single-price markets and the most congested ERCOT pathway :

- during the *small price zones* period on the ERCOT market before 2011
- after switching to locational prices (from 2011).

Although this is not a perfect comparison, the results are fully in line with the expectation that market congestion management based on real marginal costs enables better use of critical infrastructure and the most economically efficient resources.

Figure 2. Use of critical network assets in ERCOT and the EU



Source: ERCOT Annual State of the Market reports; ACER & CEER (2008 datum abstracted from IMM graphic presentation; 2009 is estimated)

Taking into account the current load on the transmission grid and the huge challenges related to the implementation of new investments in high-voltage networks, this kind of improvement in the use of system resources will be incredibly important.

8 Cf. SOM Report 2011 and SOM Report 2012.

9. Locational market in other countries

The locational market has, over time and as energy markets have evolved, found application in the most competitive wholesale markets outside Europe (cf. Annex 1. Experience of selected energy markets with LMP).

It is now developing widely in many countries around the world - outside Europe. In Europe, in some countries - e.g. in Germany - there is great resistance to changes in the functioning of the energy market. These are mainly political concerns related to the change of market rules in a situation where many companies have incurred high investment costs.

Table 1. Competitive wholesale markets and their approach to locational prices

LMP:	Small zones:	Large zone:
ISO New England ISO New York PJM (Atlantic Central Coast in the Unit-ed States) Mid-Continent ISO (North America) Southwest (U.S.) Power Pool California ISO ERCOT (Texas) IESO (Ontario) EIM (Western North America) New Zealand Singapore Argentina Chile Mexico Philippines Brazil* Russia	Scandinavia Italy Japan	EU without Scandinavia and Italy AESO (Alberta) Colombia

*Brazil is arguably not a competitive wholesale market; Australia, as a gross pool, exhibits characteristics of all three types.

10. The process of running the locational market - the next steps

The introduction of the locational market is a process that requires a spread in time:

1) Change planning should start four years earlier.
2) A legal analysis of acquired rights is necessary, e.g. with respect to grid connections and transmission capacities in Poland.
3) It is particularly important to change the functioning of the day-ahead market.
4) Data requirements for the location-based pricing system may seem discouraging, but unlike the challenge of introducing LMP at the distribution level, most of the data is or should already be available. At present, it would be difficult to ensure the reliability of a modern energy system without access to such data. Existing data can be used to design the LMP system, which determines the distribution of system resources in the most efficient and flexible way based on real locational marginal prices.

11. Stimulating low-cost alternative resources

DSR and energy storage are increasingly cost-effective and their development is stimulated by the needs of the system - improving the flexibility of the energy system. On the other hand, the dispersed nature of these sources means that their role increases due to the possibility of using them in specific network locations. With the current approach to energy valuation, the values of these nontraditional system resources are not sufficiently appreciated and valued in Europe.

DSR and distributed energy sources are largely beyond the reach of centralised administrative processes (e.g. balancing and re-dispatching services). At the same time, it can be expected that in the future the heating and transport systems will be integrated into the energy system through electrification of these sectors. New sources of demand can radically change the way electricity is used and the balancing options. Transport and district heating can offer transmission system operators additional opportunities to manage regional congestion. The rapidly declining cost of distributed energy resources, in particular for the consumer's own use (*behind-the-meter*), further increases the benefits for the energy transformation that can be achieved through a more accurate valuation of electricity. Those in favour of a single-price approach often stress that the development of the transmission network is the best way to increase flexibility and reduce congestion costs. Although it is true in theory, in practice the construction of new transmission networks is still lagging behind the needs of a rapidly changing energy system. The expansion of the network encounters great social resistance.

Transmission investments are relatively cheap compared to the construction of new generation capacities. With technological progress, new storage and DSR capabilities are emerging, which are increasingly competitive in terms of price, and these projects can be developed much faster than large infrastructure projects.

12. Market power

Liberalised energy markets function properly and are economically efficient if they are competitive. One of the challenges to be addressed when planning changes in the organisation of the energy market is the risk of concentration and the potential of abuse of market power.

Market power

Market power is the ability of a company or group of companies to raise the price by withholding capacity from the market. The abuse of market power leads to a deterioration in prosperity. In the energy sector, market power can occur both at a zonal level as well as within zones, when intra-zonal congestion temporarily creates a smaller *market in the market*, where a particular entity holds a dominant position.

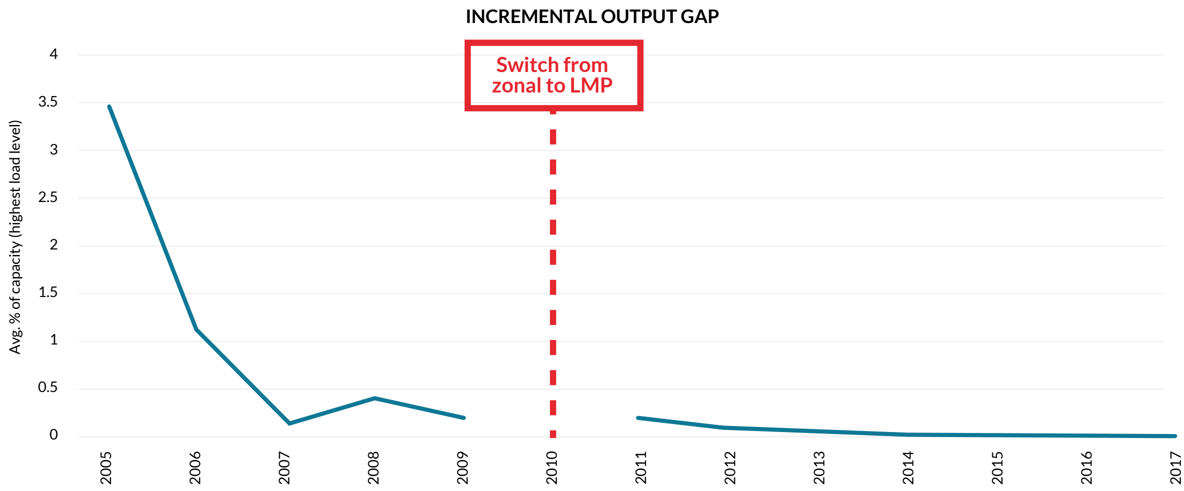
Large price zones may create the illusion of limiting market power through greater competition between entities in a given zone. However, this does not take into account the situation in the regional dimension, or even in smaller, divided price zones. While entities with market power in a given location are not necessarily able to increase the zonal price, they may abuse their position to create network congestion within the zone, replace more competitive resources and earn a surplus (over the market price) for removal of the restrictions.

Wherever congestion arises - between zones, within zones or without zones - there is a risk of abuse of market position, regardless of the approach to locational prices. LMP markets do not delineate zonal boundaries, thus minimising the risk of concentration and largely eliminating the distortions and opacity which are a handicap in zonal markets. Of course, this issue cannot be ignored and every market model should try to counteract this phenomenon.

The most basic mitigation step is to test *ex-ante* for the existence of structural market power, - that is, of the ability to control price in a market area by withholding capacity. As experience in monitoring and enforcing competition in the energy hub markets became available, the ex ante structural tests were complemented by ex post ”conduct-and-impact” tests. The purpose of these tests is to analyse whether there are financial incentives for abuse of market power and whether there is evidence that this position has been or is likely to be abused.

A good example is ERCOT monitoring in Texas. After the transition from a zonal to a nodal market in December 2010, a higher rate of structural market power was detected. Between 2005 and 2009, the weighted average number of hours when structural market power was detected was 13%, compared to 25% in 2017, for example. During this period, tests were carried out on the ERCOT market to assess the behaviour of generators, e.g. whether there was intentional blocking of generation capacities in order to inflate prices. The test examined the amount of capacity that should be competitive but is not present on the market. The results indicate that despite the higher observed rate of structural market power, evidence of the abuse of market power has been reduced (see Figure 3 below).

Figure 3. Test results in ERCOT before and after the introduction of the locational market



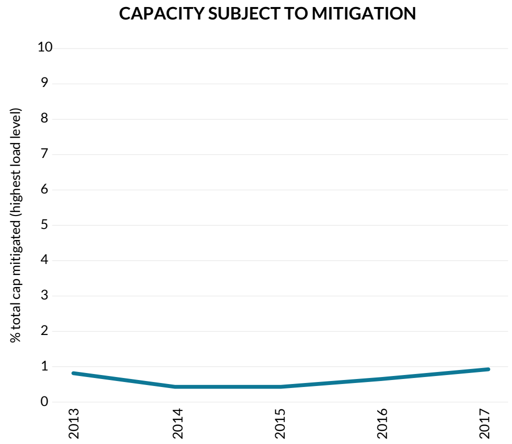
Source: ERCOT Annual State of the Market reports

ERCOT was initially controlling generation bids aggressively whenever structural market power was found, by limiting bids from the impacted generators to their variable costs. Many observers believed this was over-reacting, mitigating bids when there was no actual threat to competition and thus damaging the market's effectiveness. In response, ERCOT adopted an impact test in 2013 to determine whether actors with structural market power were able to benefit from the abuse of that market power.

As shown in Figure 4 below, the result was that the rate of mitigation has been below 1% of total capacity even during peak demand hours. In other words, the reason market participants were not acting on structural market power was that they could not profit from doing so, meaning there was no actual threat to competition.

Any attempt to restrict competition must be complemented by strong market monitoring. It is important to act as close to real time as possible. Legal tools to reduce and eliminate similar practices in the future are also important.

Figure 4. Capacity offers are limited in ERCOT during peak demand hours - test result.



Source: ERCOT Annual State of the Market reports

In conclusion, localised abuse of market power is an issue that needs to be addressed regardless of the pricing methodology chosen. Twenty years of experience with LMP markets around the world shows that in such a market model, market power abuse can be effectively managed. This is much more difficult to accomplish in the case of European single price zones, partly because of a lack of transparency. The elimination of price zones reduces the risk of general market concentration.

13. Market liquidity

Another aspect to be taken into account when discussing market model is the liquidity of the market or the volume of transactions concluded in relation to the volume of physical power. The lower the liquidity, the lower the economic efficiency of the market. The greater the number of offers available on the market, the more likely it is that the expectations of the seller and the buyer will meet. Zone markets offer the appearance of high liquidity due to the ability to trade with anyone in a very large zone at the same price. However, in the event of network congestion, many of these transactions cannot be executed or require costly mechanisms such as redispatching. The apparent increase in economic efficiency resulting from the large volume of available capacity may be stunted or erased by losses resulting from inefficient congestion management.

14. Price risk

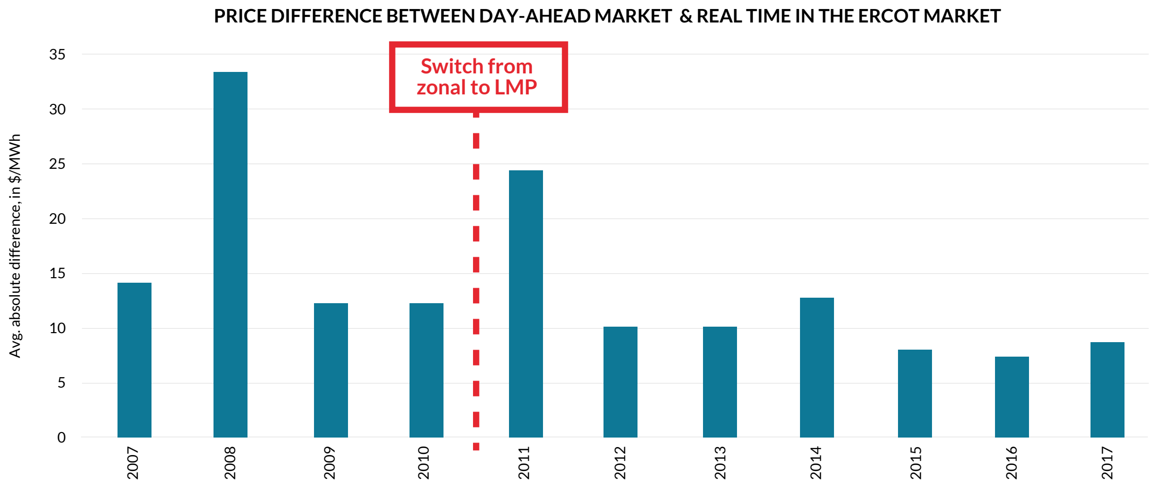
Locational marginal pricing increases the frequency of price differences between the place of generation and the place of sale of the electricity. This happens at least for some time until the restriction causing the high price level is removed. As a result, the level of liquidity and thus the conditions for the industry may vary considerably from one node to another. Where the trading volume is smaller, the market participants concerned must take into account the higher level of price and volume risk. If this is not taken into account, the cost to overall market efficiency may outweigh the benefits of more precise locational prices. The LMP markets deal with this issue in several ways:

1) Designation of a small number of "hubs" - or central commercial nodes, that connect a large number of individual resource and load nodes. Buyers and sellers connected to these hubs can trade at them, increasing the liquidity available to them to trade with others in the market. Prices are still set at each node, and liquidity between a node and the hub may still carry a price risk, although experience with the approach has shown it to be quite successful in reducing market risk.

2) Establishment of a forward market in which allowances to sell electricity are traded in places of the network where there is congestion, without imposing congestion costs on market participants. These rights are created by modelling network congestion within existing security limits. The rights are periodically sold at auction. Purchasers have the right to freely trade them at their own discretion until close to real time.

3) A *virtual tender*, where bids are submitted on the day-ahead market and settled at current prices without real production and consumption. These are purely speculative financial offers that create additional liquidity in day-ahead trading, giving physical market participants additional opportunities to manage market risks. This is a common feature of many LMP markets, but requires careful design to reduce opportunities for abuse.

Figure 5. Market liquidity ratio in ERCOT before and after switching to locational prices



Source: ERCOT Annual State of the Market reports

In the ERCOT market, all three mechanisms mentioned above have been put in place to address the issue of trading liquidity independent of the introduction of the locational market in 2010. As shown in Figure 5, liquidity in the market has actually improved compared to the period prior to the switch to LMP. This experience has been replicated in other markets.

15. Price justice

On the locational market, customers in different locations may have different prices. The smaller the zones, the more the energy valuation reflects the actual marginal costs at a specific location, and the more widespread and diverse are the price differences. As the most granular of locational pricing systems, locational marginal pricing can achieve greater efficiency and flexibility but also a more widely diverse set of differences in prices. This involves political risks and questions about the conditions under which consumers operate. It has to be taken into account that the introduction of the locational market may, in the short term lead to a larger price difference. Over time, however, prices provide incentives and create public support for the new investments (in energy storage, generation units, networks) that can cost-effectively resolve the underlying congestion, and these differences will blur. Local society will see the benefits of new grid or generation investments. Despite the different regulatory systems, different approaches have been taken to minimise the risk of large price differences.

1) **Accepting LMP for generators, but maintaining zonal prices for the majority of customers (model used in ISO - New England and ERCOT).**

   Some market efficiency and flexibility benefits are thus waived. Nevertheless, many of the advantages of the locational market are preserved by ensuring that the load zones reflect the real constraints of the network. Generators receive correct price incentives, thus discouraging them from increasing transmission problems. The ability of smaller customers to respond to market conditions (higher prices) improves over time, so there is a possibility to move to a more sophisticated locational market model after some time.

2) **Distribution of congestion rents collected by the system operator.**

   Simplified, the congestion rent is the difference between how much customers in a given location pay for their consumption and how much is paid to generation to supply that consumption. Congestion rents are collected by the system operator. The system operator can mitigate the impact of high prices on consumers resulting from locational costs by distributing to those consumers a larger share of the collected congestion rent.

16. Security of supply and capacity markets

It is important to consider how the introduction of a locational market affects the stability of energy supply at a price that consumers are willing and are able to pay.

The benefits of a liberalised market are only fully realised if energy market prices are set on a transparent basis, based on marginal energy costs. It is not only about the marginal cost of producing MWh in the merit order. It is also necessary to take into account the cost of meeting the demand for reliable supply and impacts of congestion, especially as transmission and balancing costs are increasing.

Power recovery - new investments

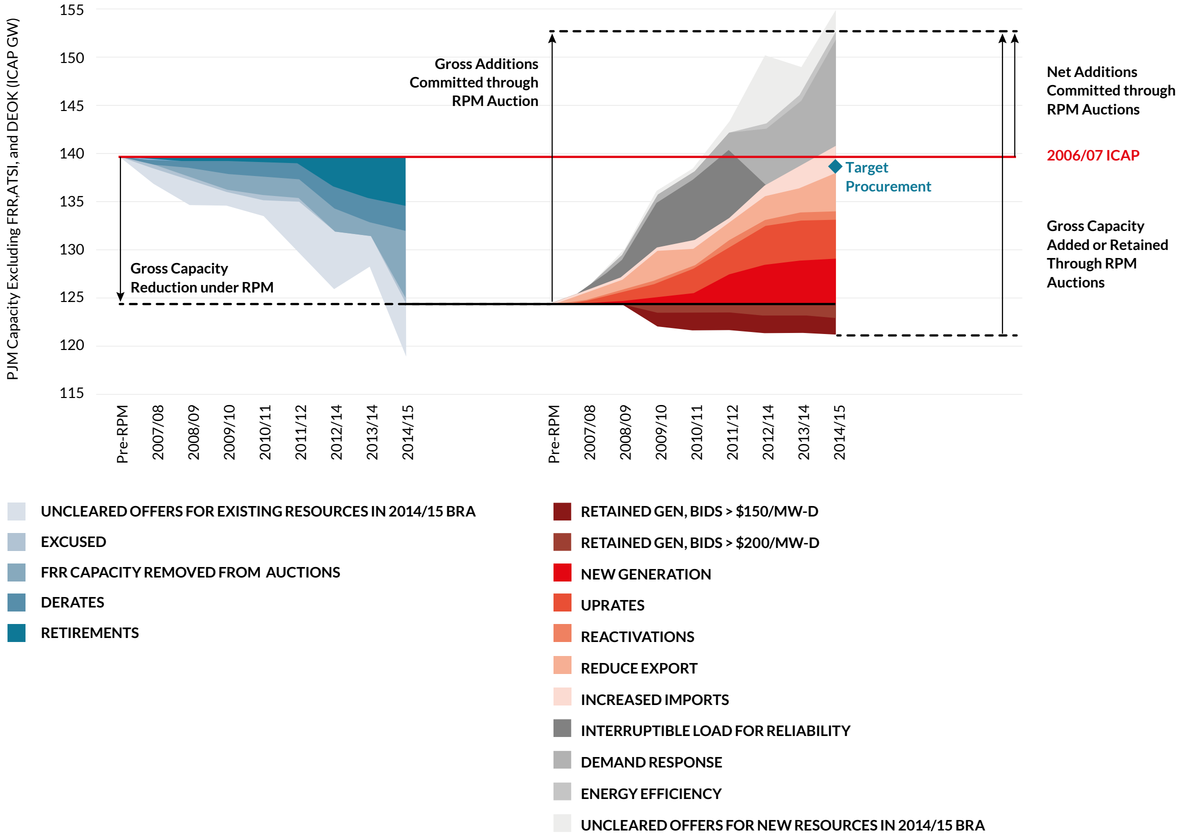
Only a price that takes into account the real and full marginal cost will give impetus to new investments - those that the system and security of supply require and where they are most urgently needed.

Prices that do not take full account of all components of marginal energy costs, including locational costs, can cause the problem of ”missing money.” Where energy prices properly reflect the marginal cost of energy, there is no ”missing money.”

Locational market and capacity market

The capacity market is not a remedy for investments in new generation capacity. British and Polish experience confirms that despite high preparedness fees, the capacity market did not translated into new investments. An inherent feature of capacity remuneration mechanisms (CRMs) is the lack of incentives to solve real problems of the system. The capacity auction cannot be carried out in a way that reflects the location differences in the value of the capacity. As a result, CRMs are not able to replace or effectively allocate the missing locational value for power.

Figure 6. Withdrawal of generation capacity and new investments on the PJM market in 2006-2015.



Source: 2nd Performance Assessment of PJM's Reliability Pricing Model (The Brattle Group, 2011)

Locational markets generate much better price signals, which are important for investments, which in turn are necessary to ensure a stable supply of generation units. It is worth noting that it does not have to be only large units, but also new transmission networks, storage, DSR. To give an example, the US PJM market has been in operation since 1997. Figure 6 above shows the balance sheet for shutting down and introducing new capacity over the period of nine years until 2015. The PJM market attracts the investments needed to reach the resource adequacy target, even beyond what is necessary. The same success in attracting the necessary investments can be observed in other LMP markets in North America, none of which have a long-term capacity market.

Security of supply has always been about more than just "keeping the lights on." It is about value for money, ensuring a level of security of supply that represents a welfare-maximizing trade-off between the value of additional security of supply and the cost of providing it. It is about providing an acceptable level of security of supply at the lowest reasonable cost for the consumer.

17. Summary

- The most important challenge for energy is to reduce emissions at a reasonable cost for consumers and at the same time to ensure security of supply.
- Liberalised wholesale electricity markets in different regions have adopted different electricity pricing models. Markets have evolved to reflect more and more precisely the differences in the marginal costs of generation and transmission at a specific location.

The current electricity market model is no longer fulfilling its functions. Problems related to price signals to reproduce production assets are accumulateing. The development of transmission networks encounters a number of problems ranging from social resistance, the length of investment processes to costs.

- This report analyses the reasons why the energy transformation in the European Union may encounter obstacles related to the development of the system, e.g. the expansion of the transmission grid.
- The locational market can support energy diversification. A location-based market is more economically efficient. It not only stimulates investment in new generation resources and networks, but also in unconventional resources such as DSR, storage and other flexibility options.

The analysis also takes into account certain aspects of the practical functioning of locational markets, such as market power and competition, liquidity and risk management, ways to address equality issues and the impact on security of supply. Experience shows that each of these problems can be effectively solved through good design and implementation of the locational market.

Poland is considering the introduction of a locational market. The ERCOT market was at this stage in 2010. It is worthwhile to present arguments presented by the Independent Market Monitor concerning the expected benefits of the transition from zonal prices to locational prices on the ERCOT market in Texas in 2010[9].

- Improve congestion management capacity, which is one of the most important functions in electricity markets.
- Congestion management through market mechanisms.
- Economic incentives for market participants to invest in and deploy the most needed resources.
- Better use of resources than in the zonal market, where price increases are often observed even when capacity has not been fully utilised.
- Optimization of network utilization at a higher level than in the zonal market.
- Increased efficiency of integration of variable resources (wind and solar energy).
- Correct price signals for investments in new capacity - better congestion management.

Since the implementation of the locational market, i.e. from 2011 to now, the annual reports show that these objectives have been achieved.

9 2011 ERCOT Wholesale Electricity Market Status Report, page 27.

18. Annex I: Experience of selected markets with LMP

It is worth considering examples of several competitive electricity markets such PJM, ERCOT, IESO and NEMO.

PJM

The PJM market comprises a total of 13 states (though not all of them) in the central-eastern region of the United States.[10] In 1997 energy markets were liberalised, bilateral trade and system planning were introduced and zone prices were maintained. (This hybrid structure was and is common in North American markets.) The zones were delimited on the basis of physical network constraints. At that time, the choice of zonal prices was based on the conviction of key market participants that the average annual cost of congestion was small and did not justify the costs and complexity of a full locational marginal price. The unintended consequences of this "simplification" became apparent almost immediately. At the time of congestion, there were opportunities for arbitrage between the zonal spot market and bilateral planning of work, precisely in the periods when the commercial incentives created by these price anomalies were the most problematic. PJM was forced to implement *ad hoc* emergency procedures to protect the system. In 1998, federal regulators approved locational prices for both generation and use of PJM's network. At that time PJM covered only parts of eastern Pennsylvania, New Jersey and Maryland. About 1700 nodes have been identified on this market. In 2000, PJM implemented a financially binding day-ahead market with locational prices, taking into account system security constraints. These changes were to allow for a better linkage between day-ahead market planning and real-time generation units and, consequently, to reduce market inefficiencies. Today, with the expansion of the PJM market, there are about 10,400 nodes, out of about 2,000 generating nodes and 8,100 consuming electricity.

ERCOT

Between 1998 and 2010 in the USA, all but one liberalised market (ISO-New England, ISO New York, PJM, Mid-Continent ISO, Southwest Power Pool and California ISO) transformed from a zonal market to a locational market, at least in terms of prices paid to generating units. The last operator was ERCOT, the independent system operator (ISO) in the Texan market (and the only independent operator not regulated by the Federal Energy Regulatory Authority). The ERCOT wholesale market was launched in 1995 as a hybrid market similar to PJM, but with one spot price throughout the market and socialised congestion costs. In this respect, the market was similar to the current system applied in most EU Member States. It quickly turned out that congestion costs were higher than expected. This was partly due to the use by market participants of the possibilities of manipulation created by a uniform price structure throughout the market. In 2002 ERCOT adopted three (soon four) price zones. However, as early as 2004, independent evaluations showed that the zoning structure did not improve the situation and that the number of inefficiencies and unwanted incentives (related to the management of restrictions both within and between the four zones) was increasing.[11] Attempts to improve the administrative situation on an *ad hoc basis* were ineffective and limited the ability of the system to respond dynamically to changing circumstances and to make full use of existing resources. It has become clear that the zone option - both the original "big zone" and the transition to smaller zones defined by the restrictions - is, at best, not a very expensive simplification. In 2006, ERCOT and the Texas Regulatory Commission started to plan the implementation of locational pricing along with other market improvements, including a financially binding day-ahead market, taking into account system security constraints. In December 2010, ERCOT introduced locational prices for producers (prices for most end-users are still averaged over the five zones defined by *commercially significant restrictions*) and launched the day-ahead market. (Southwest Power Pool was the last of the liberalised markets in the United States to introduce the day-ahea market. The annual market reports prepared by the Independent Market Monitor since 2011 have shown significant improvements in all areas affected by the changes, including a significant increase in the use of transmission infrastructure, which in turn led to a more reliable and cost-effective integration of variable resources. This was a key objective at a time when the share of such resources has risen to almost 20% of annual energy in 2017, in a market that is basically isolated from the rest of the North American network. This makes the share of variable resources in ERCOT (so far almost all wind turbines) one of the highest in the world.

10 For a more complete profile of the organised American ISO/RTO markets, including PJM, see

11 Detailed discussion on market distortions available in the [2008 SOM Report].

IESO

The Independent Electricity System Operator (IESO) manages the wholesale electricity market in Ontario, Canada. The IESO market was created in 2002 as a "two-shift" market with a single spot price for the whole province, with an initial timetable established on the basis of unlimited offers, but with real-time work distribution administratively taking into account the security constraints of the system. In this respect, it is similar to the current system in most EU Member States (including Poland). From the outset, the Market Structure Committee clearly recognised that there are significant shortcomings in what was supposed to be an 18-month transitional arrangement with a single-shift locational market. However, the expected changes did not materialise despite the fact that there were significant market inefficiencies. The lack of transition to a *one-shift* locational market also prevented the introduction of a financially binding day-ahead market with locational pricing, taking into account system security constraints. Temporary solutions had to be introduced which only increased the administrative complexity and non-transparency of market operations. In 2016, IESO initiated a market recovery project which was to solve the main problems of the functioning of the market. The planned reforms included a shift to location-based prices and the adoption of a financially binding day-ahead market, taking into account the security constraints of the system. In addition to locational prices for manufacturers, locational prices will also be introduced for some customers (DSR and storage). All other customers will have the right to choose such prices, and if they do not use it, they will be bound by the zone prices. The Province of Ontatio will be divided into 10 zones defined by significant system restrictions. In addition to solving 15 years of market failure, IESO and the government of Ontario are striving for the rapid integration of variable sources.

NEMO

The National Electricity Market Operator (NEMO) is the independent system operator for all points of consumption in Australia, except for Western Australia and the Northern Territories. The market was established in 1998 and remains atypical in many respects. It is a common wholesale market that resembles the earliest model adopted in the UK market - with central planning of all production and distribution by the system operator - while most of the liberalised markets are, like PJM and ERCOT, markets in which producers themselves plan production and the spot market is physical. NEMO centrally plans the operation of generators based on locational marginal cost, but accounts for customers and producers based on zonal prices. There are five zones corresponding to the borders of the five states covered by the market. The NEMO market has seen increasing problems in recent years in terms of market concentration, manipulation and anti-competitive behaviour leading to what has been identified as an alarming increase in energy prices. In 2016, government NEMO market participants commissioned a NEMO market reform project. The plan recommends the adoption of a financially binding day-ahead market, taking into account system security constraints - for reasons that include better incentives and access to a wider range of flexibility options, including the share of demand, but do not include any recommended changes in zonal prices and clearing. This may be due to the belief that a centralised model for planning work in the wholesale market based on marginal locational cost will be sufficient. Regardless of whether this is the case, it seems unlikely that a similar planning and distribution system will be taken seriously in European markets.

Many other systems can be described here, but these four show how to reach the LMP market. What seems striking is that while the liberalised markets started from many different starting points, most have followed similar paths to locational prices or follow them in combination with binding, safety-restricted day-ahead markets.[12] Although the benefits of such a model of action have long been recognised and in some cases led to action at a very early stage in the process of change, the debate on the net benefits in other cases took longer. The common denominator, which ultimately raised the rate and indicated the scale for many system operators and market authorities, was the expected improvement in the flexibility and efficiency that these mechanisms offer in exploiting the opportunities for the integration of variable renewables (and, where there are largely non-controlled nuclear power plants) in a reliable manner and at the lowest reasonable cost to consumers.

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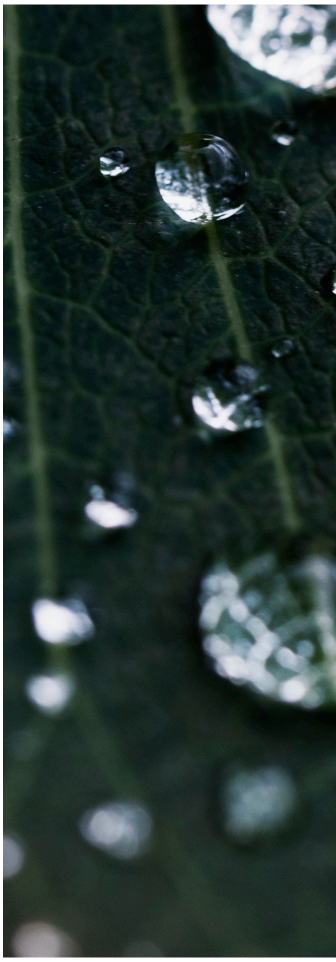
12 It is worth noting that even in the interconnected system in the Western United States - a region with some 38 separate balancing bodies that have long opposed the transition to the ISO regional market - a recent initiative to pool resources into a regional *energy imbalance market* has, from the outset, adopted auctioneer locational prices, largely due to the opportunities offered by a faster increase in the number of volatile resources across the region while maintaining an acceptable security of supply standard.

Notes

Locational market in Poland.

Security of supply, costs and the impact on the energy transition



FORUM ENERGII, ul. Chopina 5A/20, 00-559 Warszawa

NIP: 7010592388, KRS: 0000625996, REGON:364867487

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