CAPACITY REMUNERATION MECHANISMS ON ELECTRICITY MARKETS:

EUROPEAN EXPERIENCES AND POSSIBILITIES OF HUNGARIAN IMPLEMENTATION

By

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ABSTRACT

In recent years, many concerns were formulated regarding the European electricity market design. These concentrated on the lack of price signals which would ensure adequate investments, necessary for maintaining long-run security of electricity supply. In response, in many European countries so-called capacity remuneration mechanisms were introduced which provide additional revenues for supply side assets or for additional demand side flexibility.

In Hungary the electricity market faces several challenges before the new nuclear capacities enter the market which also raises the possibility of a capacity remuneration mechanism. Thus, in my thesis I assess the accessible European experiences and try to calculate two possible scenarios for a Hungarian CRM.

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LIST OF ABBREVIATIONS

EC	European Commission
TSO	Transmission System Operator
NRA	National Regulatory Agency
ACER	Agency for the Cooperation of Energy Regulators
MEKH	Hungarian Energy and Public Utility Regulatory Authority
MAVIR	Hungarian Transmission System Operator
HUPX	Hungarian Power Exchange
SoS	Security of Supply
CRM	Capacity Remuneration Mechanism
SR	Strategic Reserve
CM	Capacity Market
FiT	Feed-in-Tariff
EOM	Energy-only-market
DAM	Day-ahead Market
ID	Intraday market
PhF	Physical Futures Market
IC	Interconnector capacity
DSR	Demand-side-response
LOLE	Loss of Load Expectation
CCGT	Combined Cycle Gas Trubine
OCGT	Open Cycle Gas Turbine
NPP	Nuclear Power Plant
RES-E	Renewable energy based electricty

INTRODUCTION

Electricity plays central role in everyday life, the service-oriented economies of the developed countries prioritize electricity ahead of other forms, being the clean (for the end-customer) and most widely applicable carrier of energy. European electricity sector, however, has observed a quite contradicting market environment in recent years. The promising outlook of the industry is assured by a continuing urbanization and electrification of industrially new territories (like hyping electric heating, the electrification of mobility etc.) thus macrotrends designate further increasing role for the sector. Besides, more demanding expectancies have been also formulated towards the industry as the environmental aspects of the widely discussed, so-called energy trilemma[1] (WEC 2016) became more emphasized also in policy-making. Therefore, the policy decisions of the last decades shifted from a security of supply focus to an equal treatment of environmental, cost-effectiveness and security issues.

In this context, Germany led the way with a complete turnaround, called 'Energiewende' which aims to phase-out nuclear capacities and boost renewable electricity. This policy, not only in Germany, resulted in vast support of renewable power generation, while on the other hand the regulatory actions towards completing the internal market for energy in Europe also continued. From an overall perspective both policy was implemented quite successfully, as national markets for electricity became interconnected and prices started to converge and decrease in whole Europe. Meanwhile, renewable power generation (mainly solar and wind) capital costs also decreased thanks to the accumulating technical experience in both operation and technology production. Not exclusivel, but these policies, however, had serious spillovers, affecting the whole industry coming into a transitional condition.

[1] *Energy trilemma is the concept of the World Energy Council and it represents the threefold policy goal of energy industry i.e. Energy security, Energy equity and Environmental sustainability*

Economists, like Keay, M. (2016) and professional organizations like the International Energy Agency (2016) also argue that the prevailing market design observed such significant distortions that important regulatory interventions and market reforms have to be carried out to maintain efficient and safe electricity supply. The most commonly referred problem is that while the whole operation of electricity market is centered around the short-run marginal cost (SRMC) of producers, renewable power plants do not have any of that. Several experts argue that the implied effect, called merit order effect (discussed in detail later) indirectly threatens the security of supply and the sufficient remuneration for new investments. Therefore, one of the possible interventions, called capacity remuneration mechanisms (CRM) aims to incentivize reliable and stable power generation and availability. As the IEA (2016) frames it, '*A capacity mechanism seeks to incentivize sufficient investment in, or to prevent the economic retirement of, capacity in order to ensure resource adequacy.*'.

Based on the above, this thesis aims to better understand how CRMs can fit into the current market design of electricity and to assess European experiences with implementation. Furthermore, as already on several forums it was discussed by the Hungarian industry (Lehocz 2016) and the regulator (Csermely 2017) to assess the Hungarian system whether it needs such intervention and if yes, what type should be applied.

1.1. Concerns on the Hungarian electricity market

Like the European markets in general, there might be security of supply concerns on the Hungarian electricity market which could form legitimate basis for regulatory intervention. Before detailed analysis of the possible actions, below the thesis tries to point out three pivotal features of the Hungarian market supporting this idea. These issues below rather serve as motivation behind further analysis of capacity remuneration mechanisms in the Hungarian context than thorough evaluation of the Hungarian market.

Concern 1 – The indispensable import

Starting from the years of the global financial crisis, the net import share in the Hungarian electricity supply increased steadily until 2014 as the Figure 1 illustrates. Since then slight decrease is observed but based on the predictions of the Hungarian Transimission System Operator (TSO), MAVIR, a significant import share is to remain on the long-run (MAVIR 2016b).

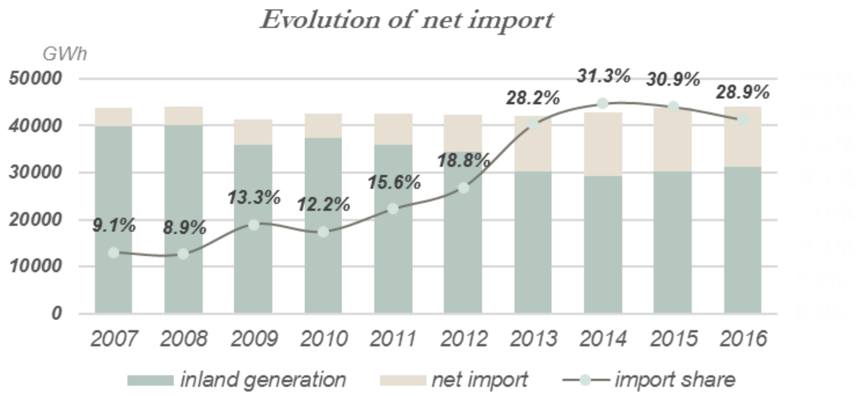

Figure 1. The historical share of net import in the Hungarian electricity supply

Although the Hungarian power system has adequate interconnector capacities for covering the excess demand compared to the inland generation potential, still policy-makers might find it risky to leave the security of electricity supply to foreign producers. The so-called *remaining domestic capacity*[2] plan for 2017 is negative for the whole year, not considering import capacities. This means that there is not enough available inland generation capacity to fulfill electricity demand in the country. But this is not only a problem of trust towards foreign generators. In case of extreme weather conditions for instance which arise regionally, effects are not restricted to domestic production (like an unplanned outage in a Hungarian power plant) and additional capacities in the foreign power systems might not be enough for the Hungarian demand. So, this issue brings us the questions of to what extent reliance on foreign production can be allowed, if it is allowed. Also,

[2] *For a period, 'remaining capacity' is calculated by deducting the maximum capacity of the year from the available capacity for that period i.e. capacity of all power plants which are ready to produce*

what arrangements can assure that foreign production will be provided for the Hungarian system in scarcity events also (this can also form the basis of CRM introduction).

*Concern 2 – Lack of investments in a degrading power fleet*Another challenge of the Hungarian energy policy is the aging and shrinking power plant fleet which is illustrated on Figure 2. As it can be seen on the graph, the last significant investment was carried out in the end of the last decade. This was the gas-fired power plant in Gönyű, since then no significant investment plans were published besides the planned nuclear investment in Paks. However, latter cannot be considered in the fleet till 2025[3], so meanwhile the situation is worsened by the fact that the operating plants are aging, which decreases the overall reliability of the available capacity.

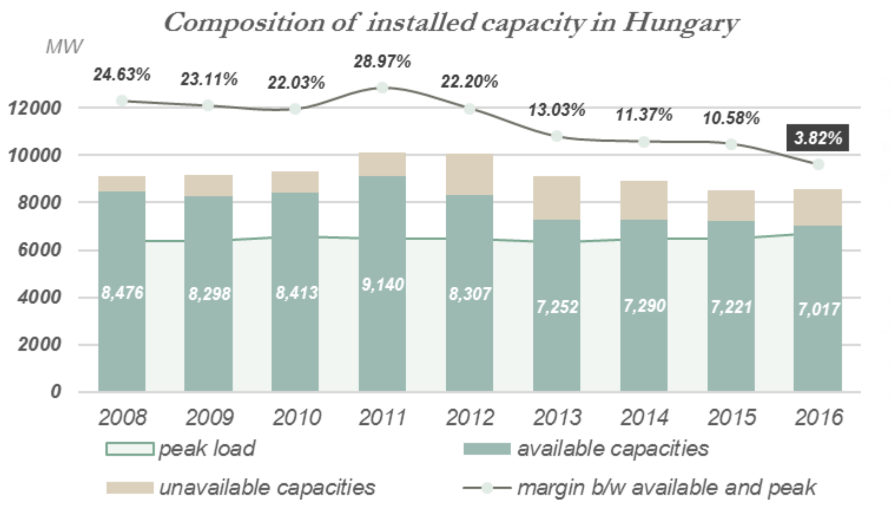

Figure 2. The historically available and non-available capacities in the context of peak load

Regarding investments on electricity market, the main problem is the long commissioning, long payback, also significant decommissioning time and capital which is necessary. Therefore, if the trends on the graph regarding increasing peak load and decreasing available capacity continues, the slightly positive margin will become negative i.e. the Hungarian system not even in theory is capable of supplying the maximum power demand in the country. The only investment which is

[3] *Leaving aside the fact, that almost all nuclear investments are behind schedule all over the world and there are strengthening doubts regarding social acceptance of the project*

underway is the planned nuclear units whose commissioning is still to be started and which will last about 8-10 years according to plans. During this time exits of a few old power plants is expected. For the policy maker, this concern might imply the question why there is no new investments underway, if there is scarcity on the Hungarian market, and secondly what regulatory measures might be available to intervene.

Concern 3 – Forthcoming intermittent renewable boom on the Hungarian market

In Hungary, renewable power generation (RES-E) is not yet widespread, in 2016 the share was around 7% based on the data published by the Hungarian Energy and Public Utility Regulatory Authority (MEKH)[4]. Two factors brought positive outlook regarding renewable capacities, one connected to the change of support schemes, and second is the lowering technology costs. Based on the press release of MEKH, over 2000 inquiries were submitted before the final deadline of applying for feed-in-tariff (FiT)[5] support. Therefore, in just a few years more than 1000 MW of solar power plant might be installed in the Hungarian system. This amount can have around 5-800 MW (approx. 10% of the prevailing installed capacity) competitive effect on the market for the high-demand-periods (i.e. daylight).

In terms of energy policy and market design, renewables have unique characteristics thanks to the support schemes. Their generation cannot be curtailed[6] by the TSO, thus in case of a stable demand for 1 hour, if an increase in sunlight causes additional solar power generation, other generators must decrease their output accordingly immediately. That is why the first important question is whether adequate flexibility is to be provided by other Hungarian generators which can follow the instant power requirements. Secondly, the long run competitive effects might be

[4] *Downloaded from http://mekh.hu/havi-adatok (Data accessed on 03/06/17)*

[5] *Feed-in-tariff support shceme is the support given to renewable power generators and which includes a fix price for the generated energy and the ban on curtailment*

[6] *Curtailment is when because of technical or economic reasons the system operator forces generator to reduce its production*

discussed i.e. import or inland generation will be priced out of the market thanks to their entrance. Latter is beneficial on the long-run, however, former might mean that the first two concerns might be worsened.

Altogether, the Hungarian supply's outlook seems to have several uncertainties. Since power industry is characterized by long investment cycles, any chance for occurring capacity shortage has to be evaluated in a timely manner. Therefore, the understanding of CRMs as possible intervention tools and choosing possible frameworks to implement in Hungary might be a relevant task at the time.

1.2. Methodology

The chosen topic requires processing a wide range of literature and carrying out both qualitative and quantitative assessment. In order to properly see the possible place of CRMs in the prevailing market design, in Chapter 1 the main segments of the used market model is described and a special attention is given to security of supply and how operators realize revenues on the market. Also short overview is given on the main problems of this market operation for introducing the different CRM designs in Chapter 2. Next experiences and the EU standpoint are also presented for the reader to conclude what are the most important messages for newly implemented CRMs in the EU. After having an oversight on CRMs, the Hungarian market is to be analyzed shortly by Chapter 3 with highlighting the most relevant features of Hungarian market functioning and outlook from a security of supply and capacity remuneration point of view. After setting up the scene for the Hungarian market, Chapter 4 chooses and analyzes two CRM design for the Hungarian market which could be possible from a policy-maker point of view. Finally, Chapter 5 formulates the main policy messages concluded from the analysis.

Chapter 1 ELECTRICITY MARKET DESIGN IN THE EU

For the thorough understanding of how CRMs can fit into the current market, the prevailing market design applicable for the EU is discussed below.

1.1. Value chain in energy industry

Generally power supply industry can be characterized as a network industry, however there are special characteristics which make the market design more complex. There are important distinctions which can be made both about the operation and the roles inside the value chain. First, for assessment it is important to note that physical and financial flows can only be matched ex-post (a fine illustration of the differences is Figure 8) which is because of the physical characteristics of the grid. Therefore, metering and accounting can be highly complex and inevitable for operating the market. Roles are also important to distinguish as almost all segments of the value chain has also regulated and competitive market players. From this point of view the grid infrastructure should be mentioned which can be considered as a natural monopoly and operated by regulated entities. Latter companies will always be at the center of trading and matching supply and demand, where the most crucial task is to ensure that congestions are handled appropriately fulfilling all trading and physical constraints.

These constraints are originated from the fact that from the grid's point of view supply and demand has to be equal at all time, so balancing evolved as separate market place with several submarkets. To make it more hard to assess, the field is highly sensitive in political sense which results in submarkets also on the retail market where in many countries regulated and competitive prices are also applied.

Finally, the transitional state of play, already mentioned in the introduction, can be also concluded from the reorganization of the conventional value chain. The historically dominant central power generating units are supplemented by small-scale near-the-customer generating infrastructure which hardly fits the conventional one-way value-chain of the industry. Nowadays there are important developments rather on the end of the value chain, which forces utility industry to evolve its business model and become more customer-oriented.

1.2. Market design

In the European Union, according to the TFEU[7] (EC 2008) the main goal in energy industry (as in many other industries) is to create the internal market. In line with this document already three energy packages were passed by the EU Parliament while a fourth milestone has been already proposed by the EC in the end of 2016, called Winter Package (EC 2017). The European Target Model however, is not yet a manifested document, rather it is a constantly broadening set of proposals which aims at perfecting an energy-only market (i.e. the basis of economic transactions are the amount of energy (MWh) which is consumed and generated, <u>*not*</u> the power which is available from the generators).

According to (Keay 2013), the internal market has two main characteristics: (1) *energy-only regional* markets based on zonal marginal pricing and (2) *market coupling*, enabling that in zones the lowest possible prices can occur besides effective cross-border trade. However, while already in 2011, the EC set the deadline for completing internal energy markets for 2014 (with the help of detailed network codes, intended to set the rules of the different levels of market integration), in 2017 yet another set of proposals were prepared by the EC with new ideas. Now many suggest that the completion is expected to be possible only in the beginning of the 2020s.

Electricity as a commodity has several unique characteristics which make market mechanisms more complex than in several other commodities. Namely, summing (Keay 2006) and (K. Gerse 2014) the following issues should be mentioned.

[7] *TFEU is the Treaty on the Functioning of the European Union*

- The special relationship between demand and supply comes from several facts. Electricity, unlike most goods is not storable, which makes supply exposed to demand. Additionally, demand has almost zero elasticity, which together results in a supply side which cannot influence its production and the traditional tools to deal with excess demand (queuing and pricing (Keay 2006)) does not work because of technical constraints.
- Supply side investments are highly capital-intensive and long-term projects are general requiring a more-than-average stability and predictability regarding to regulatory and market environment.
- The industry has another important part which is the network and infrastructure needed to maintain and which is considered and regulated as natural monopoly. Therefore, the value chain between generators and consumers consist of a complex system in which competitive and regulated markets need to co-operate. Keay, M. (2006) also points out the interesting asymmetry between transmission infrastructure and production assets. In many cases transmission lines (natural monopoly, only built based on regulatory and/or political decisions) can substitute supply side assets (which should be built based on market signals) however, the relation never holds in the other direction.

The above features already imply that liberalization of electricity markets is not possible with pure deregulation (as having a regulated segment in the middle of the value chain). To be operational, the value chain needs electricity suppliers to operate on a few separate, still interdependent markets.

1.2.1. Segments of the energy-only market

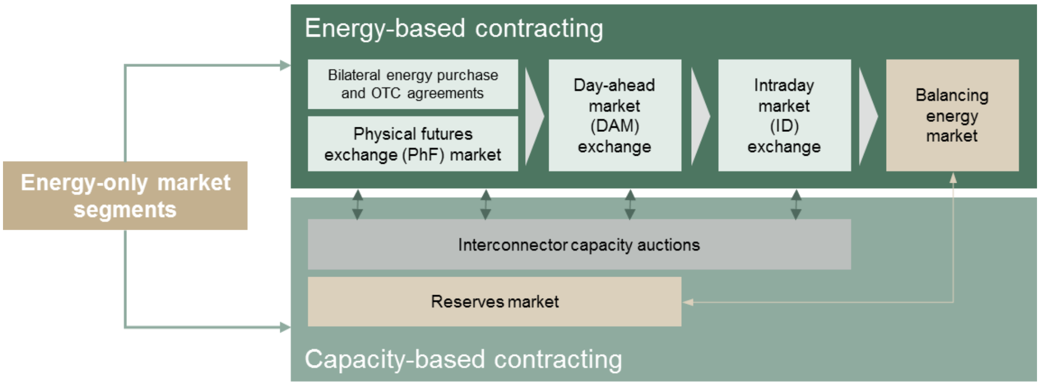

Figure 3. The relevant market segments on which generators and traders are operating and realize profit

As already stated, the cooperation between segments is the core of operation. And despite its name, 'energy-only' it does not rely only on products derived from energy (MWh) it has inevitable parts which are capacity-based market segments (Figure 3) whose primary aim is to serve and make the energy-based market segments technically operational.

Generators through their traders market their produced energy basically on five market segments, the futures market with yearly, quarterly, monthly and weekly products, also traders can cover their portfolio outside of the power exchanges e.g. bilateral contracts or OTC markets, then comes the spot market of electricity, the day-ahead market, then in more and more regions intraday markets are also in operation to cover the imbalances after the day-ahead market closure. Finally, there is the last resort for the transmission operator (TSO), the balancing energy market which is to cover the imbalances left after the intraday market closure for the sake of safe operation (hence the non-storability).

These market segments operate on a regional basis, however, the interoperability of different regions could not be possible without the interconnectors which connects the so-called bidding zones[8]. Latter represents the geographical fragmentation of the electricity markets however, these

[8] *Bidding zones are regions for which traders do not need to consider any transmission capacity constrain, the market mechanism does not include transmission capacity allocation*

usually cannot be considered as separate markets (for instance, in Hungary the electricity supply would not be possible considering only the inland – inside bidding zone – production). The trading between these zones is carried out through a capacity-based market, which is the cross-border capacity auctions. Traders can only buy/sell electricity across biding zone-borders if they own enough transmission capacity rights.

Another capacity based market is the reserves market. This market is to ensure that there is enough capacity unused in the system which can provide balancing energy to maintain the short-run SoS.

1.2.2. Capacity remuneration on the energy-only market (EOM)

Power plants do not only offer energy as their product, as for the system not only needs energy. Therefore, following the approach of (Lopez and Lorenz 2015) there are three different products which can/should generate revenue for power plants. These are the energy (in MWh) which is produced and sold to the end-customers on one of the platforms, secondly the flexibility of the power plant, which is the capability to change power output following the changes in demand. Latter is sold (in MW/min) currently to the transmission system operator on the reserves market and the costs are covered by grid fees. Last, availability of the power plant is also a product which, according to many economists, should also be marketed on a separate market. This is now hardly priced on the market; this deficiency would be supplemented through the introduction of CRMs. Meanwhile, availability is only valuable in scarcity situations for which the concept of scarcity rents applies.

In the prevailing model using the terminology of (FTI CL Energy 2016) an operator can earn additional revenue for its availability in two ways, through scarcity rents and through a mark-up on SRMC (illustrated in Appendix). Former one can be the result of such rare events when demand can hardly be met by available generation. This time if some customers get curtailed and not provided by electricity, the price in theory would hit the value of loast load (VOLL) which would guarantee the so-called scarcity rent for covering fixed costs. However, important to mention that in most cases price caps are set for wholesale prices well below VOLL.

The concept of mark-up above SRMC simply originates from the idea that electricity markets will always remain oligopolistic and entry has high barriers, this way price-setting producers can influence the market price with risking selling less, but altogether earning more.

1.3. Measuring security of supply on electricity markets

Measuring security of supply is a bit of a challenge for policy-making as possibly it should be a metric used for quantifying the counterfactual. Therefore, several approaches emerged basically all centered around some stochastic assumptions or methodologies. Below the paper presents which metrics the British regulator prefers based on its methodology review (DECC 2013). *Reliability margin* is the ratio of excess capacities compared to the de-rated capacity which fulfills the peak demand. De-rating is by using technology-specific experimental data to reduce the actual capacity to a reliable level on which that technology can be available for a specific period of time.

Loss of load expectation (LOLE) and the expected energy unserved (EEU, sometimes EUE) are more sophisticated, stochastic metrics for measuring SoS and used by most of the European TSOs. In Hungary, the probabilistic version of LOLE, the loss of load probability (LOLP) is used and set to 1% based on Gerse, A. (2015).

1.4. Problems with the energy only market

The core of competition on the market is the already mentioned merit-order. There, basically the supply curve is constructed from the short-run marginal costs (SRMCs) of the different generators by a stepwise order. This supply curve is crossed by the demand curve for each time unit the exchange uses for clearing (mostly 15 minutes or 1 hour), which results in the uniform clearing price. This mechanism is the main argument against energy-only markets, as energy industry is one of the most capital intense areas, where return of investment is mostly measured in decades and asset-related entry barriers are traditionally high. In contrary with that, SRMC (by definition) considers only short-run costs, generators mostly decide above their market entry based on fuel-related variable costs. Especially after renewables entered the market in significant amount, two widely discussed problems emerged.

Missing money problem

First one is the missing money (and markets) effect which originated from the simple problem that the market operation being catered around SRMC, investment decisions cannot be made (Newbery 2016). This is the case if for the capacities which have high fixed costs are marginal ones, therefore they are cleared on their SRMC, thus they have no surplus for remunerating capital costs and fixed operation and maintenance costs. This is the case mostly for conventional gas-fired and coal fired power plants, especially with the new ones.

Merit-order effect of renewables

The second problem is the so-called merit-order effect of renewables. With them a new type of actor appears, as they act on the market following a close to zero SRMC. This way they are not even a 'participant' on the market, on the merit-order they came into as the first players, therefore pushing towards marginality generators who would be feasible to operate without renewables.

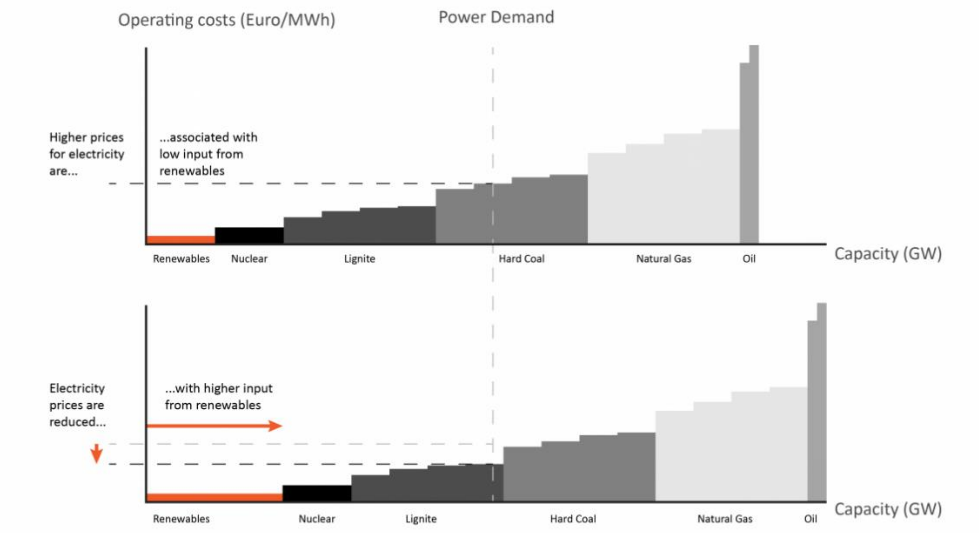

Figure 4. The merit order and the effect of renewables on the clearing price (cleanenergywire.org 2015)

However, the system needs these conventional generators which are not exposed to weather conditions, as demand needs to be supplied constantly. The loss resulted by the renewables in-feed can partly be compensated on the reserves market, where conventional generators have technological advantage. However, it is most probably not enough for recovering fix costs of generators. At the end of this process, conventional generators with high fix costs, therefore newly installed, modern power plants are the ones which are ruled out from the market. This however hinders the policy goals of the EU, as it helps carbon-intensive, old power plants to stay in the system.

Finally another important issue with the current market mechanisms, that it has several parts which is to ensure low enough prices and not letting high prices occur. These are price caps which prevent marginalized power plants to take advantage of extreme prices coming from scarcity pricing[9]. Hypothetically, this would allow for generators with high fix costs to operate in a feasible way with only generating power a few tens of hour yearly.

[9] *Scarcity pricing:*

Chapter 2 Reviewing CRMs in the European context

In its detailed overview of market reform possibilities towards the transition to low-carbon power systems, the International Energy Agency (2016) designated a separate chapter for capacity mechanisms. The field is already quite broad as many countries implemented such mechanisms is various ways. Below I try to categorize these and give a perspective on the most important experiences of European implementations.

IEA in its publication simplified the question of whether to introduce a CRM or not to a decision tree, presented on Figure 5. In this the central role is scarcity pricing as in theory scarcity pricing and CRMs might be considered as substitutes. However, examining the different examples the picture might become more complex than only letting scarcity pricing or not.

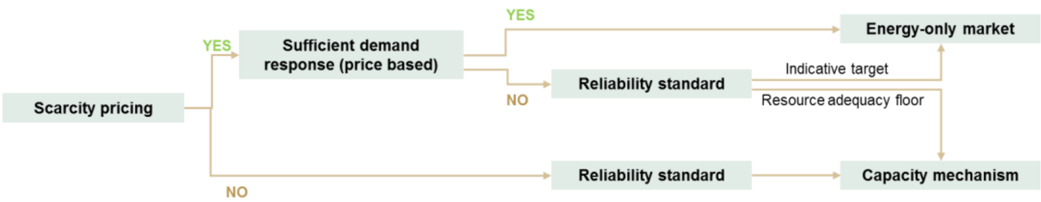

Figure 5. The decision tree describing policy choices regarding CRM implementation (IEA 2016)

2.1. Types of CRMs

The most widely used categorization og CRM setups were drawn by ACER (2013).. According to this report we can differentiate between 5 different options which are already observable in Europe as Figure 6 also shows these.

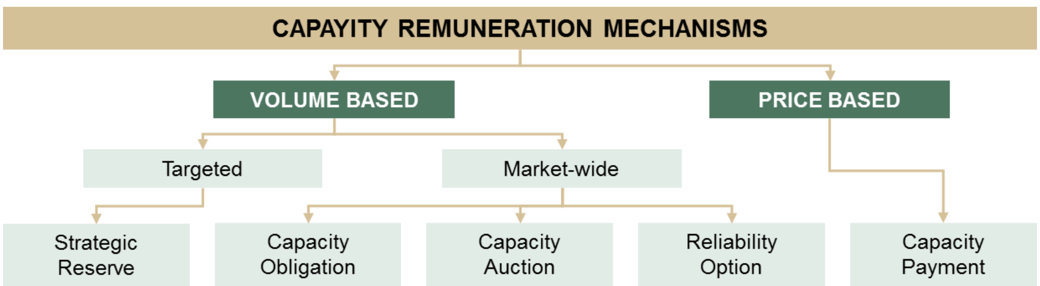

Figure 6. The different possible models for CRMs (ACER 2013)

Table 1. The descriptions of different CRM types (Hancher, De Hauteclocque, and Sadowska 2015)

Strategic reserve	A central agency (the regulator) decides on how much capacity from how many generators are necessary for ensuring the adequate SoS. After the decision, the stated amount is contracted out based on tendering, and the contracted generators are excluded from the energy market for the time of the contract *Rationale*: Old power plants can be excluded from the market and from baseload[10] generation for example because of climate policy reasons, still maintaining backup power for SoS
Capacity obligation	Large suppliers and consumers are obliged to contract a specified amount of capacity, therefore not only the offered energy should be procured, but associated capacity also through for instance certificates. Also if in some scarcity situations suppliers do not have the capacity, while energy is not supplied, penalty is required. *Rationale*: The mechanism tries to avoid from a customer perspective non-supplying, still the model can be constructed on competitive grounds.
Capacity auction	Similar to the strategic reserve, only the contracts are tendered by the TSOs and these interventions are one-off, so the TSOs can use it in temporarily inadequate supply side interventions. Also these generators are not excluded from the energy market *Rationale*: It might be an efficient, still minor intervention from the TSO side, if applied properly.
Reliability options	In this model the regulator entitles one counterparty (TSO, supplier etc.) with the right to procure options with some generators. These options are constructed with a strike price, for which the counterparty can purchase energy if needed. Generators stay in the energy-only market. *Rationale*: The strike price ensures both parties, therefore uncertainty regarding to future market conditions are reduced, investments can be incentivized.

[10] *Baseload generation*

Capacity payments	Pre-determined amount of income provided to the generators. The method for determination of the exact amount can differ.

Evaluating the different mechanisms regarding main purpose, link to EOM, Benefits, pitfalls and ComPol issues

2.2. EU standpoint regarding CRM implementation

Based on market environments, evidence shows that countries ended up with different CRM setups. This diversity does not entirely serve the interest of the EU policy goals so in recent years CRMs became a central topic for EU assessment, also the Directorate General for Competition started and inquiry to see the state-of-play of CRMs in Member States (European Commission 2016a). Next the new regulatory package, published on 30th November 2016 dealt in detail with how to design CRMs on common grounds and several proposals were introduced which is illustrated on Figure 7.

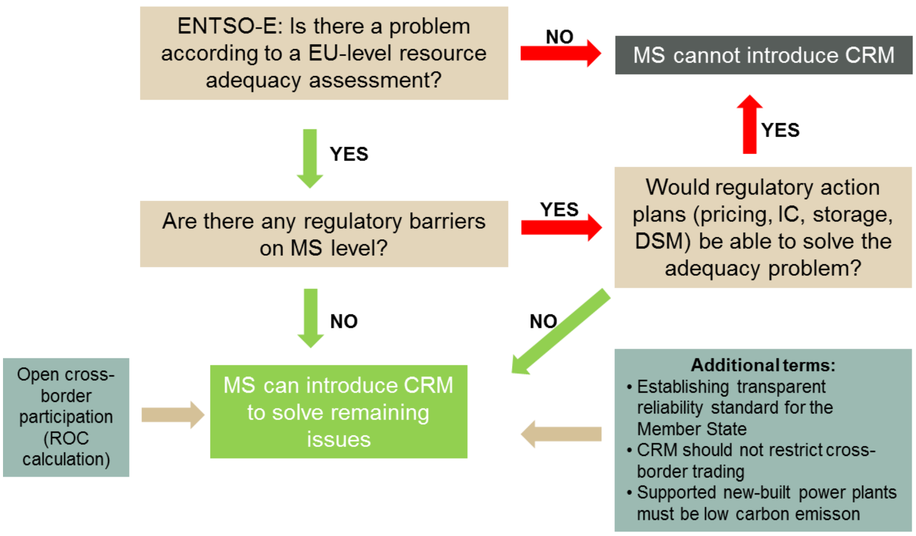

Figure 7. The proposed way of validation for new CRM implementation in a EU Member State (MS) (Kaderjak and Kerekes 2017)

2.3. Already existing mechanisms in the EU

Although the most common way of clustering the different mechanisms is the one shown by Figure 6, the implementation of those mechanisms is not straightforward. The report of the

European Commission, prepared by the Directorate-General for Competition in 2016 (European Commission 2016b) found 28 different CRM schemes in 11 countries. Below the study tries to distinguish the key design elements of three countries' CRM setups and link them to those special characteristics which might have driven the policy making process.

2.3.1. Belgium

In Belgian electricity supply, besides the long-serving conventional generators, import also plays an important role. Based on the data of the European Network of Transmission System Operators – Electricity (ENTSO-E)[11], in 2015 the nuclear and fossil units provided almost 60% of the supply along with the 24% of import electricity. The remaining 17% came from solar, wind and other renewable energy sources. This energy mix might imply scarce inland capacities, as the import share is significant but the problem, which triggered the need for CRMs is more sophisticated than that. The presentation by (De Clercq 2015) from Elia, the TSO of the Belgian power system, reveals that besides the 14 GW of peak demand, the country had 20.6 GW installed capacity in 2013 and the generation adequacy problem described in the presentation originates rather from the outlook and availability of those capacities. As having nuclear ad the backbone of the country's electricity supply, the power plants' scheduled closure in 2015 unveiled the SoS concern first. Also besides the nuclear phase-out passed already in 2003, according Vandenberghe, W. and Gonne, R. summed up the reasons in (Hancher, De Hauteclocque, and Sadowska 2015) in three more factors: low investment appetite; retirement of existing plants and intermittency of renewables. In general, the Belgium energy policy built on and borne the consequences of two important decisions:

[11] *Downloaded from https://www.entsoe.eu/db-query/production/monthly-production-for-a-specific-country (Data accessed on 30/05/17)*

- Environmental scope: Phasing out nuclear through a moratorium for the construction of new nuclear power plants and supporting intensively renewable energy technologies, which mean that the baseload power plants of the Belgian power system is to be closed and instead intermittent generation enters.
- Market integration: The successful CWE market integration, which coupled the markets of Germany, France, Luxembourg, Belgium, Austria and the Netherlands together with the renewable support scheme resulted in high import share and missing money problem causing low investment appetite and retirement/mothballing of existing capacities.

According to the Nuclear Phase-Out Act, accepted in 2003, 1800 MW nuclear power plant should have been closed in 2015 and also the suspension of other nuclear units because of safety issues, which resulted in a significant increase in net import. As part of the governmental actions the lifetime of 1 GW power plant was extended by 10 years, and capacity mechanisms were proposed to ensure long-term generation adequacy by the energy minister.

Capacity mechanisms

The Belgian energy system planning relies on three different entities: the TSO (Elia), the Ministry (Federal Energy Agency) and the regulatory commission (CREG). All of them are obliged to monitor the SoS issue in the power system, but the Federal Energy Agency, as the part of the Ministry is authorized to initiate and legislative changes based on its own Forecast Study, prepared in every four years, and the consultations with Elia and CREG. Latter organizations are also have the right to propose legislative changes or any intervention to the Agency and to the Ministry in case of SoS risks.

Two types of capacity mechanisms were introduced in 2013 with adopting the Energy Policy Plan of the energy minister. One mechanism gives the opportunity to the Ministry to tender for new power plant capacities, but a strategic reserve was also introduced giving opportunity to the TSO to contract power plants, aiming to exit the market for temporary for easing temporary SoS risks. The Energy Policy Plan introduced the two mechanisms as complementary instruments, strategic reserves serving short-term adequacy issues, while the tendering process targeting the long-run solutions. However, as the table also shows the tendering solution has not been worked out properly, and CREG also had relevant doubts regarding the proposal as the applicability is not clearly defined and raises discriminatory issues also (Hancher, De Hauteclocque, and Sadowska 2015).

Experiences

Experiences are limited only to the strategic reserve. Elia first launched its tender for the winter period of 2014/15 after publishing and consulting the required security of supply analysis. Based on the press release of Elia (Elia Group 2017) for the winter of 2016/17, 750 MW is contracted but have never been used before. Considering latter and the costs mentioned in (Sia Partners 2016), end-consumers pay 0.67 EUR/MWh for these contracts which have not been used yet, the cost benefit analysis of this scheme might be questionable.

2.3.2. France

The French electricity industry is characterized by the immense share of nuclear power generation. In 2015, the share of nuclear was above 85 % in the inland power supply, and the country was a significant electricity exporter as data shows[12]. However, the energy policy of the country opted also for electric heating, which seemed obvious based on the high amount of baseload power available. As a result, the temperature sensitivity of the demand increased excessively, therefore the pace of peak load[13] increase became higher than the pace of consumption increase i.e. for a decrease of 1 °C in daily average temperature, the peak demand increases by 2.4

[12] *Downloaded from https://www.entsoe.eu/db-query/production/monthly-production-for-a-specific-country (Data accessed on 30/05/17)*

[13] *Peak load is commonly referred as the annual maximum of demand in terms of power*

GW (more than 2% of peak demand) (FTI CL Energy 2016). Latter was the main motive behind introducing the capacity market, based on the so-called NOME Law, passed in 2010.

The market started to observe lack of new investments, low cost recovery on energy-only market in the mid-2000s. When RTE, the French TSO in its predictions first identified significant risks in security of supply for the upcoming years, the Parliament reacted with a new Multi-year plan of investment and a working group. Latter was launched to prepare the proposal on how to handle peak demand growth. Thus, a new proposal was presented for the new market design in France (NOME) which was adopted by the parliament in December 2010.

Besides the capacity mechanisms, the new electricity market design included another unique framework, called ARENH. This guaranteed special, regulated access for non-EDF suppliers to energy generated by the EDF-owned nuclear units on a regulated price (because of the Comission's concerns on the low competition on the French market). Capacity mechanism in NOME was initially framed to offset ARENH and make all supplier to contribute to SoS.

Capacity mechanism

The French capacity market which was proposed by a Senate Committee with the help of RTE and the regulator was built on fundamental choices made by the Committee (FTI CL Energy 2016),

- opting for a market-based solution which does not include any public financing,
- no distinction regarding to technology or existence of remunerated capacities,
- least possible intervention into the functioning of the prevailing energy-only market (including the international market)

The European Commission started its state aid investigation in 2015 November, and finally approved the French measure on 8th November 2016 (European Commission 2016c). The approved system functions as a market where capacity obligations of suppliers and capacity certificates of producers are matched. The market is illustrated by the Appendix 1. The main functioning features of the market is the four-year-long lead time within which, the certification process for operators can be fulfilled and already the trading starts between operators and suppliers. For the suppliers, the obligations necessary to procure is set by the regulator in terms of a LOLE value to be achieved.

Experiences

There has been no real experiences with the capacity market as it has been operational since the beginning of 2017, but a detailed modelling and evaluation was carried out by FTI Consulting (FTI CL Energy 2016). In this for the short-run they do not expect any distortions on the market as the bidding strategies and behaviour is not affected by the mechanism (as the economics of EOMs are centred around SRMC which is not affected). For the long run, the same report highlights the positive effects of the capacity market on DSR, as the eligibility criteria gives the same level playing field for DSR as all other. Thus, the price elasticity increase of demand is expected handling one of the core issues on electricity markets. Another aspect is emphasized which is the high consideration of interconnectors which aims to avoid overinvestment inland and gives credit to production abroad also (initial calculation of LOLE target was carried out with 7 GW of ICs out of the existing 9 GW).

2.3.3. Great Britain

British energy industry has some characteristic features which makes energy policy decisions special in the country. First, being an island requires special approach regarding SoS but regarding natural resources. From the industrial history perspective, it is not an accident, that coal-based and conventional power generation has high traditions in the country. In addition to that, Great Britain always led the way in nuclear industry, besides the 62% share of fossil in inland generation the country had 21% from nuclear in 2015 (based on ENTSO-E data[14]). However, in the 2000s with the newly set decarbonization targets and observing an aging power plant fleet, the long-run generation adequacy became uncertain. The Department of Energy and Climate Change (DECC) also realized similarly to other European countries that the existing market design does not provide enough incentive for new investments. Therefore a new proposal was prepared, called the Electricity Market Reform which included several modifications regarding market design including a CRM (Yiakoumi and Rouaix 2016; Department of Energy and Climate Change 2013).

The main aims of the proposal were security of supply, decarbonization and more affordability for end-customers and not only supplemented the EOM with the capacity market, but also reformed balancing in the EOM and created the legislative framework for implementing Contract for Difference.

Capacity mechanism

British electricity market design has several features which acts as a forerunner for continental European market solutions regarding its Balancing markets, the energy-only markets, also capacity markets. The capacity auction of Great Britain is an auction-type bidding process carried out 4 years ahead of delivery the price is set on paid-as-cleared basis. The security of supply is assessed by National Grid (TSO) against the criteria set by the Government. Based on the report, also the government decides on the target capacity which is to be auctioned for the corresponding years, by setting a demand curve based on the net cost of new capacity (net-CONE). Regarding eligibility, the mechanism is technology neutral and demand-side assets and interconnectors are also taken into consideration. Only capacities supported in other mechanisms are excluded which are the renewable supports, the CfD mechanism and the balancing reserve participants. For participating, an obligatory prequalification is carried out, after which bidding is voluntarily. The

[14] *Downloaded from https://www.entsoe.eu/db-query/production/monthly-production-for-a-specific-country (Data accessed on 30/05/17)*

length of contract differs depending on the type of capacity, as generally it is a 1-year contract, but for refurbishment also 3 years can be offered and for new built, 15 years. Finally, demand side response has another special feature, which is that it can only bid on the T-1 auction as it is hard to predict whether a demand side asset will be available for DSR 4 years later or not.

Experiences

Regarding experiences, the British capacity market is one of the most widely discussed CRM. It has already 3 years of experience, thus already several enhancing proposals were published by several authors (Orme 2016; Gammons and Anstey 2015). The papers mainly researched how closely the pre-set targets of introducing capacity remuneration mechanism in Great Britain are met by the results of the first auctions. Conclusions highlighted some common phenomena which should be addressed by some regulatory changes:

In the first auctions (held in the end of 2014 and targeted the 2019 year) power plants, which indicated that they would stay online independently from the auction outcome. Therefore, an unnecessary amount of subsidy will also be paid, representing an avoidable excess increase on customer bills. Secondly decarbonization is poorly targeted, some gigawatts of coal-fired and even oil-fired power units submitted winning bids. Finally (Orme 2016) argues that smart energy technologies e.g. DSR and storage are poorly subsidized and the auction process focuses on conventional generation. (Gammons and Anstey 2015) also adds that compared to the American PJM capacity market, DSR results are disappointing, where 9% of the available amount of money was entitled to DSR providers.

Table 2. The pivotal design elements of the reviewed CRMs in three countries

	Belgium Strategic reserve	State tendering	**France** Capacity market	**Great Britain** Capacity market with auctions
Category	*strategic reserve*	*capacity auction*	*capacity obligation*	*capacity auction*
Main purpose	*termporary intervention*	*long-term incentive*	*mid- and long term incentive*	*long term incentive*
Eligibility	*- mothballed or closed plants - demand side flexibility*	*- new capacities in Belgium or in a neighbouring country - technology-specific: gas fuelled (OCGT or CCGT)*	*certified operators of - existing capacities -planned capacities - demand side response*	*prequalified capacities of - existing, - planned, - interconnector, demand side or generation capacities*
Responsible to procure	*Elia (TSO) on the order of the FEA (Ministry)*	*FEA (Ministry)*	*electricity suppliers*	*DECC (Ministry) with the help of ERM Delivery Body*
Criteria and assessment	*LOLE if no other norms are available*	*not determined*	*suppliers need to fulfill LOLE regulation*	*LOLE Assessment*
Approval	*CREG (NRA)*	*only advisory from Elia (TSO)*	*Operation by RTE (TSO), supervision by the regulator*	*DECC*
Lead time	*1 year ahead*	*not determined*	*4 yrs*	*4 zrs*
Length of contract	*2 years*	*not determined*	*annual*	*1 yr or 3 yrs for refurbishments or 15 yrs for new built*
Volume	*set by the Ministry*	*set by the Ministry*	*suppliers need to fulfill LOLE regulation*	*DECC*
Remuneration (provided through)	*bidding process (EUR/MW)*	*subsidy per MW with pre-determined annual cap*	*continous capacity trading between suppliers and operators (EUR./MWh)*	*auction process £/MW pay-as-cleared*
Costs (beared by)	*Transmission tariff end-customers*	*not determined*	*Supplier's price end-customers*	*Supplier's price end-customers*

2.4. Conclusions

After reviewing the background of three countries' CRMs (Table 2) and the European standpoint on the issue, some important conclusions can be drawn:

- Different prevailing energy mixes in electricity industry result different CRM setups which is mainly originated from the country-specific SoS issue which has to be addressed accordingly by the framed capacity market. In France it was the lack of generation capacity to meet peak demand in extreme cold weather, originated from the fact that electric heating is the most commonly used in France. Meanwhile in Belgium it was the expected exit of conventional power generating units, and finally in Great Britain it was the decarbonization goals and the low reliability attached to import.
- Oversubsidizing is an important concern to be taken care of throughout the desingn of a possible CRM. In Great Britain there are academists who argue that oversubsidizing only exacerbates the original market failure (Newbery 2016).
- Interconnectors and demand-side response (DSR)15 are already inevitable part of a possible CRM, as well as regional market is planned to be compulsory based on Figure 7.
- Security of supply is a politically sensitive topic, therefore regarding CRMs, the main decision makers are mainly Governments. However adequate, independent energy planning competence is inevitable for policy-makers supported by the professional institutions (mostly TSO and NRA). This is the case also in Great Britain, Belgium and France, but in Germany and other EU countries as well.

[15] *DSR: nowadays already consumers can be active participants of te electricity market as there are business and technological solutions to market the curtailment of ones demand like it would be generation asset.*

- Compliance with EU guidelines seems to be unavoidable which include low carbon requirements, regional participation, preliminary action plans to exclude price regulations, new technologies like storage and DSR etc.
- From a policy point of view it is not the question of how harsh the reliability margin should be i.e. how much capacity to contract, it is rather the approach we would like to handle energy policy and accordingly to frame possibly a CRM.

Chapter 3 THE NEED FOR CRM IN HUNGARY

After reviewing the European experiences and guidelines regarding CRM implementation, a detailed view should be formulated on the Hungarian power market structure. Thus, a competent policy recommendation is to be provided which applies the different conclusions regarding CRMs for the Hungarian market environment. Below the thesis gives an overview on the functioning and prospects of the electricity sector in Hungary, and on how a CRM would fit into this picture.

3.1. Electricity in the Hungarian energy policy

In recent years, Hungary has provided two internationally disputed energy policy issues besides the government's several other controversial decisions, namely the nuclear power investment with state-aid and the regulated decrease of retail energy prices. Although the prevailing Government provided long-run energy strategy in 2011, only the nuclear capacity investment can be considered as the part of a conscious energy system planning. The Energy Strategy 2030 (Ministry of National Development 2012) was passed by the Parliament in 2012, which accomplished two important responsibilities of policy-making[16]: (1) after considering different scenarios, it appointed the so-called Nuclear-Coal-Green[17] scenario to follow based on the economic feasibility study and (2) provided a pathway for constructing action plans accordingly which would foster the implementation of this strategy.

Yet after 5 years, regarding the main cornerstones of that scenario significant deficiencies might be observed i.e. (1) according to news there is no sign of planning or execution of the estimated new coal-fired capacity which was included in the Strategy with 400 MW, (2) the phase-out of the FiT scheme was delayed by 4 years, although on 1st January 2017 the new scheme has

[16] *The thesis does not intend to qualitatively assess the policy choice, taken by the Ministry in 2012, rather to briefly evaluate the role and influence of existing decisions in the Hungarian energy policy*

[17] *Nuclear-Coal-Green refers to a scenario in which besides new nuclear units, new coal-fired and renewable units will be installed*

stepped into force and (3) the new nuclear units are in planning phase but several news suggest that the commissioning will be behind schedule and will not be completed in 2025 and 2026. Furthermore, some of the action plans have not been provided by the Ministry of National Development, including the Power Plant Development Action Plan. Instead, retail prices emerged as one of the main tool of politics which brought additional uncertainty into an industry already struggling with excessive uncertainty (as already presented in the Introduction). Concluding the above, overviewing the energy policy of recent years gives an impression of lacking conscious policy making in the electricity industry of Hungary. The importance of this deficiency, however, seems to be growing thanks to several fundamental changes both on the demand and supply sides which are underway in the Hungarian power sector.

In power industry, demand is specific concerning its close-to-zero price elasticity as there is no real culture of allowing any interruption in electricity use. Another important characteristic is the historically proven causal relation between GDP growth and electricity consumption (Shahbaz, Tang, and Shahbaz Shabbir 2011). This strong relation, especially in terms of correlation, can be considered as the conventional way to predict consumption, however, it is also important to note that years already came in which a stable GDP growth was observed still, decreasing electricity consumption occurred (therefore the correlation is true concerning the dynamics, growth does not necessarily imply growing consumption). For Hungary, the most sophisticated and publicly available forecast is prepared based on GDP growth assumptions and top-down relations regarding overall industrial energy efficiency provided by MAVIR (MAVIR 2016a). Latter predicts stable growth of around 1% in the coming years, however, from a policy-maker perspective, some game-changers are about to come into electricity industry. Two important factors cannot be overlooked, namely e-mobility and renewables.

First the spread of e-mobility might add significantly to the predicted electricity growth as a redistribution would be initiated in the form of final energy form (shifting from refined oil towards electricity). Secondly the growing amount of decentralized, household PV panels and other small-sized generation technologies can can entail decreasing demand for electricity from the centrally dispatched power plants. These effects along with other fundamentals like vast digitalization, electrification and the shift from natural gas based heating towards electric heating are hardly modelled in the Hungarian context but can play determining role in policy decisions, but are not the scope of this paper. below I try to assess the market functioning and the supply side from the limited perspective which is necessary to thoroughly assess a CRM application in the country.

3.2. Market functioning and dynamics

The operation on electricity market requires the cooperation of several actors both regulated and non-regulated ones, the detailed organization of this cooperation might differ in several aspects even inside Europe. For the Hungarian one, Figure 8 gives a short overview. This organizational setup provides the framework in Hungary to operate all the segments introduced already on Figure 3.

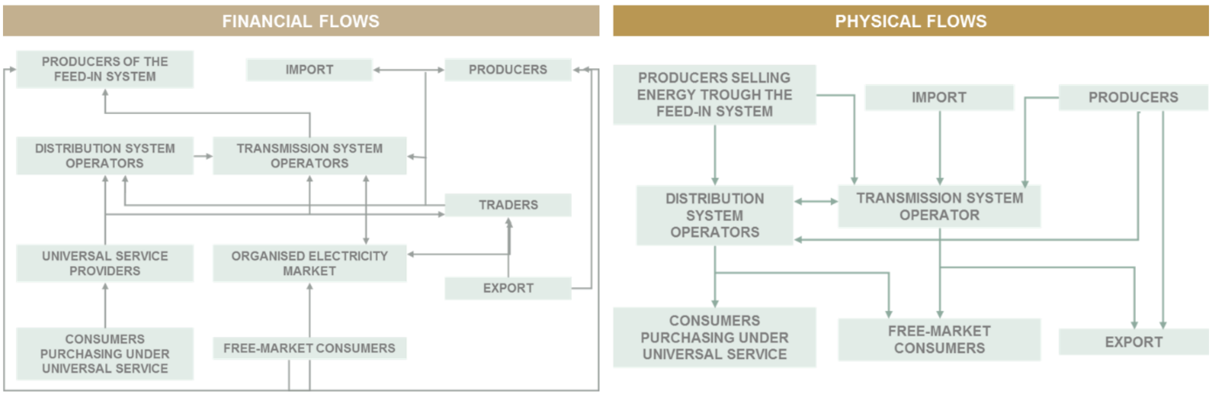

Figure 8. The financial and physical flows in the Hungarian electricity market design

Regarding market functioning, the liberalization of the Hungarian energy markets 2008 has important effect as well as the privatization of the sector in the 90's. The former market organization has still significant impacts on market shares which will be shortly assessed below. Regarding the different roles, the operators of the transmission infrastructure (TSO and DSOs) have regulated rate of return (as being natural monopolies), guaranteed by tariff regulation with 4-year-long tariff periods with annual adjustment mechanism. Apart from that, there are regulated prices in the universal service, which now covers the whole residential sector and part of the SME sector also and in the FiT system which was created for support renewable power plants and provides inflation-linked electricity price for the operators for a calculated period (maximum 25 years). Below the paper assesses the operation of the wholesale market as the most important field intervention in case of CRMs and also briefly presents the retail market in order to later understand CRM effects on retail prices.

3.2.1. Generation and wholesale market

As it was already presented in the introduction, the relevance of CRM implementation in Hungary is originated from a significant decrease in available capacities and share of inland generation in Hungary, presented on Figure 1 and Figure 2. Below the background of these trends are shortly assessed through wholesale market price, inland generators' competitiveness and import.

After the liberalization of the electricity market, the next milestone was the establishment of the Hungarian Power Exchange (HUPX Zrt.) in 2010. Since then the market started to adjust its operations and contracts to the new market set up, proven by the constant growth in market liquidity observed since the foundation. This accommodating process resulted in HUPX Day-ahead market (DAM) becoming the new benchmark price for assessing market profitability of different generators and for other bilateral market contracts.

The distribution of contracts and electricity trading among the different types of contractual forms is hard to estimate, the last report available on the topic is the Annual Report provided by MEKH (2016). Based on this in 2015 the market share of the largest power plant operator companies on the electricity market was 50.3%, which implies a HHI index of 1578. The most important player of the Hungarian market is MVM Hungarian Electricity Ltd. (the former central buyer of the non-liberalized market) had approximately 37% market share, which more than half of the domestic electricity production (66.75%). Latter data is especially interesting when considering the Hungarian installed capacities in 2015, where MVM in contrast with the more than 50% inland market share of electricity market, only has 32.64% (Appendix 4). Therefore, MVM also possesses the most competitive power plants on the country.

Comparing prices in the last 5 years, results in a strong negative trend in terms of average daily prices as well as the distribution pattern of those average prices (Figure 9). So, the range and the mean/median level of prices also decreased in the last five years which made market environment hard especially for generators with more uncertain operational costs, e.g. gas-fired power plants depending on the volatile natural gas market. This decrease in price might be an effect of several factors, although in the inland supply side there were no such trend which would have caused constantly decreasing prices, therefore it is probably the effect of cheap, accessible import on the market which priced out marginal inland generators.

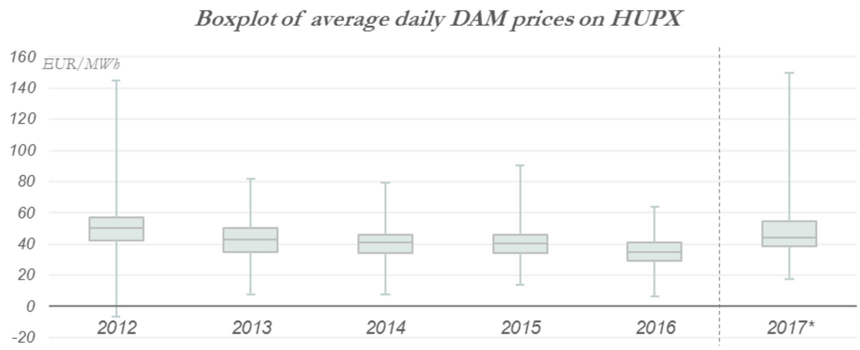

Figure 9. The distribution of daily average prices of electricity since 2012

This latter argument is supported by load factor data from the last 5 years (Figure 10) which clearly shows difference between the nuclear power plant (Paks NPP), the lignite-fired power plant with high utilization rate and the utilization rate of gas-fired units in the country (Budapesti PP, Gonyu CCGT, Virtual Power Plants, Dunamenti CCGT). While the former ones run on close to maximum utilization. Therefore, gas-fired power plants' competitiveness might have been lower.

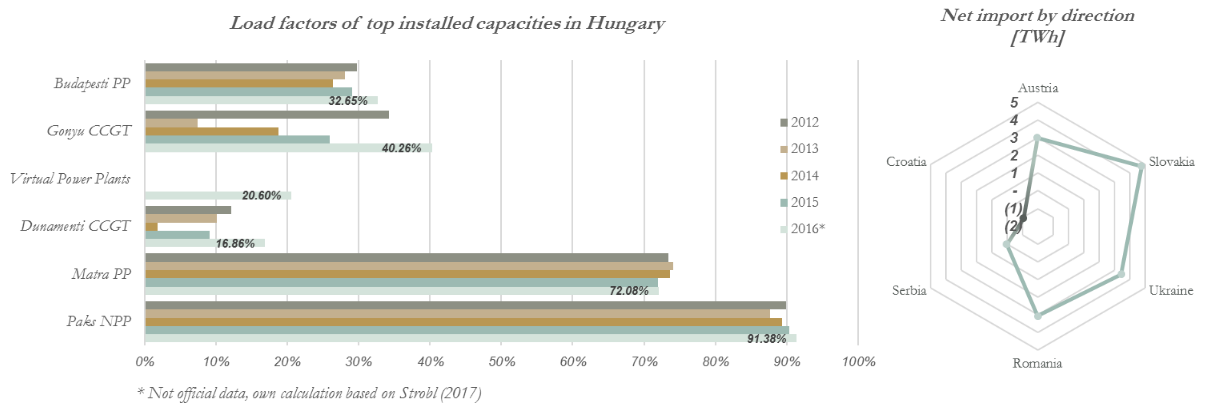

Figure 10. Load factors of top capacities and imported amount of energy by direction in 2016

Import, as already presented (Figure 1), plays an important role in the Hungarian electricity supply. Considering import, two important conclusions might be important, first the intraday distribution of import, which shows that import is the source which covers most of the differences in the hourly shape of load, i.e. the increase in electricity demand of daylight period, also called peak period (based on MAVIR data[18]). This might also imply a partly marginal role on the market for import. Second important aspect is the direction of import. The net import by direction (presented on Figure 10) is dominated by Slovakian, Ukrainian and Romanian sources, and export towards Croatia (which is probably originated from transit).

3.2.2. Retail and household prices

If considering the introduction of a new market segment, for additional revenues for producers, an obvious question is who to finance the extra revenues. Up to now, the retail market of electricity can be divided into two parts, as Figure 8 shows, the universal service and the competitive market. Former segment is established to supply household and SME end-customers with consumption under certain thresholds, however, both types of consumers can exit universal service. Up to now, for households there is only a negligible share who procures electricity on the competitive market, there is no supplier for that, which might be explained by the regulatory price

[18] *Market reports downloaded from* http://mavir.hu/web/mavir/havi-jelentesek

decrease on the universal service market in recent years based on political decisions. The share between the two segments in 2016 was 11.069 TWh in the universal service and 25.827 TWh on the competitive market. The remaining consumed energy (around 7.197 TWh) was sold on other special submarkets according to the data, provided by MEKH[19]. Therefore, almost one third of the market procures energy through universal service, which has a fully regulated price, set by governmental decree.

Regarding prices, in both segments the fee paid by the customer does not only consist of energy-related prices, the costs of grid operators (TSOs and DSOs) have to be remunerated through regulated prices (grid fee) which is part of the fees for both universal service and competitive market consumers. Traditionally there are other fees included in the price e.g. sectoral support for coal mines, special support elements for workers in the industry etc., however, based on the policy decision in 2013, these are phased out from the universal service fee and only to be paid by competitive market customers. Energy-related price elements are also matter of regulation, for universal service customers there is a wholesale market player (MVM Partner Zrt.) which is appointed to supply universal service providers (USPs) at a regulated energy price, then USPs sell this energy with a regulated margin. Besides there is the renewable support scheme which has also regulated energy price, only included in the competitive market price. On Figure 11 the fee of one of the customer categories for universal service fee is presented. Interesting to note that while the decrease of the energy price (2012-2014) might be explained by the wholesale market price decrease (Figure 9), in the last 3 years the manipulation was carried out in a way that the modifications of grid fees and energy price balanced out. This might be a measure for policy makers with the aim of energy price decrease.

[19] *Downloaded from http://mekh.hu/villamosenergia-ipari-tarsasagok-adatai (Data accessed on 04/06/17)*

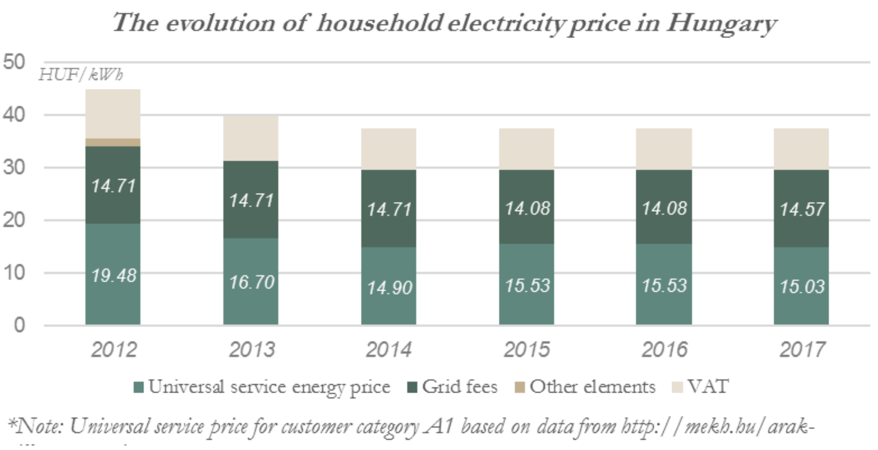

Figure 11. Hungarian household electricity fees in recent years

For any intervention on market, the costs are to be covered with the manipulation of the fee structures of the two markets (not necessarily in a symmetrical way). From a policy-maker point of view this plays a central role as it can determine which segments in what extent to bear the burdens of the regulatory changes.

3.3. Detailed view on Hungarian producers

CRMs are different regulatory measures to support the supply side of the electricity value chain, therefore below the paper gives a detailed overview on the present and future outlook of the Hungarian electricity system.

3.3.1. Merit order

Based on pricing behaviour, the Hungarian supply side can be divided into several categories depending on the main revenue source of the power plant operators. The simplest business model is the renewable energy generation, since the supported ones' production cannot be influenced by the transmission operator and on the other hand their SRMC is close-to-zero therefore if available, these capacities market themselves[20]. Hence the merit order effect already presented, the supply

[20] *Actually the supported generation is sold by the TSO on HUPX, plant operators only sell their electricity to the TSO on a regulated price independently to the wholesale market price*

curve is pushed to the right with the amount of renewable infeed. In Hungary this is the case for the wind, solar and hydro generation. Another important category is the combined heat and power generation, whose main revenue source is heat production, therefore their electricity infeed is not driven by market price. Their primary aim with electricity is to increase revenue if they need to generate heat. Mostly, their SRMC is not be competitive, so they are on the end of the merit order but they sell electricity whenever they produce heat.

Generally, the remaining power plants run based on their marginal costs. In Hungary two power plants can be highlighted, the lignite powered Matra PP and the nuclear Paks power plant. These have the lowest SRMC on the market, mostly import cannot compete with them. Another important class is the gas-fired units (CCGTs) which have more volatile fuel prices the driving factor here is their efficiency, which can differ significantly. Latter together with the natural gas contract the power plant operator can negotiate are determining, how close they can stick to the western prices. This is competitive landscape in which import competes with mostly the marginal gas-fired units. For 2016 already Figure 10 showed incremental progress in the CCGTs' load factors which also supported the relevance of efficiency as the highest load factor was achieved by Gonyu power plant. Based on the above one can conclude that on the Hungarian market, gas-fired power plants and import play the role of price-setter. The market dynamics is also illustrated by Figure 12 which gives an impression how serious merit-order effect of renewables and competitive pressure of import might be based on approximate fuel costs of 2016 (Appendix 5)

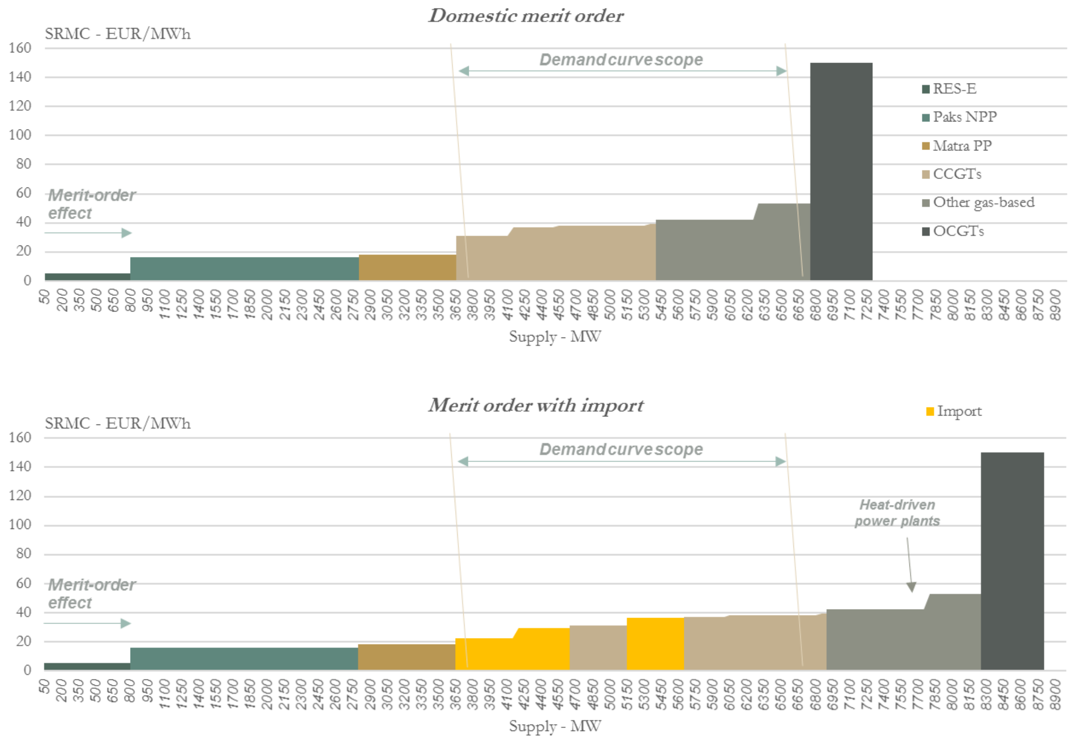

Figure 12. Stylized merit-order of the Hungarian electricity market as of 2016 (based on own estimations)

3.3.2. Capacities to be remunerated by CRM

Two important types of capacities might need additional remuneration which is existing ones and new built capacities. In both cases two types of costs are not covered by the EOM as it was already discussed, it is the fixed operational and maintenance cost (fix O&M) and also the capital costs if the capacity was built recently as none of these are priced into SRMC.

For the Hungarian market, as the Appendix 5 also shows, regarding existing ones the important goal would be to have the gas-fired capacities to stay in the market (for instance Debrecen CCGT already exited the market at least temporarily). For them short-run solution would be also necessary as probably in case of a cash-flow positive operation i.e. covering at least fixed O&M costs would be enough to maintain the power generation and minimizing further capital costs through one-off impairment losses. However, for new-built ones the pivotal deficiency is the lack of certainty in market prices which can only be off-set through long-term incentives and intervention. Regarding technology, in Hungary several plans were published to build CCGTs, new coal-fired power plants were also under consideration and of course the planned new nuclear units could also realize additional revenue especially that nuclear plants are the most intense regards to fixed O&M costs because of the high security standards and needs.

3.4. Capacity outlook of Hungary

Hungarian power sector is observing an important transition originated from several factors. During this period security of supply might be an important factor to consider. Therefore, below the paper assesses some important game-changers that are identified on the market which might imply changes relevant to regulatory point of view and then the available SoS calculations for the current capacity environment is presented.

3.4.1. Expected inland game-changers

Regarding capacities available in the Hungarian power system, four developments can be considered as the most influential events in the years coming. In chronological order, first the interconnector capacities is to be increased towards Slovakia which is already the main source of import direction of the country (Figure 10) in 2020 according to the news and the development plans. Primarily the effecs will be a decrease in wholesale market prices, which would further increase the penetration of import into the inframarginal capacities (illustrated by Figure 12). This way on one hand the security of supply will be enhanced but only with foreign capacity and the price decrease might cause economic retirement of gas-fired capacities.

After the new interconnectors, the exit of Matra PP can be expected for the mid-2020s as it reaches its technological lifetime. The outlook of the lignite mines are uncertain, no information is available for plans regarding the construction of new units. The retirement create an important gap on the generator's market, which can imply both the increase of import and the higher utilization of gas-fired capacities on the market.

The next progress on the capacity side is the Paks 2 investment which includes the construction of 2400 MW in two units, entering one in 2025 and one in 2026. As of now, the communication strategy of the Hungarian Government is that this investment is the key towards safe, carbon-neutral energy supply for the 21st century. However, the uncertainty is high regarding this investment as recent international experiences show that nuclear investments are usually behind schedule, and also social acceptance can be easily manipulated and only a short period is enough for mothballing the investment. However, even if the investment is successfully managed, the effects on the market are hard to forecast. The co-existence with the old nuclear units equals roughly 4400 MW of generation capacity with which a renewable boom makes the merit-order shifted extremely to the right and brings down wholesale prices. Even so, export would be necessary because the low demand hours are lower than nuclear output which is hard to curtail. Finally this would also mean the after the retirement of Paks 1, the capacity outlook would bear high risks.

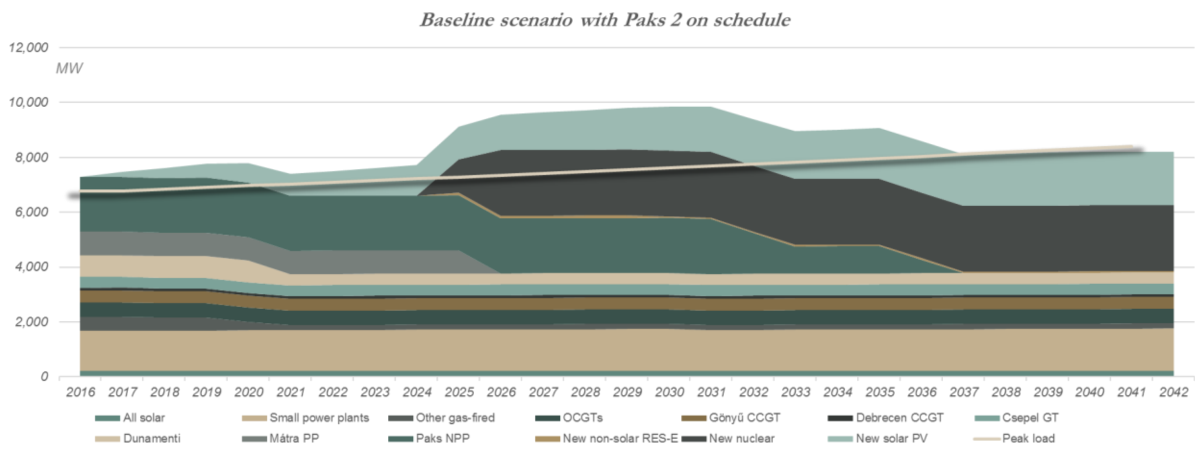

Figure 13. Expected changes in the capacity outlook and peak load

The last considered game-changer on the Hungarian market is the increase in renewables on the long run because they might have more and more important effects on the order. Probably the focus will be on solar capacities as wind seems to be ruled out by the policy maker. For solar, however, a solid increase is expected at the household scale (which part can be hardly influenced through policy) and, as it was already mentioned, utility-scale solar power plants are expected to grow. Their effect is mainly the merit order effect which means lower prices, probably increasing import dependency at least till the entering of Paks 2 and probably lower SoS because of the potential economic retirements. The overall changes are summed up on Figure 13.

3.4.2. Metrics for SoS in Hungary

The Hungarian TSO along with its medium- and long term supply forecast for the Hungarian electricity system, also prepares the correspondent resource adequacy assessments as well (MAVIR 2016b). Their methodology complies with the European practices and use the metrics of LOLE and ENS (energy not served) calculated by Monte Carlo simulation. Their results are presented for the power plant deficient scenario [21]for 2021, 2026 and 2031. For 2026 accordingly MAVIR also sees significant risks regarding SoS i.e. almost 3000 hours of lost load and 1.2 TWh unserved energy are the expected values. Unfortunately, the report does not specify exactly how interconnector capacities were considered only implicit suggestion is if new Slovakian interconnectors are not considered.

Another method which was already discussed in section 1.3 is the reliability margin which is calculated from so-called de-rated capacities. Having the possible threats in mind, described above, the de-rated capacity outlook of the Hungarian system is shown on Figure 14. Here one can see that the derated inland capacity could even lack the amount of 1800 MW capacity to fulfill peak load in the beginning of 2020s assuming a pessimistic scenario.

[21] *MAVIR's power plant deficient scenario includes delaying Paks 2 investment (only in 2031, one block, 1200 MW is calculated.*

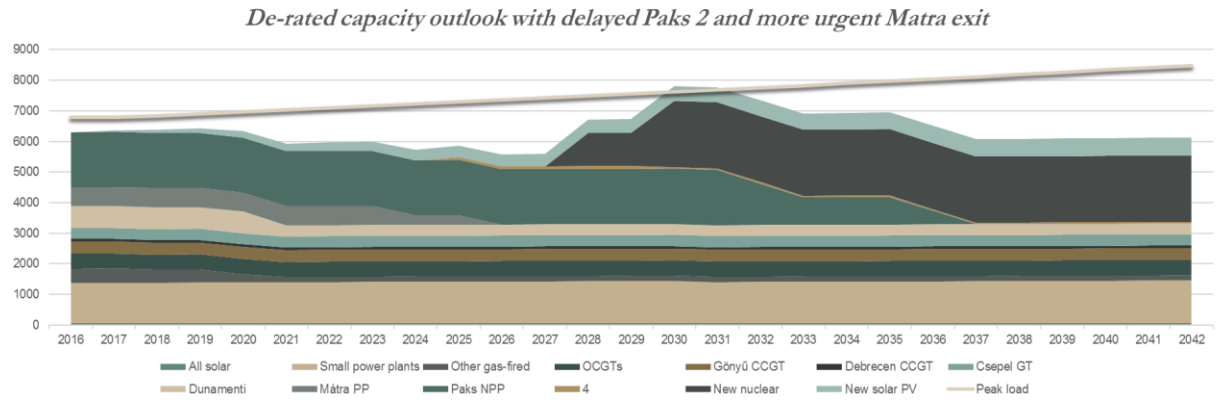

Figure 14. De-rated capacity outlook with delayed Paks 2 and more urgent Matra exit (own calculations)

3.5. Evaluation

By the metrics published by the TSO, a SoS concerns are not an issue on the short run but also the TSO and Figure 14 shows risks in the 2020s which might make creating the regulatory framework necessary for a CRM.

One important policy decision is whether to only maintain existing plants or also incentivizing new built power plants, and also the risk of free-riding on the regional market from foreign national CRMs might be an important factor to consider as our import share is already high. On the long run price outlook may be decreasing as the new interconnector and the new capacities from Paks 2 are both going to drive prices down. Also export might be necessary for Pas 2 and a regional CRM might be a good idea to crate additional market for that.

All in all the most important issue on the Hungarian market is which might be addressed with a potential CRM in Hungary, rather on the short-run. On the long run it is the question of game-changer whose modelling is necessary.

Chapter 4 IMPLEMENTATION OF A CRM IN HUNGARY

In the previous chapter the risks regarding generation adequacy were identified for which implementing a capacity remuneration mechanism could provide a solution in Hungary. However, as Chapter 2 described, the design and choice of the implemented CRM can only be constructed with careful considerations about the prevailing power system in the country, and about how to handle different technologies in the scheme, the regional participation and dominating policy goals in the country. Also, effects on the functioning of energy-only market segments must be thoroughly studied. In this context, this study aims to choose and design the fundamentals of two applicable forms of CRM for the Hungarian market, whose evaluation is restricted to create the necessary framework for the appropriate decision-making. Therefore, modelling the effects on market operation is not the scope of thesis because of time and resource constraints.

4.1. Assumptions regarding policy outlook

Therefore, in this chapter the paper considers a situation in which the policy maker opts for introducing a CRM in Hungary based mostly on the conclusions given by Chapter 3. However, it is not obvious which type of capacity mechanism should be analyzed in the Hungarian context as a wide range of implementations exist already in the EU. Below two possible policy scenarios are described, both imply a matching CRM types which can be later discussed.

In the first policy scenario, the Hungarian policy maker aims to avoid the adequacy risks of coming years of a possible capacity scarcity because of a delaying Paks 2 investment and scheduled exit of Matra PP. In this context, it wants to implement measures with the policy focus on SoS concerns covered by inland capacities for a temporary amount of time. Thus, a regulatory framework is set up including the possibility of procuring a targeted *strategic reserve* decided on member state level. With this action the policy maker acknowledges the new nuclear units as the ultimate answer to national SoS issues but also creates the necessary environment for an urgent decision making process for any unplanned progress.

In the second policy scenario, policy maker puts long term offsetting missing money effect on the market into focus, thus incentivizing both new built and existing capacities. While ensuring SoS on a contractual basis with enough capacity, it also gives space to regional market up to a rational extent following the EU approach. With creating a new market segment for trading *capacity obligations and certificates* between suppliers and producers on a regional basis, the policy maker acknowledges that ensuring the sufficiently high reliability margin might be inefficient solely inland. However, it is ready to create the necessary regulatory framework in which on the basis of the TSO's competence a safe amount of foreign capacity can be contracted for ensuring SoS besides inland ones.

Below the possible implementation of these two CRM types are described and assessed by the paper to be able to provide thorough policy recommendation in Chapter 5.

4.2. Strategic reserve

As it is also presented in Appendix 1, strategic reserve is the most commonly used type of CRM in Europe which gives a sound basis for the implementation in Hungary. The exact implementation differs in the different regulatory and market environments, therefore after an overview on the Hungarian ones, the main cornerstones of an adequate design is presented below embedded into the Hungarian electricity market.

4.2.1. Design

Table 3.

Eligibility

The SR is a remuneration mechanism which can be procured in a targeted way, therefore only one or two domestic power plants can be contracted this way. This type is not technology neutral, preferably aging conventional power plants like gas-fired and coal-fired power plants might be included.

Fit into market design

The contracted power plants can only be operated on TSO order, as it must be excluded from the energy market. With this basically becomes a regulated asset under TSO supervision, thus SR has only small modifications on the prevailing market design.

Compliance with EU requirements

Section 2.2. already showed that EU is not in favour of domestic targeted CRMs, so it would probably not be approved with full subsidiarity regards to decisions, however, the fact that many countries already uses such mechanisms makes it hard to veto from EC.

Criteria and assessment

Based on international best practices LOLE/EEU assessment should be carried out. LOLE estimations are already prepared by MAVIR, however, the modelling of different scenarios should be improved preferably in MAVIR, but there would be advantages [22]in establishing professionally independent policy-oriented modelling institute.

Volume

Volume would be calculated by latter assessment, but approved by Ministry.

Responsibilities

Ex ante approval of volume and the procurement process of capacities would be initiated by the Ministry thanks to SoS being a primarily political issue;

TSO would actually procure the capacity and the operation of the reserve would be controlled by this entity;

NRA would have the role to ex-post validate costs occurred at the TSO during operation.

Possible participants on Hungarian market

As the main aim is to maintain indispensable capacities for SoS, the possible participants are ideally power plants, which either because of low competitiveness, or because of age are aiming to exit market. Based on this One of the Dunamenti units, or of the power plants in Budapest, or the CCGTs with low utilization of Debrecen and Nyiregyhaza. Eventually the Matra power plant can also be in competition.

Lead time and contract length

The assessment should be carried out 1.5 years ahead of delivery for two seasons, which means that for instance in 2017 Q2 the generation adequacy assessment should be carried out for 2018 summer and 2018/19 winter seasons. The contracts therefore would be signed seasonally.

Price, pricing and penalties

[22] *A independent modelling institute would lack the pressure coming from high market independency and unbundling and owners' intetions to influence*

The price of capacity would be set by a bidding process and clearing would be settled on pay-as-bid basis. Latter is necessary as it is not allowed to have the participants bid under their costs, thus threatening SoS. Still this way power plants with the lowest capital and fixed O&M costs can win and the lowest possible effect can occur.

Activation rules

Based on the international best practices (e.g. Belgium) the activation would occur in two ways, one is the market-based i.e. above a certain wholesale market threshold on the day-ahead market, the TSO calls in the SR and pays regulated price for the generated capacity. Second option is the technical one i.e. when because of externalities the expected load cannot be met by the capacity in the EOM.

Costs

The costs would be covered directly by the TSO, which can remunerate itself through the regulated grid fee tariff.

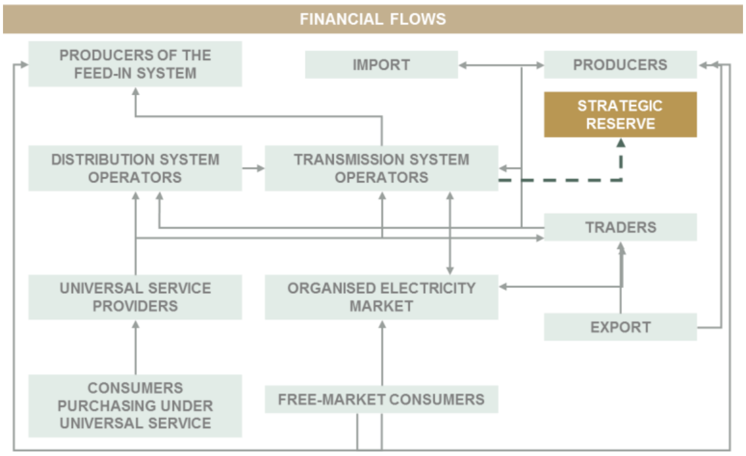

Figure 15. Strategic reserve fitting into the current Hungarian market design

As Figure 15 also demonstrates, one of the most important benefits of this design is its simplicity. Latter is the reason why there is no significant effect in the market operation or the merit order, so price effects regarding energy can be ruled out. The contracted power plants would only be in relation with the transmission system operator, the costs can be estimated as being regulated. Another feature of the design is that it can serve as a last resort in the context of regulatory environment, once created. This way temporary interventions can be implemented.

4.2.2. Fitting into market environment

Regarding the Hungarian market environment, some of the effects, taking place because of the game-changers described in section 3.4.1 might be answered. Firstly, if the timing of Paks 2 entering and Matra PP exiting the market would open up a scarce period, SR could be used to maintain the operation of even Matra PP or another mothballed power plant. Also, threats from the renewables can be partly handled on the short run in case of an excessive RES-E boom in Hungary and extreme merit-order effect causing economic retirement of important units.

Regarding the market operation, important that from an investor point of view SR does not solve missing money problems to any extent, therefore probably the net import of the country would be the same, and might increase thanks to the new interconnector towards Slovakia. However, from the policy maker point of view it is a comfortable policy tool, which considering the general Hungarian bureaucracy might lead to antitrust issues (being a targeted procurement, closely under political supervision).

4.3. Capacity market

Table 4. The possible design elements of a regional capacity market in Hungary

Eligibility

Implementation of CM would be market-wide i.e. all capacities are to participate at least for certification. Furthermore, also demand-side-response capacities, interconnector capacities and cross-border capacities could participate.

Important to limit though the amount of cross-border capacity to be allowed to procure as TSO must be able to guarantee the necessary amount of interconnector for cross-border activation.

Fit into market design

A whole new market segment would be created, which would incur new financial flows between suppliers and generators, clearing platform might be provided by HUPX.

Compliance with EU requirements

With fulfilling requirements like technology-neutrality, possibility of cross-border capacity contracting, including demand side flexibility might be enough for the approval of EC. Already implemented French example is also positive.

Criteria and assessment

General assessment should be carried out to assess the supply side of the CM and whether the CM is functioning adequately by TSO.

Volume

Not the actual volume would be determined by the Ministry, only the reliability standard which is to be fulfilled by each supplier individually.

Responsibilities

For procurement, the sole responsible parties are electricity suppliers;

TSO would supervise that the approved certificates are available

NRA would have the role to approve certificates given to producers.

Possible participants on Hungarian market

For certificates, all capacities have to apply for. In the actual market participation is voluntary but probably all capacities would be included in the market operation.

Important to note that not only inland capacities would be included.

Lead time and contract length

Trading would start 4 years before delivery, demand side response capcities would join the market 1.5 years prior to delivery. After the 1 year milestone, only secondary, balanced tranding agreements can be fulfilled.

Price, pricing and penalties

The price of capacity would be set through continuous trading of certificates and obligations. The pricing of participants would be ideally based on their fixed costs, therefore gas-fired units with high reliability but low fixed costs can remunerate themselves. Regarding penalties, the level has to be set at a level high enough to deter non-compliance for suppliers.

Activation rules

The activation is quite simple for the domestic certified producers as they are automatically activated throughout their commercial operation, however for cross border capacities, the TSO has to implement special procdures which can asure the priority dispatch of contracted capacities across the border if needed.

Costs

The costs would be covered by nd-customers, as it would be additional cost for suppliers.

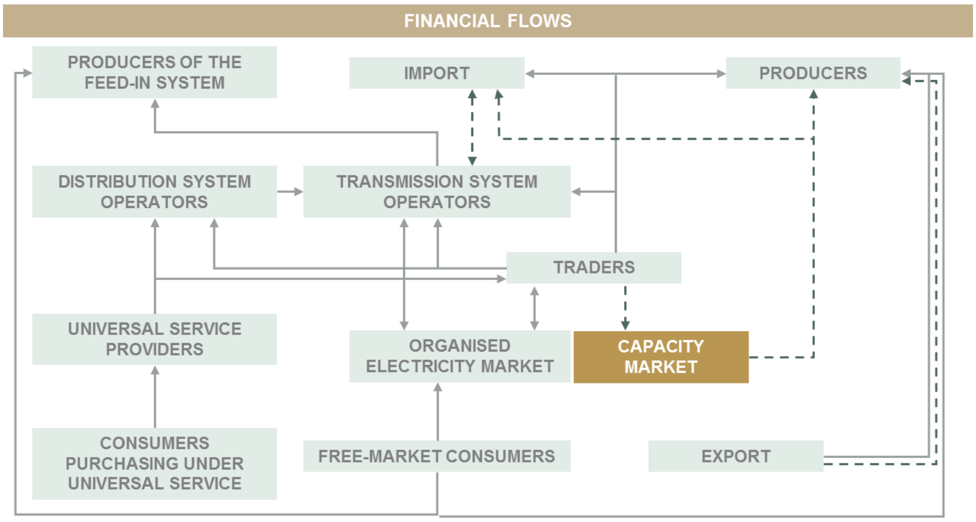

Figure 16. Fitting regional capacity market into the Hungarian market design

Figure 16 shows that the intervention is much more complex than in the case os strategic reserve. A new market would be established for which the current Hungarian exchange, HUPX can also offer platform. There, traders can match their capacity obligations through continuous trading, TSO and NRA would only be involved in supervisory roles and the former should also take care of assuring cross-border participation.

4.3.1. Fitting into market environment

Regarding the effects of coming game-changers, implementation of a capacity market would mainly soften those. In general, a capacity market's primary benefit is that it aims to smooth out one-off effects which are quite easy to observe in a such capital-intense market as electricity. Therefore, implementation of CM could possibly ease the instant price pressure of the new interconnector towards Slovakia, as well as the negative price effect of the possible co-existence of the old and new nuclear power units. Also, it would be able to provide incentives for new investments other than Paks 2. Altogether, CM would rather address the issue of missing money than purely focusing on security of supply.

From the investor point of view, the latter easing of missing money effect is positive, but of course the detailed modelling of price effects and pricing behavior must be examined thoroughly. From the regulatory point of view, the low level of policy-maker influence has to be mentioned which is not that common in Hungarian energy policy. However, one must admit that implementing a CM can enhance regional competitiveness of the national electricity industry.

Chapter 5 POLICY RECOMMENDATIONS

After the assessment of the Hungarian electricity market and evaluating 2 possible CRM setups in the previous chapters, the policy-related conclusions and general recommendation are listed below. First, overall recommendations are formulated based on mainly Chapter 2 conclusions and evaluating Chapter 3. Next, the two chosen CRMs are to be evaluated based on common criteria.

General policy recommendations for electricity sector

The overall Hungarian electricity sector has some deficiencies which should be addressed both from institutional and market design point of view. In Chapter 3, the paper assessed why the term transitional was used for the Hungarian electricity market. Acknowledging this process going on inside in the industry might result in some policy-related decisions which must be made for a successful transition (and for all the thesis, transition in Hungary is not the green energy transition cited by the global industry, rather it is the transition in which the traditional roles and functioning of the centrally controlled market are finally left behind).

The paper already assessed how successful the energy strategy is implemented after passing in 2012 by the Government. On one side the lacking actions are the result of shifted and more politically driven policy goals, however, on the other side the delayed action plans and slow progression might be improved by establishing forward-looking and proactive institutions for policy-support. Energy policy decisions nowadays is a modelling intensive job which cannot only be left for the transmission system operator, whose primary aim is to stay neutral and only considers given facts and mainly technical constraints. International best practices (like the British former Department of Energy and Climate Change and its vast amount of analysis, the close cooperation of French government and TSO etc.) also proves that data intense modelling and market analysis are essential for making efficient policy decisions.

Important aspect of recent European energy policy decisions is exactly the capacity remuneration mechanisms. While the EU policy is always about the energy-only market, in the northwestern European region there are hardly any country without capacity remuneration mechanisms. And still, these countries in recent years already observed overinvestment and the partly originating low wholesale prices. Therefore, probably excess electricity production in that region is ensured in the medium term (because of CRMs) which can further maintain the low prices in the Central Eastern European region as well. Thus, the Hungarian power fleet may not become in the short term more competitive in the region.

Finally, for the Hungarian electricity generation portfolio there are important game-changers which are going to alter the fundamentals of market operation. First, attached to these investment decisions (new interconnector, new nuclear power plants etc.) thorough market impact assessment should be prepared which would increase the certainty of market outlook. The present uncertain situation of the European market makes it essential for incentivizing new investments, unless only state-aided energy market investments is the policy choice. Secondly, for these investments, being capital intense and more importantly sensitive in terms of stakeholder management, grounded risk assessment shold be prepared as for instance on the capacity side the interaction of Matra PP exit and Paks 2 entering and the co-existence of old and new nuclear units represent high uncertainty which is now addressed by any publicly available assessment.

Comparison of Strategic Reserve and Capacity Market

Regarding the implementation of a CRM in Hungary, there are basic policy choices to be made already before opting for assessment. These questions are mostly centered mostly around the role of import and renewables. As Hungary is highly interconnected with its neighbors, European adequacy assessments generally state that Hungarian supply is secure because of the available approx.. 4.5 GW of import capacities. Still for example in January, 2017 based on the assessments of MEKH (2017) there are situations in which regionally there might severe scarcity threatening inland security of supply. In such cases countries might prefer their own SoS issues rather than exporting.

Therefore, based on the market assessment, done in this document, the core issue on the Hungarian market is more likely a missing money effect problem than a pure Security of Supply concern. That is the problem which results in low competitiveness of Hungarian generators compared to regional ones. This is true with assuming that exit of Matra as well as the entering of Paks 2 are carried out as scheduled. However, if there are significant deterioration from the schedules and another black-swan-like event occurs, there might be severe SoS concerns as well. Based on these argument two CRM implementations were assessed and compared in Table 5.

Table 5. The assessment of strategic reserve and capacity market

Assessment	SR	CM	Comments
Simplicity	++	-	Based on the assessment how they would fit into the current market design
Distribution effects	+	0	For strategic reserve costs on each side is regulated therefore distribution of supplier and consumer surplus can be optimized
Security of supply	+	+	The two addresses the issue in different ways, but both can be efficient accordingly.
Investor perspective	-	+	Strategic reserves do not address the missing money effect, while capacity markets primarily aims to achieve that.
Policy-maker perspective	+	+	Same as for SoS, differently but both can serve policy makers well
Robustness and adaptability	+	++	For adaptibility, both solutions perform well, however, robustness is only true for CM if accurately designed. (as it can react to investment cycles automatically)
Cost allocation	0	+	SR being a targeted CRM, cost allocation is manually decided, while for CM the more reliable power plants can be funded which would be the core solution for missing money effect
Threats and risks	-	+	For CM, market-wide mechanism with low political control might provide lower risks in the Hungarian environemtn.
Merit-order effects	+	0*	Only intervention of SR is a technical price cap for wholesale market price, while for CM this issue has to be modelled accurately.
Effect on Hungarian power plant fleet	0	++	In case of accurate design, the competitiveness of Hungarian operators can enhance, therefore import might decrease

Based on the above the implementation of a regional capacity market would be more beneficial because:

- it would replace the solidarity-based regional SoS agreements with contracts if necessary, and therefore it would not lead to excessive overinvestment and overspending in Hungary,
- also it would mean a general smoothing of volatility observed on the renewable-driven electricity markets,

- thus it would provide additional incentives for new capacities which might become necessary once the presently dominant nuclear and lignite power plant will not be in operation.

CONCLUSIONS

After reviewing the background of capacity remuneration mechanisms both regarding economics (both of current market design and its deficiencies') and regarding European experience the paper assessed the Hungarian market environment whether it needs regulatory intervention for securing electricity supply on the medium run or the prevailing market environment provides sufficient incentives for incumbents and possible entrants as well.

Based on the market assessment the implementation of a capacity market would be preferable along with other important policy measures which would enhance both the institutional framework and both the creditability of the Hungarian energy policy. Latter is the main problem in the country, however, considering both geopolitical and prevailing plans on nuclear investment, a regional CRM would be the best option for Hungary, as it would increase competitiveness for the conventional sector of generation, it could create a solid gound for safe import dependence which seems unavoidable, as well as a prosperous market environment for new built generation assets like Paks 2 in which export and the lower price environment of the regional markets can only be handled in the business models.

Finally implementing CRM is also acknowledging that electricity generation has not only products of energy and flexibility, but also availability. Based on the literature assessed during this thesis work, the author gives credit to a future market design all across Europe where separate markets for each three products will be cooperating efficiently.

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APPENDIX

Appendix 1. Illustration of scarcity rent and mark up above SRMC

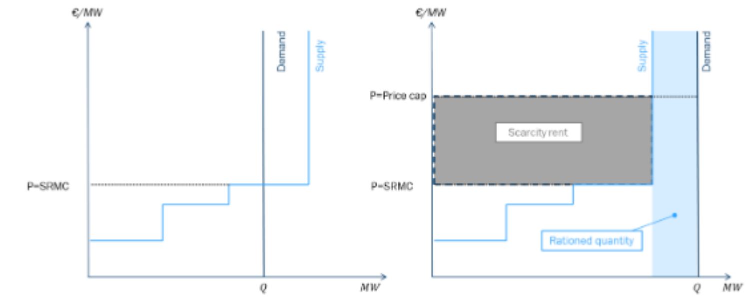


Figure 2-1: Wholesale electricity market clearing price in regular and scarcity conditions (with inelastic demand)
Source: FTI-CL Energy, 2016

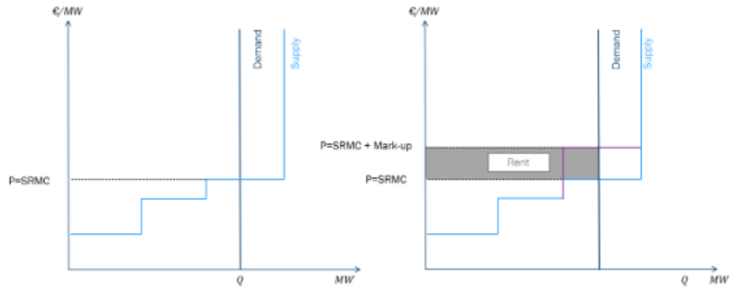
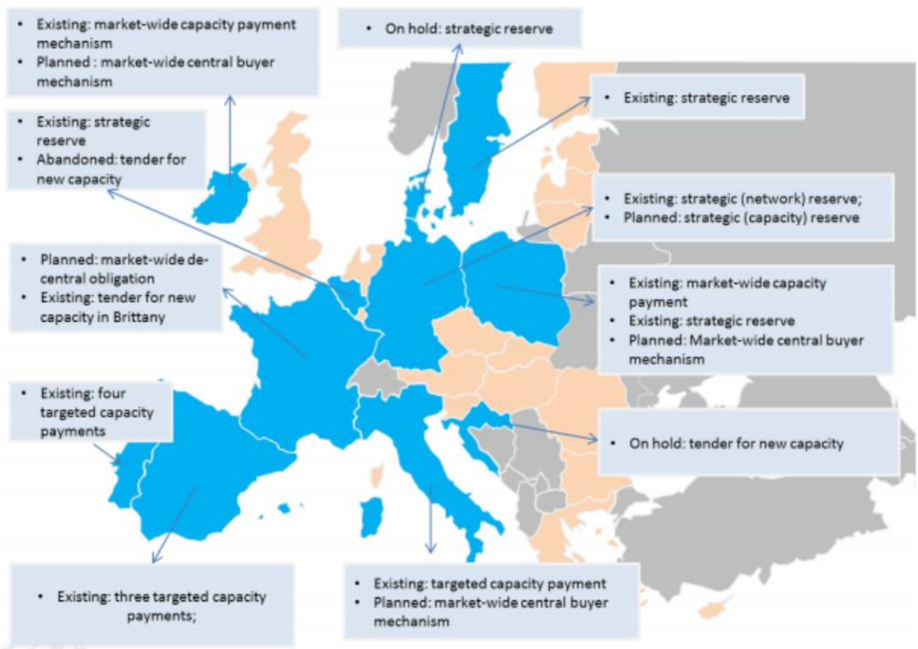
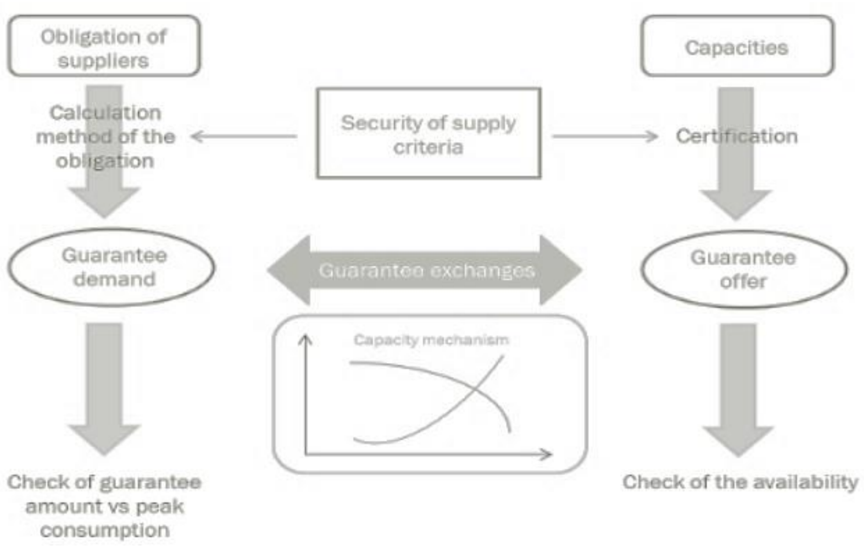


Figure 2-2: Wholesale electricity market clearing price with and without mark-up on SRMC
Source: FTI-CL Energy, 2016

Appendix 2. Map of implemented CRMs in Europe



Appendix 3. Illustration of the French capacity market (FTI CL Energy 2016)



Appendix 4. The market shares of the domestic power plant operator companies/groups in 2015 by installed capacity and production (MEKH 2016)

Table 7: The market shares of the domestic power plant operator companies/groups in 2015 by installed capacity and production

	Installed capacity (MW) [11]	Market shares (by capacity)	Net production (TWh)	Market shares (by production) [12]
MVM[1]	2766	32.64%	15.387	37.37%
RWE[2]	966	11.40%	5.323	12.93%
Tisza Erőmű Kft.[3]	900	10.62%	0	0%
MET Power AG [4]	794	9.37%	0.494	1.20%
E.ON[5]	433	5.11%	0.966	2.35%
Alpiq[6]	403	4.76%	0.474	1.15%
EP Energy[7]	396	4.68%	0.992	2.41%
Veolia[8]	95	1.12%	0	0%
Other domestic power plants[8]	1721	20.31%	3.850	9.35%
Domestic power plants total	8474	100.00%	27.488	66.75%
Net import			13.690	33.25%
Gross consumption			41.178	100.00%
3 largest power plant operator companies[9]	4632	54.66%	20.711	50.3%
HHI-index[10]		1468		1578

Appendix 5. The Hungarian power plant fleet and its data (own collection and estimation)

	Source	Measure	Paks NPP	Mátra PP	Kispest PP	Ajka PP	Bakony GT	Lőrinci GT	Litér GT	Sajószöged GT	Dunamenti	Csepel GT	Kelenföld GT	Debrecen CCGT	Gönyű CCGT	Újpest GT	ISD_Power	Pécs Biomass	Bakony Biomass	Other gas_fired	Other biomass	All solar	All wind	All hydro
Installed capacity	MAVIR	MW	2000	854	113	48	116	170	120	120	794	395	188	95	433	105	64.5	85	30	852	106	210	330	54
Variable O&M cost	IEA Projected cost	EUR/MWh	6.5	3.1	2.5	2.5	4	4	4	4	2.5	2	2.5	6	2	2.5	4	5	5	5	5	0.5	5	1
Efficiency		%	33	31	35	25	38	25	25	25	45	48	32	52	58	32	35	32	32	45	32	100	100	100
2016 production	Strobl, 2017	TWh	16.056	5.392	0.37	0.0875	0.0074	0.0025	0.0018	0.003	1.1712	0.498	0.3699	0	1.5271	0.4222	0.1141	0.5721	0.1842	2.753	0.65	0.174	0.6649	0.258
Load factor 2016		%	91.64	72.08	37.38	20.81	0.73	0.17	0.17	0.29	16.84	14.39	22.46	0.00	40.26	45.90	20.19	76.83	70.09	36.89	70.00	9.46	23.00	54.54
Fuel price		EUR/MWh	3.2	4.64	16.92	12					16	16.92	16.92	16.92	16.92	16.92	16.92	FiT	FiT	16.92	FiT	FiT	FiT	FiT
Fuel cost		EUR/MWh	9.696969697	14.9677419	48.3428571	48	0	0	0	0	35.5555556	35.25	52.875	32.53846154	29.17241379	52.875	48.3428571	0	0	37.6	0	0	0	0
SRMC		EUR/MWh	16.1969697	18.0677419	50.8428571	50.5	150	150	150	150	38.0555556	37.25	55.375	38.53846154	31.17241379	55.375	52.3428571	5	5	42.6	5	0.5	5	1