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Session 4: Perspectives on Capacity Markets

Future Market Design for Reliable Electricity Systems in Europe

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The increasing amount of intermittent renewable generation will cause unprecedented change in the European energy sector. System operation is already calling for flexibility from thermal units to cope with the uncertainty and variability of increasing wind and solar production, and simultaneously low operating costs and subsidies for renewables are causing turbulence in the electricity markets. It is evident that balancing capacity from thermal units is needed in the future, but are markets able to deliver this capacity that meets future requirements?

There is an ongoing debate on the need of capacity mechanisms in Europe to secure sufficient amount of generation capacity in future. However, the challenges of the future also require an increasing amount of flexibility to deal with intermittent generation. Capacity mechanism designs presented so far will not solve this problem. Where the need for flexibility is becoming more and more apparent, the market mechanisms to attract flexibility are still unclear.

This paper will shows recent case studies on the value of flexibility in two large power systems – UK and California –, made by recognised consultants. Based on the findings from the value of flexibility studies, Wärtsilä did a large analysis on the potential market models to reward flexibility in the competitive energy market. This paper introduces a market model to incentivize flexible capacity, while ensuring capacity adequacy in the future power systems.

1 CHANGED MARKET ENVIRONMENT

Decarbonising the energy sector is one of the main objectives of the EU. To meet this objective, significant amounts of variable renewable capacity have been installed already and a lot more will be deployed by 2020 and beyond.

Reliable system operation requires increasing balancing capabilities in electric power systems having increasing amounts of Renewable Energy Sources (RES). This is because the output of variable RES generation is never fully predictable (forecast errors) and has variability that adds to the typical variations in electricity demand. Since RES production generally has feed-in priority, the remaining capacity has to adjust its output to balance total electricity production and demand. Electricity demand as well as output from RES can change rapidly and not necessarily in the same direction. System operators therefore need to have capacity available that can respond quickly to these changes. The impact of RES deployment on electricity markets is severe. Variable RES generates electricity at very low marginal costs and therefore pushes thermal capacity higher up in, or completely out of, the merit order. This means reduced operating hours and less revenue for thermal capacity. In addition, subsidized RES output depresses electricity prices, which make the feasibility of thermal plants even more challenging. Thermal capacity is still needed in high RES system to balance the system, but the profitability of these assets is jeopardized.

Several EU member states have identified a concern that the market may bring forward insufficient capacity under current market arrangements as a result of plant closures and the lack of investment in new capacity. There is a potential market failure associated with a perceived political risk of allowing prices to reach high levels at peak times. Such high prices would be required to remunerate plant running at lower load factors, so that they are able to recover fixed costs whilst operating for only a small number of hours per year. This issue has been termed the “missing money” problem.

However, there is another issue that must be addressed since it is not simply “capacity” that is required in high RES system. Consideration must be given to delivering the “right types” of capacity, and in particular, that a sufficiently flexible mix is available. Without appropriate price signals, there is an equally important concern around “missing flexibility”.

2 VALUE OF FLEXIBILITY IN THE FUTURE POWER SYSTEM

Though the increasing need for flexibility has been recognised among TSOs and market players, the value of flexibility has not been quantified or identified in the market arrangements. To identify and quantify the market value of flexibility, Wärtsilä has developed several studies around this topic with the approach summarised in Figure 1.

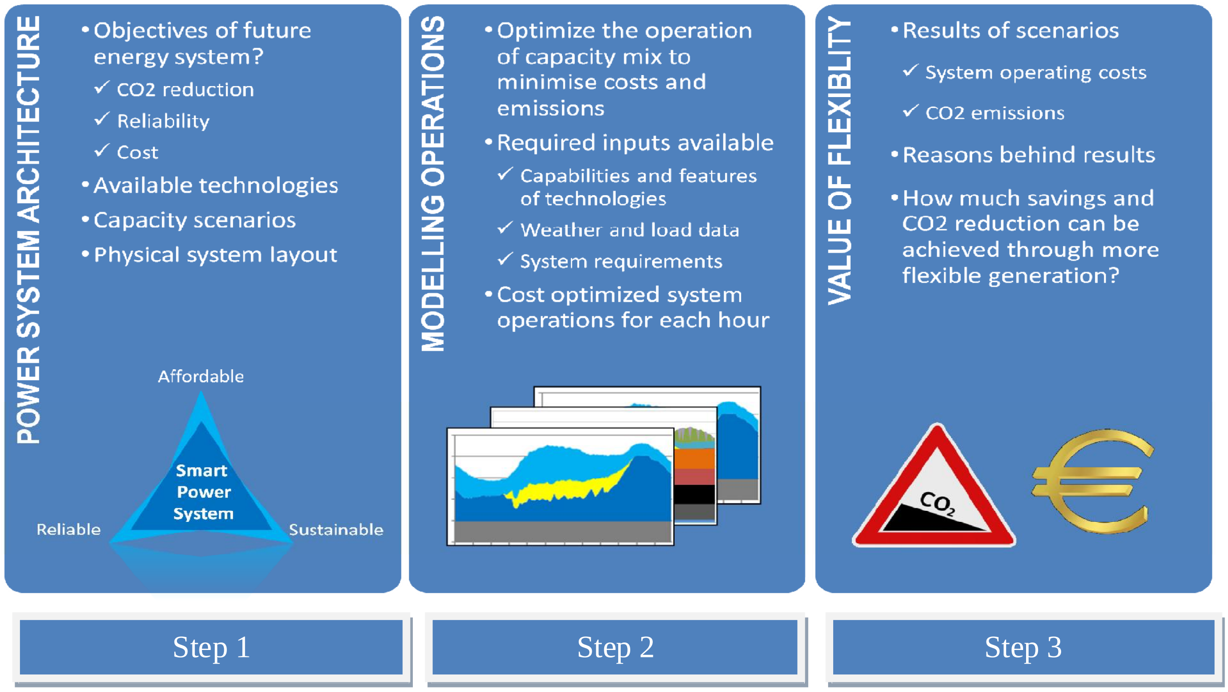

Figure 1 Approach to define value of flexibility

The first step in the process is to define the future power system architecture to be analysed. The architecture is based on the objectives of a power system, such as emissions, reliability and costs, as defined by policy makers. To verify how the set objectives can be achieved, several capacity scenarios are created with different mixes of available technologies, as for example was done in the European roadmap 2050. The output of phase 1 is a power system architecture that can meet future objectives set by the Governments.

The power system architecture provides input to the **second phase** of the process, which consists of modelling the power system operations (dispatch). For the studies presented later in this paper, the dispatch software PLEXOS was used. Inputs for the model consist of the future expected capacity mix including the capabilities of these technologies, weather and load data, system requirements (such as required system reserves) and market operation (e.g. how are reserves procured against which price). The tool will optimize the generating costs of such system in a chosen interval in line with the trading blocks of the system (e.g. every 30 minutes).

The third and final step in the process is to define the value of flexibility by comparing the results of different scenarios. Power system modelling provides the system operating costs and CO2 emissions as an output for each scenario, allowing comparison between scenarios.

2.1 Flexibility from thermal generation

Different generating technologies have different ways of providing flexible electricity. Some generating technologies are able to start up from zero output and then increase their output ('ramp up') within a matter of seconds. Other technologies may take a number of hours to start up, but once they are generating above a stable level they can quickly flex their output up to meet the system needs (typical of large units such as combined cycle gas turbines (CCGTs), and large coal plant). Typically, these slower technologies provide the system flexibility requirement today.

While providing flexibility from conventional technologies (called 'part-loading') may have been efficient in the past, it is not likely to be the most efficient way to provide the increased amount of flexibility needed in the future. The extra costs created through part-loading include:

- Increased carbon costs,
- Reduced fuel efficiency,
- Increased numbers of generators needed on the system, and
- The cost of curtailing wind generation to maintain the security of the system.

Given these costs, if conventional sources of flexibility are used in a system with higher levels of renewables, the full benefits of decarbonisation may not be achieved and consumers will end up paying higher prices.

'Smart Power Generation' (SPG), such as Wärtsilä's modern gas power plants, can provide very flexible generation capacity, avoiding the costs associated with part-loading. SPG can produce savings through:

- **Speed**: A quick response from zero output, and the ability to be able to respond almost instantaneously to fluctuations in the supply and demand balance of electricity. Therefore, SPG plants do not need to be part loaded to provide required flexibility.
- **Sustainability of output**: Unlike other fast start technologies, Smart Power Generation can start up quickly and hold its output without needing to be relieved quickly afterwards,
- **Efficiency**: It incurs minimal costs for being on standby as reserve, but can deliver much needed electricity in the same (or in some cases quicker) times as conventional flexible technologies[1].

2.2 Value of flexibility – Case UK 2020 & 2030

An analysis by UK's DECC (Department of Energy and Climate Change), published in August 2012[2], estimates that flexibility from a range of sources such as Demand Side Response (DSR), increased interconnection, storage and thermal generation can generate significant savings to UK consumers, particularly in a scenario with a high wind penetration.

Following the report from DECC, Redpoint Energy and Imperial College London carried out further analysis of the potential value of system flexibility through detailed modelling of the UK power market and balancing costs. The focus has been on supply-side flexibility provided by 'Smart Power Generation' (SPG). The results however are more generally applicable to all sources of flexibility (DSR, storage and interconnection).

The modelled scenarios are based on DECC's and National Grid's (UK's TSO)[3] projections on the demand and capacity mix development by 2020 and 2030. Two separate capacity mixes were investigated under different wind scenarios (high wind and base wind). In the "NO SPG" capacity mix, gas generation capacity is represented by efficient CCGTs with a small fraction of OCGT. In the "SPG" Capacity mix, 4.8 GW of the most fuel efficient CCGT capacity is replaced

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[1] Further, the technology's fuel efficiency is comparable to that of conventional CCGTs (SPG 50%, CCGT at full load 55%).
[2] DECC, August 2012, Electricity System: Assessment of Future Challenges
[3] Base Wind: DECC Updated Emissions Projections, central (Oct 2011)
http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx

by 4.8 GW of Smart Power Generation (SPG)[4]. SPG has a slightly lower net electrical efficiency but superior operational flexibility compared to CCGT.

Figure 2 shows the capacity mixes for the "NO SPG" case and "SPG". For each case, the capacity mix is shown for the two different scenarios (high wind and base wind) for the years 2020 and 2030. The different technologies in the capacity mix are indicated using different colours and the amount of installed capacity is shown in GW on the vertical axis.

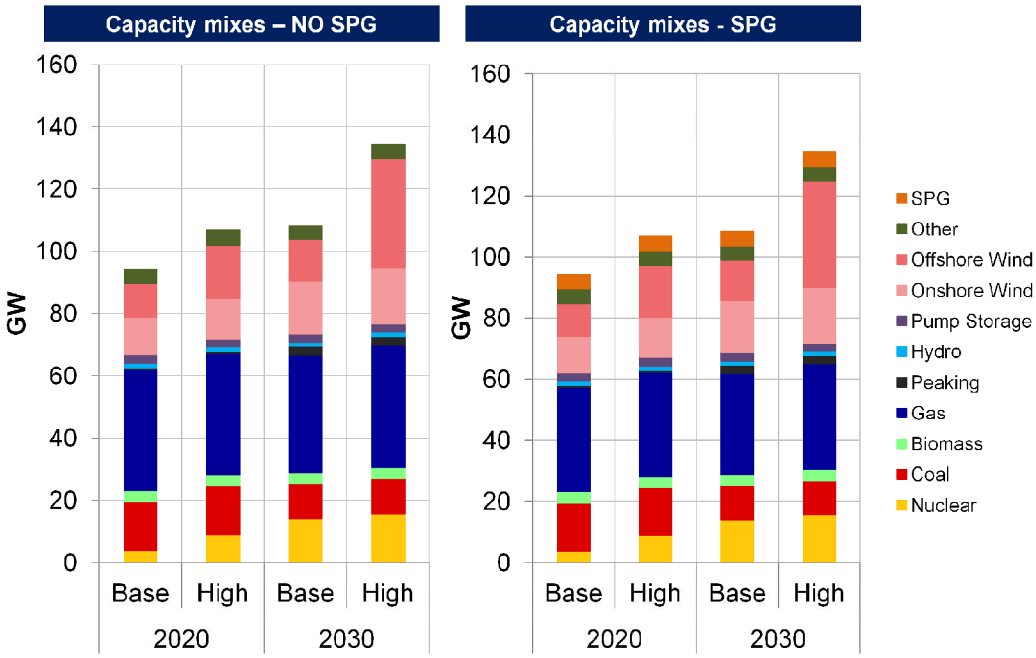

Figure 2 Capacity mixes for power system modelling in the UK case

Figure 3 demonstrates the impact of SPG to system flexibility provision. The figure compares for the years 2020 and 2030, the scenarios high wind and base wind, for the cases "With SPG" and "No SPG". For each case, the colour bars indicate which technology is providing which amount (in percentage) of the required system flexibility. For example, by installing SPG in the system, by 2020 under the base wind scenario, 40% of the required flexibility is provided by SPG because SPG was the least cost option. Depending on the case, SPG is the least cost option to provide flexibility 35-40 % of the time. With SPG providing system flexibility in an optimal way, more room is available for efficient CCGTs and coal generation to run at full load, providing cheap electricity to consumers.

[4] The 4.8 GW of SPG approximates the volume of new-build CCGT to 2020 under the base wind scenario. We have assumed no new SPG post-2020.

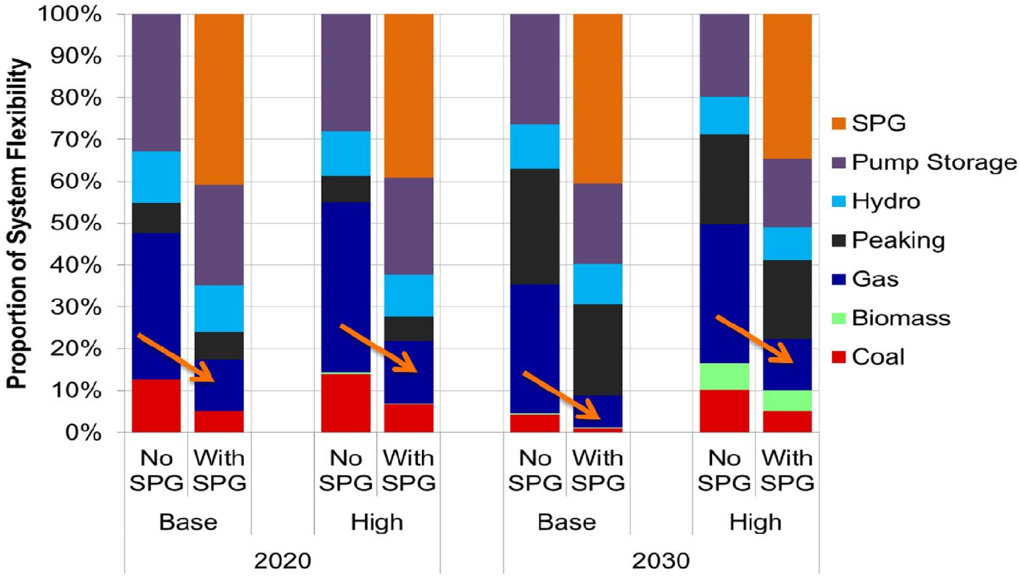

Figure 3 Provision of flexibility across the year

The analysis demonstrated that, depending on the wind scenario, flexible gas generation could save the UK consumer between £380m to £550m per year by 2020 through reduced balancing costs. Modelled savings are estimated to be significantly higher in 2030 (£580m to £ 1,540m) as the volume of wind of the system is anticipated to increase further. Figure 4 shows the overall system balancing costs (total cost of flexibility), and costs savings due to SPG.

Potential cost savings due to Smart Power Generation

Balancing costs – flexibility provision (£ mn per annun, real 2011)	2020		2030	
	Base Wind	High Wind	Base Wind	High Wind
Costs - No SPG	692	1008	834	2781
Costs - With 4.8 GW SPG	311	464	256	1244
Cost Saving due to SPG	**381**	**545**	**578**	**1537**

Figure 4 Modelling results for UK balancing costs

To give some scale to the potential savings in balancing costs, these are compared to the UK system-wide generation costs. Due to increasing amount of low-cost renewable generation generating electricity at almost zero marginal cost, the total generation costs will reduce when the output of renewable generation increases. However, the need for balancing actions will increase accordingly, and these costs will have a significant role by 2030. The saving potential of SPG is as high as 5 % in 2020 increasing to 19 % of total generating costs in 2030. Figure 5 shows the savings compared to total system generation costs in SPG scenarios.

Scale of potential system savings (£ mn per annum, real 2011)	2020		2030	
	Base Wind	High Wind	Base Wind	High Wind
Total generation costs (£ mn)	13164	11682	10176	8282
Saving in balancing costs (£ mn)	381	545	578	1537
% saving	**3%**	**5%**	**6%**	**19%**

Figure 5 Value of flexibility in UK system in 2020 and 2030

2.3 Value of flexibility – Case California 2020

The state of California in the USA has ambitious targets to increase the generation from renewable sources up to 33 % by 2020. This development has started the debate on the required flexible assets to secure reliable operations of the power system. The Californian system will face another issue in near future, when power plants totalling 12 GW capacity with once-through cooling are at risk to retire due to new environmental regulation. The Californian system operator (CAISO) has analysed this risk and came up with the conclusion that 5.5GW of new CCGT and OCGT (50-50 split) is required by 2020 to secure power system reliability.

KEMA DNV analyzed the Californian system for 2020 by using dynamic system modelling. The base case for the power system modelling was the Californian system for 2020 with 33 % renewables penetration (wind and solar but excluding hydro) and 5.5 GW of new gas turbine plants (50-50 split between CCGT and OCGT) The alternative modelling scenario had the same basic assumptions, but 5.5 GW of gas turbines was replaced with 5.5 GW of Smart Power Generation.

Figure 6 shows the flexibility provision by technology in different scenarios for two main ramping products: Load following up and Regulation up. SPG is the cost optimal solution to provide load following over 60 % of the modelled hours, and around 80 % of the required regulation service. It can be seen clearly in figure 6 that SPG provides the majority of ramping services (load following and regulation), allowing more efficient gas generation to run at full load and provide cheap electricity, instead of offering system services.

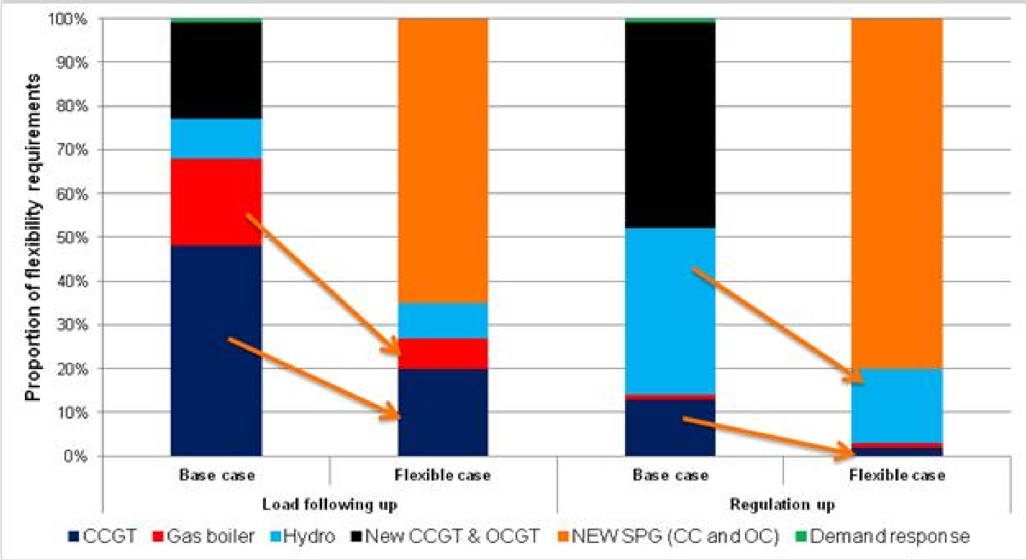

Figure 6 Flexibility provision in California in 2020

By introducing 5.5 GW of SPG instead of 5.5 GW of gas turbines in the system, the Californian consumers save around 900 MUSD per year representing around 11 % savings in system level generating costs. The cost breakdown of total system operating costs for the modelled scenarios is shown in the Figure 7.

Cost category	Base case Million $	Flexible case Million $	Cost savings in Flexible case
Variable generation cost	4 963	4764	199
Start and stop cost	179	96	83
Emission cost	1 463	1 401	62
Import cost	327	379	-52
Ancillary service cost	1 201	603	598
TOTAL system operating costs	8 133	7 243	890

- Flexibility reduces system generating costs by letting the cheaper generation to provide more energy, and avoiding the usage of inefficient generation
- Flexibility provides additional CO2 savings
- Import cost increase, due to slightly lower efficiency of SPG
- Over 50 % savings in system service's costs
- Value of flexibility around 900 MUSD/a (11 % system level cost savings)

Figure 7 Value of flexibility in California in 2020

2.4 Value of flexibility - Conclusions

Based on the studies performed by KEMA DNV, Redpoint Energy and London Imperial College, it is evident that including SPG into the generation portfolio reduces total system operating costs in systems with high penetration of RES. This is due to the specific characteristics of SPG, such as ultra quick start-up, allowing this technology to provide flexibility to the system at much lower costs compared to other thermal generating technologies that have to run at part-loaded. In addition, by adding SPG to the capacity mix of a power system other thermal plants no longer need to run part-loaded and can produced electricity at a higher efficiency which reduced overall generation costs. A system without SPG can provide flexibility by running plants at part load, but such actions significantly increase cost to consumers as shown in the studies. The value of flexibility in the examined 60GW (UK and California) peak load system with high RES penetration is analysed to be >> 500 MEUR per year. Translating this to a European size system, the value of flexibility is approximated to be >> 5 bn EUR per year, already in 2020. Consequently, flexibility should be one of the key parameters of future power system and energy market designs.

3 ELECTRICITY MARKET VISION FOR HIGH RES SYSTEM

Lately, there has been an active debate on capacity mechanisms in many European Union member states. In February 2013, the European Commission asked for stakeholders' inputs on potential ways to secure capacity adequacy and system reliability in a future system with high amounts of RES. However, such a power system also calls for flexibility, not just capacity. As clearly indicated in the studies above, in high RES power system flexibility is no longer an invisible and low cost side product of power generation, but a key factor in power system design and optimization.

Though the studies presented earlier clearly show the benefit of having flexibility in the capacity mix, current market arrangements do not reflect the value of flexibility or incentivize investments in flexibility. There are several issues in current market setups that "hide" the cost of inflexibility into consumer bills and consequently prevent investments in new flexible capacity. Simultaneously, energy-only market setups are struggling to keep capacity adequacy on healthy levels in this new reality.

Wärtsilä studied several electricity market models with the aim to develop an electricity market model that will incentivize flexibility and ensure capacity adequacy for a system with high amounts for variable RES. The market model should secure capacity adequacy, incentivize the right type of capacity, and lead to the least cost to consumer The overall market model design that will deliver this is shown in Figure 8, and is based two markets existing next to each other. The Energy Market, consisting of the wholesale electricity markets (day-ahead, intra-day and balancing market), together with a Flexibility Market establishes a competitive market environment where all market players can compete on an equal basis. A competitive Capacity Market would be introduced only if needed, to secure capacity adequacy. Below, each market is described in more detail.

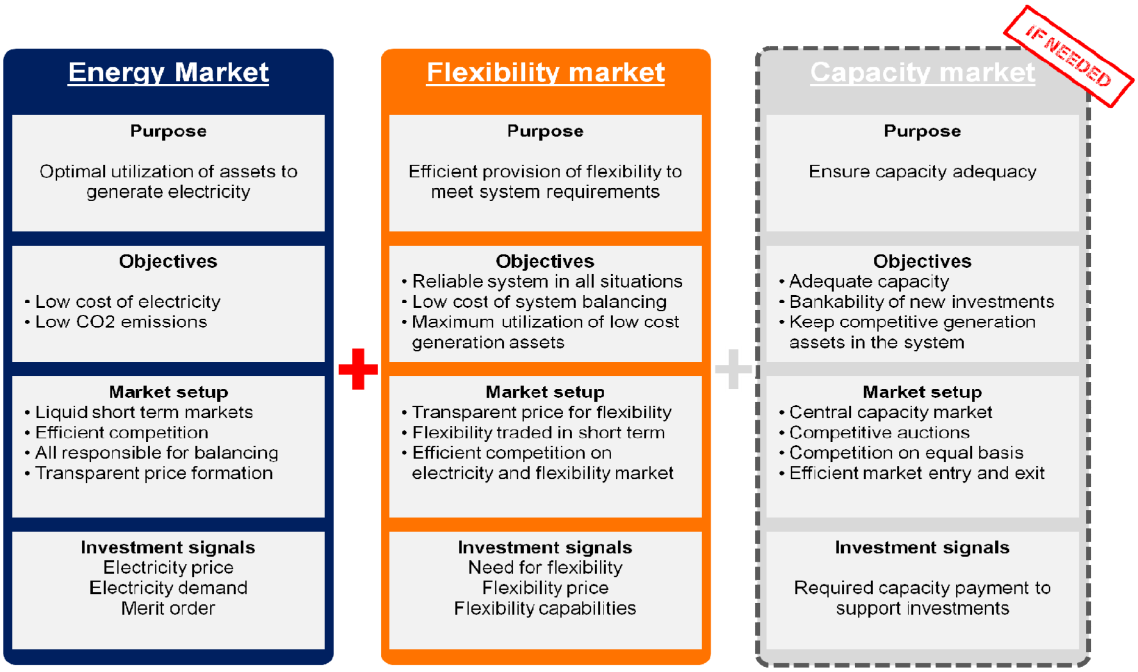

Figure 8 Market design for high RES power system

A competitive **Energy Market** forms the basis of the market model. The objectives of energy markets are to provide low cost electricity and low CO2 emission in all situations through competitive short term markets. Cost reflecting imbalance prices will increase the imbalance exposure of all market participants (where all participants are responsible for balancing), which incentivizes to be in balance at gate closure. Supply and Demand for Energy closer to gate closure is therefore expected to increase because each market player, in order to reduce the risk for out-of-balance penalties, will take efforts to be in a balanced position at gate closure, either through changed positions within its own portfolio of options (changing outputs of own power plants, DSR, etc.), or through trading. This development enhances the liquidity in intra-day markets, and provides additional income for flexible assets through balancing and intra-day markets because these units will be in a position to supply energy shortly before Gate Closure.

However, it would be hard, or even impossible, for providers of flexibility to capture the total value of flexibility through energy prices only. Therefore, in addition to the Energy Market, we propose the introduction of a market place for flexibility. A competitive **Flexibility market** would be a day-ahead option market for flexibility to increase/decrease energy the following day. The flexibility market would replace existing procurement strategies of TSOs and would make the procurement of system services more transparent to market players. TSOs would procure required flexibility (reserves) to satisfy the system needs for the following day from the flexibility market, when the volumes are not locked away under long-term contracts. The flexibility market would also be open for market participants to procure flexibility to hedge against intraday prices and imbalance exposure. Key features of the flexibility market are the following:

- **Buyer of flexibility:** Voluntary procurement of market participants. The TSO would procure always flexibility to the system needs, but the procurement of market participants could reduce the amount procured by the TSO.

- **Volume:** Market participants determine their own volume requirements depending on their willingness to hedge against price risk and the TSO provides the backstop in the DAH auctions to ensure that the system has the flexibility needed. The total volume of flexibility requirement is known through the TSO procurement strategy which provides stable volumes and liquidity in the flexibility market.

- **Products:** Multiple products (e.g. 5 min ramping, 30 min ramping etc.) defined by the TSO in consultation with industry, to ensure the needs of the system are met. All products require an option to deliver and increase or decrease in physical energy in a future settlement period.

- **Timeframes:** DAH timeframe aligns (or allows co-optimisation) with the energy market, and provides a daily reference price for different flexibility products. A secondary within-day market for market participants and the TSO to trade their options as more information emerges. Clear DAH reference prices can allow long-term financial contracts to be struck between flexibility providers and market players or the TSO.

- **Delivery:** Option holder (market participant or the TSO) may exercise the option by calling for energy to be delivered prior to gate closure. Self-provided flexibility must provide information to the TSO within-day on whether it will be exercised. After gate closure any unused options would be exercisable by the TSO in the balancing market.

- **Cash flows:** Flexibility cleared through the DAH auctions (other than self-provided reserve) is paid the market clearing availability fee (per MW) for the contract period (next 24 hours or hourly products). Utilisation fee (per MWh) is paid upon exercise. Unused flexibility must be offered into the balancing market at the fixed utilisation fee, for dispatch and payment by the TSO.

- **Cost recovery:** Option holder pays the availability fee to the flexibility providers. Availability fees incurred by the TSO could be recovered via an information imbalance charge levied on out-of-balance market participants.

- **Monitoring:** TSO would certify physical capability of capacity providers seeking to offer into the DAH auctions. Any options exercised would be notified to the TSO in the same way as physical energy.

A central **Capacity market** would be established if the Energy + Flexibility Market are not delivering investments or are not able to keep existing plants in the system. The purpose of the capacity market is to ensure capacity adequacy by providing so-called administrative capacity payment, which compensates the "missing money" from market operations. The future markets (energy and flexibility market) are volatile by their nature, while investors may require stable cash flows to be able to finance their new projects. In this case, a capacity market could enhance the bankability of new projects. Capacity market (like any capacity mechanism) should concentrate on securing the capacity adequacy, not specifying what type of capacity is needed. It should be technology neutral and treat all forms of capacity (demand and supply) on an equal basis. Well functioning energy market together with flexibility market would reward capabilities, when capacity market only provides the "all-in price" required by investor to make the investment.

4 ELECTRICITY MARKET VISION EVALUATION

An optimal power system provides affordable, reliable and sustainable electricity to consumers. The electricity market structure should provide incentives to investors to invest in new power generation which meet the set system objectives. It is relatively easy to design a market model which meets one or two of the set cornerstones of an optimal power system or favours some technologies over others. To assess the feasibility and compatibility of the proposed market model, evaluation criteria have been developed for this purpose. These criteria assess the market model from different perspectives taking into account the most relevant stakeholders. The developed evaluation criteria and the high level impact assessment are shown in Table 2.

Table 1 Market model evaluation

Criteria	Description	Evaluation
Impact on capacity adequacy	Delivers adequate peak capacity to minimise risks to security of supply	+ If required, the introduction of market wide capacity mechanism ensures capacity adequacy + Transparent and competitive market provides market based investment incentives
Impact on flexibility	Enables the value of flexibility to be transparently revealed, supporting the required volume of new investment	+ Transparent market for flexibility at the DAH stage can create a liquid reference price to support investment + Reduced imbalance exposure provides strong incentives for market to procure flexibility + SO provides a backstop to ensure that the system needs are met, and to aid liquidity
Facilitates competition, entry and exit	Encourages efficient competition and new entry, as well as retirements where this is economic	+ DAH flexibility market with clear reference price could encourage new entry from flexibility providers - Capacity mechanism may encourage older less flexible plant to remain on the system. Therefore essential to implement flexibility market before capacity market.
Impact on financing	Long-term bankability for investors, and ability to attract diverse range of investors and sources of finance	+ Flexibility market revenues allows flexible capacity to be more competitive in the Capacity Market, enhancing bankability - Investment on a project finance may not be viable + Strong cost targeting could encourage joint venture opportunities, for example between wind developers and flexible capacity providers
Impact on affordability	Consumers pay no more than necessary to deliver decarbonisation and security of supply	+ All costs visible for market players + Competition in all stages - SO may be more risk averse than the market with respect to both capacity and flexibility, increasing overall costs to consumers
Reliance on well-functioning wholesale market	Importance of a liquid and well-functioning wholesale market to the success of the model	- Within-day liquidity likely to be important to facilitate secondary trade in flexibility
Reliance on central decision making	Extent to which investment decisions are made by a central body	- Central determination of adequacy requirement + Cost of flexibility visible to market players and flexibility market providing market based tools to hedge against imbalance risk
Complexity	Complexity of the market arrangements and the subsequent investment decision	- Complexity in central determination of adequacy requirement - Definition of SO role as backstop flexibility provider may be difficult to design, monitor and enforce - Need clear mechanism to reduce imbalance exposure for hedged market participants if flexibility option hold after gate closure
Government and regulator views	Level of long-term political and regulatory sustainability, avoiding risk of further intervention	+ Can deliver system adequacy and flexibility needs + Provides efficient balance between market and the SO + Market based option as far as possible + Flexible generation securing affordable electricity to consumer - Potentially increased central decision making due to CM

5 CONCLUSIONS

Increasing penetration of variable renewable generation into a system changes the power system operations and impacts market fundaments. The biggest hit is taken by the thermal fleet. Operating hours of this fleet are reduced, whilst at the same time the average electricity price is lower. As a result the market based revenues for thermal plant is increasingly uncertain. Simultaneously, system operators are calling for flexibility from generation side to balance the fluctuations of variable renewable generation.

As shown in the case studies, flexible capacity can provide savings of several billion Euros annually to European consumers. This is the value of system flexibility, or on the other hand, the cost of system inflexibility. In the foreseen future EU power system, flexibility should no longer be an invisible and low cost side product of power generation taken care by the system operator, but a key factor in the power system design and optimization.

Today the capacity mechanism is at the center of the EU Electricity debate due to risk of capacity shortfalls. While continuously trying to ensure capacity adequacy, adding flexibility to the system should be higher in the agenda. There are potential market based approaches to incentive investments in flexibility, which do not require administrative cash flows, but call for a reallocation of system costs from the TSO to the market, making the cost of flexibility visible for market players. To develop a reliable, affordable, and sustainable power system, several actions are needed.

- Firstly, understand that the energy market environment has dramatically changed due to increasing amounts of variable RES generation, and this new environment requires increased services (flexibility).
- Secondly, recognize the value of flexibility and make it visible for market players through cost reflective imbalance prices and by developing short term energy markets.
- Thirdly, create a transparent market place explicitly for flexibility enabling efficient procurement of system services, and providing clear market signals for investors in flexibility.
- Fourthly, ensure market entry for new players and bankability of new projects by introducing a capacity market, if the Energy and Flexibility markets are not delivering the investments.
- To avoid the risk of “locking-in” a wrong type of capacity, it is important to note that steps one to three are implemented before step four is considered.

Many market players are calling for a market based approach regarding the EU electricity market structure. It is possible to design an electricity market which provides investment signals for the right type of capacity, and ensures capacity adequacy in at the same time. However, this requires a new approach to electricity market design, since old tools are no longer suitable in the changed market environment.