Assessing resource adequacy in an integrated EU power system

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EXECUTIVE SUMMARY

The EU power sector is facing for several years an investment dilemma with both continuing overcapacities of conventional power generation assets, and a few locally constrained adequacy issues[1]. Consequently, nationally oriented Capacity Remuneration Mechanisms (CRMs) and market exit barriers have been introduced by several Member States in an uncoordinated manner, often giving little consideration to the actual system adequacy problem or possible market distortions they induce.

Ongoing Commission's sector inquiry on CRMs suggests that there's an important lack of consistency between adequacy assessment, reliability standards and the introduction of such remedial actions, e.g. there often a mismatch between the outcome of adequacy assessment and the capacity procured in CRMs. Moreover, current Member States' practices as regards to adequacy assessment largely fail to consider the benefits of regional solutions such as the potential contribution of imports and exports. Existing methodologies also overlook in a large extent what can be the contribution of non-conventional sources of energy to adequacy, such as renewables, demand side response or storage in the future.

Considering this, it appears to be a strong case for further aligning the way resource adequacy is assessed. This includes to harmonise at EU level methodological aspects in a first place, like the use of most advanced stochastic approach that will ensure a systematic and realistic inclusion of wind potential in adequacy assessment. It also implies to streamline the performing of resource adequacy assessments at regional level to make sure cross-borders solutions, if needed, 1° are prioritised over national ones when proved more efficient, 2° result from a common understanding of the same problem.

Such changes also call for clearer roles and responsibilities to be defined between Transmission System Operators (TSOs), National Regulatory Authorities (NRAs), governments, European Network Transmission System Operators for electricity (ENTSO-E), the Agency for the Cooperation of Energy Regulators (ACER) and the European Commission; especially if a regional approach is chosen.

In this respect, you will find here after WindEurope's policy recommendations.

[1] For more details, see annex 1

Policy recommendations

On the methodology itself

- Ensuring future adequacy assessments are in line with the Energy Union's governance process (cf. assumptions of the upcoming 2030 national climate and energy plans)
- Developing a holistic approach that systematically and realistically include renewables, demand side response, storage and interconnections' contribution to adequacy. In particular:
  - Wind capacity credit
  - Accurate modelling of interconnections contribution using flow-based methodology
- Properly taking into account, and ensuring more transparency on the economic viability of power plants and the level of must run obligations
- Establishing stochastic approach (e.g. Monte Carlo simulation) using statistically relevant set of historical climatic data, as well as LOLE and ENS indicators, as a benchmark reference to assess resource adequacy
- Evolve towards more granular time resolution

On roles and responsibilities

- The European Commission should propose a harmonised methodology for adequacy assessment
- ENTSO-E should be entitled to develop and update such methodology ensuring adequate stakeholders' consultation
- Developing a regionalised approach to adequacy assessment by:
  - Firstly, encouraging bottom up cooperation in regional fora in order to develop joint assessments in addition to national assessments
  - In fine, evolving towards fully regionalised adequacy assessments whose consistency with EU methodology will be checked by ENTSO-E
- ACER should be entitled with the competence to oversee those regional adequacy assessments and develop guidance on which methodology to use for estimating VOLL
- NRAs and TSOs should provide stakeholders with a transparent and inclusive framework that will guarantee their involvement at relevant stages of the process, including by the mean of public consultations
- NRAs/governments remain responsible for setting binding reliability standards that they compare against the outcome of adequacy assessment in order to inform the need for, and size of, any needed remedial actions
- The implementation of these remedial actions should be scrutinised by the European Commission, ideally ex ante (if not ex officio procedure should be considered), in order to determine their consistency with European State Aid Guidelines

1. POTENTIAL FOR A COMMON METHODOLOGY

1.1. EXISTING FRAMEWORK

Foreseen by the 3rd Electricity Package (Regulation EC 714/2009), the European Network Transmission System Operator of Electricity (ENTSO-E) must deliver a long-term system adequacy assessment in order to provide stakeholders and decision makers with a tool to base their investments and policy decisions. Since 2011, it performs every year a Scenario Outlook & Adequacy Forecast (SOAF) looking at how balance between supply and demand is likely to evolve in Europe up to 2025.

ENTSO-E assess system adequacy by using two bottom-up generation scenarios (scenario A 'Conservative' vs. scenario B 'Best Estimate') which are based on the best national information on generation mix, and only factor in interconnection projects with a high level of confidence to be commissioned =.

In its 2015 edition of the SOAF, ENTSO-E has extended its analysis to a month resolution over the time frame 2016-2020-2025. It reflects the evolution of national adequacy assessments toward full stochastic **modelling on a pan-European basis**. Concretely, this means that power balance is assessed at a common reference point in time for all countries. This is the point with the highest load, i.e. the 3rd Wednesday of each month on the 19th hour (peak load has been achieved in all of the last three years on the 19th hour)[2].

Traditionally, ENTSO-E analysis focuses very much on the power balance (see figure 1). It is underpinned by a set of key indicators, such as:

- **Net Generating Capacity** (NGC): the maximum electrical net active power a power station can produce continuously throughout a long period of operation in normal conditions. The National Generating Capacity is the sum of the individual NGC of all power stations.
- **Reliable Available Capacity** (RAC): the part of the National Generating Capacity that is actually available to cover the load at a reference point (i.e. thermal fleet + transfer capacity limit)
- **Unavailable Capacity** (UC): part of the NGC that is not reliably available because of limitations of the output power of power plants, among others:
    - System services reserves (frequency and voltage capabilities, must run obligations)
    - Unplanned outages
    - Maintenance and overhauls
    - Intentional decisions by operator not to run the plant
    - Availability of the primary energy source
- **Adequacy Reference Margin** (ARM): the part of NGC that should be kept available at all times to ensure the security of supply on the whole period that each reference point is representative of

[2] SOAF 2015 shows that these peak loads increase over the period 2016-2025 by 0.9%, notably due to electrification process and economic recovery.

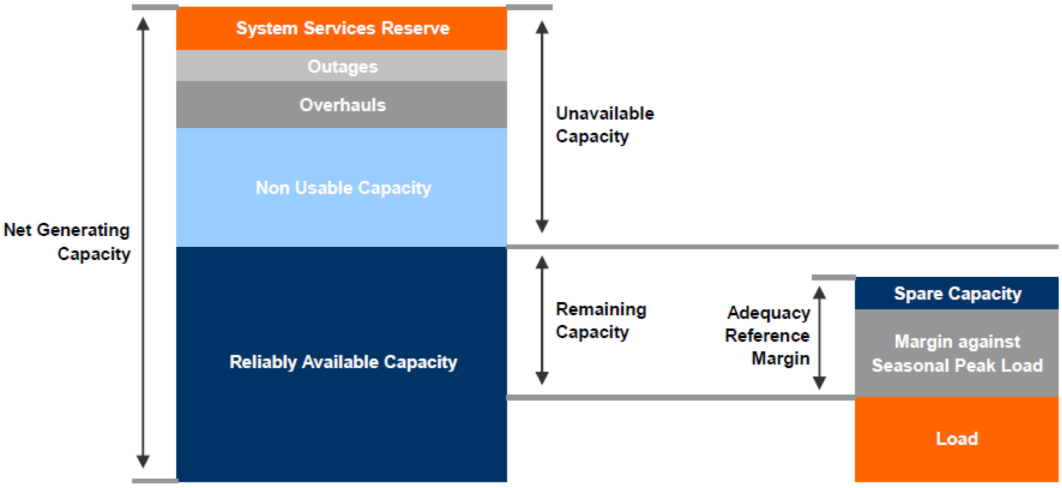

Figure 1 *Schematic depiction of adequacy methodology, ENTSOE SOAF 2015*

One of the main disadvantage of current deterministic ENTSO-E approach is that it clearly overlooked the contribution of variable renewables (wind, solar) to system adequacy. According to ENTSO-E, 94% of the NGC increase between 2016 and 2025 is considered as Unavailable Capacity, which is closely linked to variable renewables penetration. This suggests that the contribution of future installed renewables capacity to system adequacy is factored in as close to zero (see figure 2).

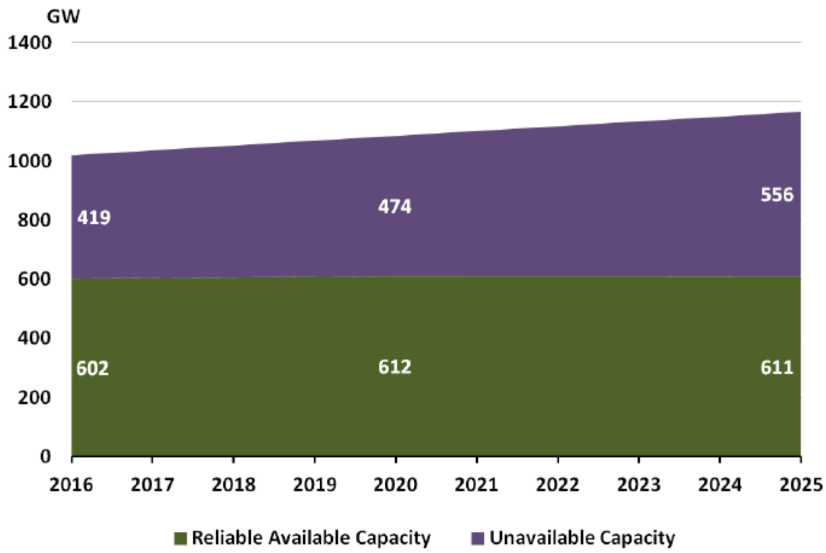

Figure 2 *Ratio between RAC and UC over the next 10 years, ENTSOE 2015 SOAF*

Moreover, the evolution of conventional capacity considered is built in most cases assuming technical aspects only (as the remaining useful life), which do not take into account the economic viability of plants under the existing regulatory and market arrangements.

1.2. KEY AREAS OF IMPROVEMENT

Although the Scenario Outlook & Adequacy Forecast has been constantly improved over the years and represents a good basis to develop an EU target methodology, it still requires some key upgrades, notably with regards to which input data are considered but also how the simulation itself is performed.

1.2.1. ON INPUT DATA

In its 2014 report on generation adequacy assessment, the CEER noted that lack of strong connection between the national scenarios for generation and load forecast, and those developed by ENTSO-E.

Regarding forecasts on installed capacity in particular, there is often very limited information available about the commercial plans of individual operators. Information on / analysis of the economic viability of existing and new plants should somehow be improved and taken into account.

It also must be ensured that future adequacy assessments take into account the objectives in terms of RES deployment and energy efficiency programmes enshrined in the upcoming 2030 national climate and energy plans, whose progress is expected tobe tracked by the Commission every 2 years.

Furthermore, most national adequacy assessments fail to capture the contribution of demand-side response (DSR). In 2014, only 3 countries reported that they include demand response as a separate factor in their load forecast. Alternatively, demand-side response (DSR) may be indirectly included in the projections through the effects it has had on the historical load curves. But there is neither a common approach across the EU to factor its impact on adequacy (see box below) nor there is a common understanding about what demand-side response actually covers. ENTSO-E SOAF only takes into account interruptible demand schemes where they exist, and start factor in DSR capabilities that are emerging in some markets (Belgium, France). The lack of data is currently the main barrier to the inclusion of demand side response.

The methodology used in Great Britain includes a contribution from demand-side response which refers to customers responding to a signal by changing the amount of energy they consume from the grid at a particular time. The historical demand data utilised to create demand distribution incorporates actual demand-side response levels (as it is transmission connected demand). Demand-side response levels are then projected based on assumptions around the potential available demand-side response for a given scenario, particularly during periods of high demand. In that case, the model treats demand-side response as a reduction in peak demand, which may vary year on year.

In France, demand-side response is defined as a generation asset, meaning that it includes implicit tariff option signals (around 3000 MW) and explicit resources available on the balancing market (less than 800 MW, source: RTE).

Council of European Energy Regulators, 2014 report on generation adequacy assessment

Similarly, a minority of Member States takes storage contribution into account in their national adequacy outlooks. When they do, it's mainly pumped hydro storage.

Last but not least, more transparency is needed as regards to the level of must run obligations. As there is little or none access to those data, it gives TSOs the opportunity to set conservative figures that might influence the result of the simulation.

1.2.2. ON THE SIMULATION

There is clearly room for improvement as regards how RES variability is modelled, which can be done in various way. Depending on the level of penetration, this can vary from no consideration at all to a precise estimation per modelling time unit, based on sophisticated data. Some countries still go with the approach of Unavailable Capacity (Estonia, Romania, Malta, Demark) while there are others like the Netherlands, Norway, Spain and Sweden that take a certain percentage as available generation: 5, 7 or 20%.

This is the reason why the use of stochastic approach and climate and weather historical data is important. France and Great Britain already go up to detailed modelling based on climate data, hub heights (for offshore wind farms) and detailed coordinates for the generation sites.

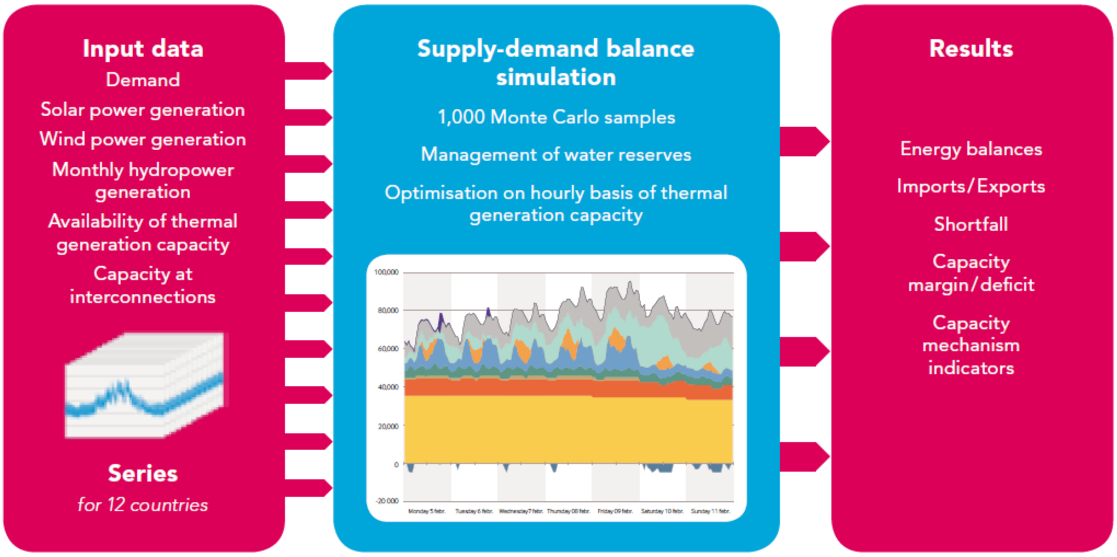

Figure 3 *Overview of method used to analyse the supply-demand balance, RTE 2015 generation adequacy report*

ENTSO-E will also move away from his classic deterministic approach. Its next adequacy assessment report will rely on a stochastic approach using Monte Carlo simulation (see Figure 3) to model the probability of a worst case at different time horizon (2020, 2025). Supply is matched against demand by simulating the operations of the European power system on an hourly basis over an entire year. This simulation takes into account key events that could put security of supply at risk, notably by using a statistically relevant set of climatic time series (over the last 14 years) from the Pan-European Climate Database.

While this evolution is quite satisfactory, a key point is whether an hourly basis modelling time unit is sufficient to capture the variability of demand and supply. More granularity in time resolution, such as a 30 or even 15 min time, might better capture the variable RES coverage of load.

High wind and solar generation penetration will also imply significant changes in the form of residual demand[3] that adequacy assessments should more and more explore. Daily gaps between maximum and minimum residual demand is likely to increase, thereby increasing the related flexibility requirements. ENTSO-E SOAF 2015 already provides some form of ramping analysis of these dynamic changes. Figure 4 indicates the higher bound for hourly residual load ramps during the worst nine hours within the 14 climatic years analysed.

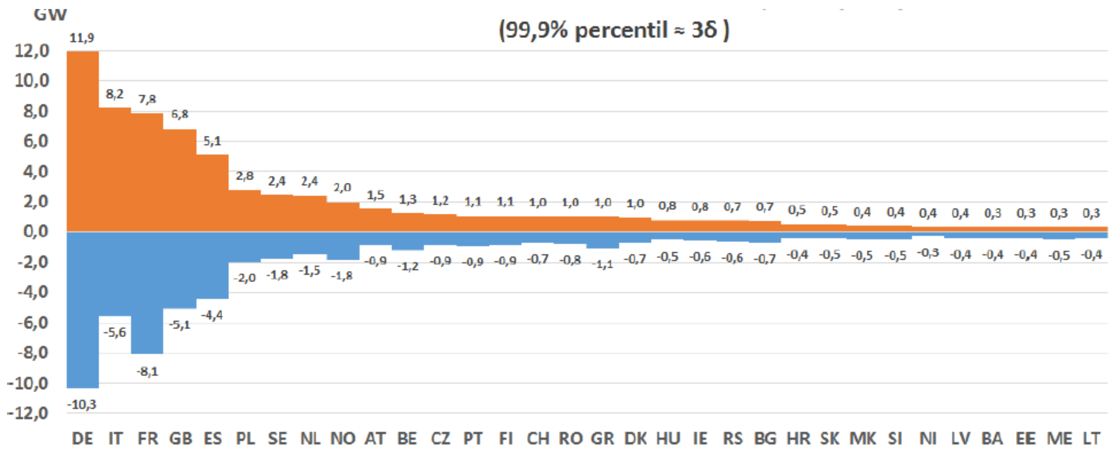

Figure 4 *Absolute values of the residual load hourly ramps by countries, ENTSO-E 2015 SOAF*

This ramping needs analysis indicates the amount of power demand that will have to be covered by dispatchable generation. This raises the question whether or not the amount of operational reserves (for system security) should be into account as "available capacity" in adequacy assessments. According to CEER, in at least 4 countries (France, Sweden, Italy and Hungary), the volumes procured by TSOs in terms of ancillary services and balancing reserves is treated as "available" capacity. On the contrary, many Member States as well as ENTSO-E substract it from their calculation. In that case, national TSOs should ensure the level of operating reserves is set transparently, and considering the potential contribution of pooling and sharing reserves across borders as foreseen by the Target Model. Besides, the inclusion or not of operational reserves should be considered together with the chosen time resolution. If they are considered as "available capacity", time resolution needs to be reduced to 15 min as shortage can still occur within an hour (not solved by day ahead trading).

[3] Defined as power demand after subtracting generation from wind, photovoltaic and must run generation.

2. RECOMMENDATIONS

2.1. WIND ENERGY'S CONTRIBUTION TO SYSTEM ADEQUACY

As previously explained, as of today, most national adequacy assessments focus on the contribution of firm generation units, with little or no consideration for the contribution of other energy resources such as demand-side response, storage, imports/exports (see next section) or renewables. In WindEurope's view, their contribution should however be systematically and realistically reflected in future adequacy assessments in order to properly reflect how the EU power system operates.

In particular, regarding wind energy's contribution, the aggregated capacity credit (annual availability factor, measure on % of a year) of the wind farms in a system depends on many factors. Among them, the characteristics of the power system in question (reliability level, geographical area, flexibility and composition of the total generation mix, correlation between low electricity price and demand) and the penetration level of wind power in the system. It also depends on a range of wind and wind technology specific factors such as the capacity factor, or location of wind farms in the system.

Despite the real physical capacity value of wind power, it is not yet regularly used for capacity planning and frequently is not given a value in power markets using deterministic adequacy assessments. In part, this is due to the diversity of methods available for calculating the capacity credit, but also to a lack of assessing adequacy at European level beyond control zones. Firm capacity from wind power has neither been thoroughly analysed in an integrated EU system nor has its interplay with other renewables such as photovoltaic been considered. Such analysis could help mitigate variability from both, increasing their firm capacity share. Moreover, the operational performance of wind turbines has improved over time thanks to continuous technological innovation. Those future improvements should somehow be reflected.

Wind capacity credit

The TradeWind[4] study found that the effect of aggregating wind energy across multiple countries increases the average capacity credit by a factor 1.7 compared with the capacity credit averaged over separate countries.

Clearly, the completion of the Internal Energy Market is instrumental for this benefit to be exploited. The wider the control zones are geographically, the higher the resulting capacity credit of wind.

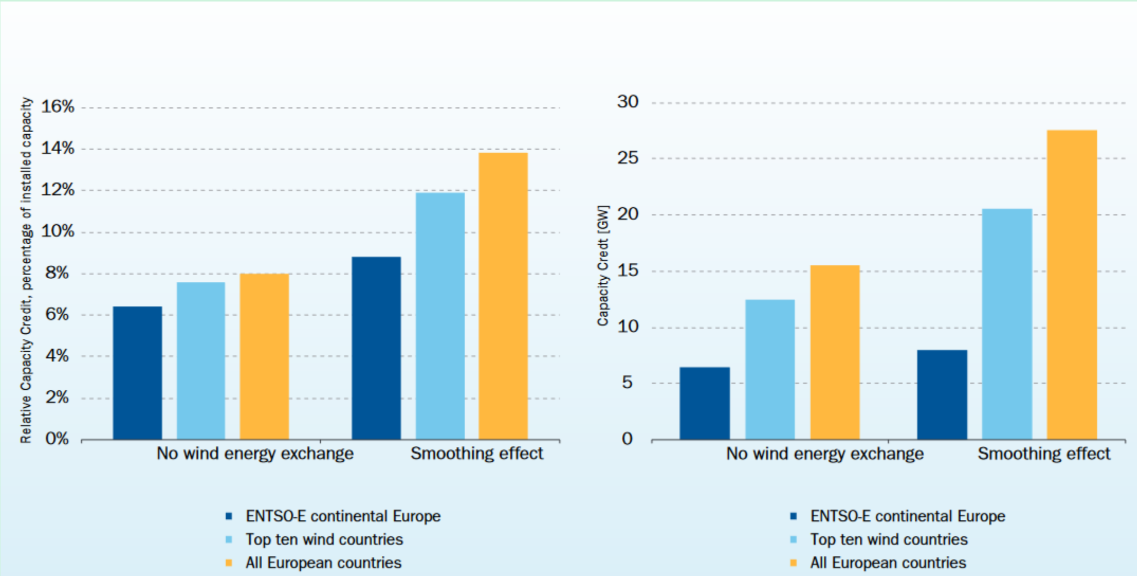

Figure 5 *Increase in capacity credit in Europe due to wind exchange between countries in 2020, TradeWind project*

2.2. TOWARDS A FULLY REGIONAL APPROACH

In a pan-European electricity market, problems (e.g. bottlenecks, blackouts etc) do not stop at national borders. Experience has largely proved that. Moreover, interconnectors play an essential role in ensuring security of supply as they can enable an efficient utilisation of electricity resources across Europe, in particular for renewables producers whose output is variable. There is a strong case to take the benefits of grid exchanges[5] (see box here after), as well as the benefits of shared operational reserves when relevant, into account. In 2014, some countries still modelled an isolated system (Norway, Estonia, Romania and Sweden) while a majority already simulated an interconnected system. As a next step, it makes sense to perform adequacy assessments at regional level. Importantly, this requires to accurately calculate the availability of interconnectors by using flow-based methodology[6]. It also implies transparent

[4] http://www.uwig.org/TradeWind.pdf
[5] The availability of interconnection capacity is mostly based on historical data (export and import flows during various periods of time), while estimated data is more rarely considered in the analysis (e.g. market component such as future prices estimations).
[6] Compared to Available Transmission Capacity method, flow-based coupling usually results in a more important efficient use of cross-border transmission capacities (as close to the physical limits as possible).

rules for the management of situations of simultaneous scarcity in neighbouring countries that will ensure that the volume of available transmission capacity is not reduced.

Contribution of imports/exports – the French case

Analysis of France on a standalone basis, i.e. not taking into account cross-border exchanges, shows how vital imports are to ensuring domestic security of supply. In that case, exchanges contribute about 8 to 10 GW on average during peak periods over the coming years. The expansion of interconnection capacity, together with the availability of capacities in neighbouring countries where declining demand creates margins, explain why this contribution is so high.

	Winter 2015-2016	Winter 2016-2017	Winter 2017-2018	Winter 2018-2019	Winter 2019-2020
Expected energy not served	53.8 GWh	85.1 GWh	458.9 GWh	128.8 GWh	133.2 GWh
Loss of load expectation	14 h	20 h	34 h	28 h	30 h
Capacity deficit	-4,600 MW	-5,400 MW	-7,200 MW	-6,600 MW	-6,700 MW

Figure 6 *Analysis of shortfall risk for the next 5 years in France without cross-border exchanges, RTE 2015 generation adequacy report*

	Winter 2015-2016	Winter 2016-2017	Winter 2017-2018	Winter 2018-2019	Winter 2019-2020
Expected energy not served	1.4 GWh	6.1 GWh	12.9 GWh	10.9 GWh	7.0 GWh
Loss of load expectation	0 h 30	1 h 45	3 h 15	2 h 45	2 h 00
Capacity margin or deficit	4,800 MW	1,700 MW	-200 MW	300 MW	1,200 MW

Figure 7 *Analysis of shortfall risk (…) including cross-border exchanges, RTE 2015 generation adequacy report*

To achieve this, voluntary regional cooperation is to be favoured in a first place where national and regional assessments would coexist. National TSOs remain responsible to assess structural adequacy concerns under scrutiny of national regulators / governments. Those assessments should be performed on a yearly-basis looking at time horizon of 5-10 years, and model the impact of an integrated system at regional level.

In fine, fully regionalised adequacy assessments, performed jointly by TSOs and based on a harmonised methodology to be developed and updated by ENTSO-E, should be mainstreamed. ACER should be entitled to oversee those assessments and scrutinise consistency with EU regulatory framework (state aid guidelines, grid codes requirements etc). This would ensure a rigorously-need based and coordinated approach to security of supply which takes into account the benefits of the Internal Energy Market. For the sake of transparency, stakeholders' consultation should be organised to provide opportunities to input on a) the harmonised methodology to be developed by ENTSO-E, b) the assessments to be performed at regional level.

1. Improved national assessments. Improving current national adequacy reports in order to include some interconnection modelling. Their outcome, matched against binding reliability standards set by NRAs, indicate the need or not for remedial actions.

2. Bottom up regional cooperation. Regional adequacy assessments are developped on a voluntary basis by regional fora such as the Penta Forum, in parallel to national assessments which remain the norm. ENTSO-E ensures consistency between the different methodologies.

3. Full harmonisation. Resource adequacy assessments are performed at regional level only, based on a harmonised methodology and overseen by ACER. NRAs remain responsible to set reliability standards but their decisions must be taken as a consequence of those assessments.

Although System Security Centres, as defined by the newly adopted System Operation guidelines (e.g. Coreso, TSC), might play a role in performing seasonal outlooks, their involvement is not relevant beyond this operational time horizon as long term adequacy concerns are more linked to investment cycles.

If outcome of the assessment proves to be insufficient capacity in order to achieve the level of reliability desired, national regulators / governments should decide remedial measures under the scrutiny of DG COMP (ex officio if not notified before introduction)

2.3. INFORMING THE NEED FOR REMEDIAL ACTIONS

Power system reliability is considered to be a « public good », and this requires that customers » collective demand for electricity is met when they turn on their appliances, subject to a socially acceptable standard for service interruption. Indeed, the variables to which the power system is subject make it uneconomical to guarantee that demand will be met at all times and under all circumstances. The goal is thus to keep the shortfall risk at a socially and economically acceptable level.

As previously explained, national regulators normally determine reliability standard which sets a level of security of supply that is deemed appropriate. If the outcome of the adequacy assessment shows it above that level, further simulations is usually carried out to estimate the additional supply needed, i.e. the capacity gap, adding the theoretical new capacity needed until the annual LOLE moves below the standard. However, one of the main findings of DG COMP interim report of the sector inquiry on capacity mechanisms is that in many countries there's not a clear link between the capacity procured through CRM and the capacity needed to achieve the reliability standard (according to the result of the adequacy assessment). Furthermore, some countries fail to scale down their level of support through CRM when this comparison of the adequacy assessment and the reliability standard would recommend to do so.

Therefore, any remedial actions should be introduced as a consequence of an identified gap stemming from the comparison of the outcome of the regional adequacy assessment (expressed in LOLE and ENS) and the biding reliability standard.

Figure 8 shows that less than half of the countries calculate Value of Lost Load[7] (VOLL) and use it as their basis for determining their reliability standard. High VOLL reflects high degree of protection desired. Some countries estimate the cost of additional capacity needed by using another indicator called "Cost of New Entry" (CONE) or "Best New Entrant" (BNE), usually based on the costs of a new peaking plant. If the VOLL is equal to CONE or BNE, this means an economic efficient level of protection is set.

Legal Reliability Standard or Target?							
Country	Y/N	Which?	Link with VOLL?	Country	Y/N	Which?	Link with VOLL?
Belgium	Y	LOLE (average) < 3h LOLE (extreme 95%) < 20h	N	Italy	N	In the future: LOLP	Possible future regime: curve linked to VOLL of 3000,-
Denmark	N	Non-legislative target for TSO to ensure max. 5 min. of disconnections per consumer/year (LOLE < 0.25).	N	Poland	Y	Reserve capacity levels	N
France	Y	3 hrs LOLE	Yes, 20.000,-	Portugal	Y	Reserve Margin and LOLE 8hrs	N
Germany	N	n.a.	Intention: Future reserve triggered at 20.000,-	Spain	Y	Capacity margin of 10%	N
Ireland	Y	LOLE < 8h	Y, 10.898,-	Sweden	N	Reserves to meet N-1 is target for TSO	N

Figure 8 *Member States' practice in setting a reliability standard, DG COMP sector enquiry on Capacity Mechanisms*

Because electricity can have different value for each customers (households, SMEs, industry etc), it is difficult to estimate it, and even more to harmonise it across countries. This is one reason why reliability standards should remain defined at national level, provided adequate stakeholders' involvement and consultation. As VOLL is likely to inform the amount of capacity to be procured through remedial measures, further guidance could be developed by ACER to evolve towards a common method across the EU.

[7] i.e. the estimated price that customers receiving electricity with firm contracts would be willing to pay to avoid a disruption in their electricity service (beyond they would accept being cut off)

ANNEX 1 – RELIABILITY OF THE EU POWER SYSTEM: STATE OF PLAY

WHAT DO WE MEAN BY ADEQUACY?

Although no common definition exists, adequacy is traditionally understood as the ability of the totality of generating units to provide adequate supply at all time, including during peak load and generation outage conditions. This means it does not include impact of transmission and distribution disturbances on the reliability of electricity supply, that greatly exceed the impact of resource adequacy.

Hence, a distinction is often made between short term operational reliability (ability of the system to withstand sudden disturbances) vs. long term adequacy (ability of the system to supply the aggregate electrical demand of customers at all times). On the other hand, one can see an increasing trend to consider the ability to supply load during challenging ramping conditions, although current adequacy assessments concentrate on the potential capacity that would be needed in different time horizons, but do not consider flexibility and balancing mechanism issues to ensure operational reliability.

The four dimensions of security of electricity supply:

- **Security**, a very short term issue (in the realm of system operation, close to real time), is defined by the North American Electric Reliability Council as the "ability of the electrical system to support unexpected disturbances such as electrical short circuits or unexpected loss of components of the system or sudden disconnection"
- **Firmness**, a short- to mid-term issue, can be defined as the ability of facilities already installed to respond to actual requirements to meet the existing demand efficiently. This dimension is linked to both the technical characteristics of the generation and network facilities and their management in the medium-term (cf. scheduling of maintenance of lines and generators or control of hydro reservoirs)
- **Adequacy**, a long-term issue, refers to the existence of enough generation and network capacities, either installed or expected to be installed, to efficiently meet demand in the long term, including when it peaks, taking into account scheduled and reasonably expected unscheduled outages. This is a long term/structural issue with usually a time horizon > 5 years.
- **Strategic expansion policy** concerns the very long-term availability of energy resources and infrastructures. This dimension usually entails diversifying fuel supply and the generation technology mix, together with long-term network planning, and it is frequently associated to other aspects of energy policy, in particular environmental concerns.

Pablo Rodilla and Carlos Batlle, The Regulation of Power Sector, 2015

The term “generation adequacy” is often used in the discussion of the need for or design of capacity mechanism. Increasingly, the terms “resource” or “‘system adequacy” are preferred as they encompass a broader range of energy resources that can provide capacity as well, including generation, demand response, storage, interconnections, better network management etc.

IS THE EU POWER SYSTEM RELIABLE?

Today, many Member States are considering a various range of mechanisms to address potential reliability risks to arise in the future, most of which to be based on a very traditional approach to adequacy assessment (ANNEX 1 provides a definition of adequacy), and implemented regardless of their fitness with a rapidly changing energy resource mix.

However, the European Commission has concluded in its 2014 energy prices and costs report[8] that in the majority of Member States the supply of electricity is more reliable than that of the United States, Japan, China and Russia. Recent DG COMP interim report of the sector inquiry on Capacity Mechanisms[9] confirms that reliability issues to generation inadequacy have been in fact extremely rare in the past years. Most noticeable ones have occurred in Italy, on the islands of Sardinia and Sicily which are not well connected to the grid on the mainland.

High growth expectations before the 2008 economic crisis, together with the availability of cheap coal on international markets and low carbon prices, triggered considerable overinvestment in coal and gas power plants in many Member States. Since 2000, total installed generation capacity in the EU-28 has increased by more than 30%[10] whereas power demand has significantly declined in recent years as a result of economic downturn (-6.3% between 2008 and 2014[11]). This contraction of power demand has also been accompanied by a downward trend of peak demand. Increasing gap between peak demand and potential supplies, as well as the drop in wholesale electricity prices over the last decade, therefore suggests continuing overcapacity in the power generation fleet.

GROWING CONCERNS OVER SECURITY OF POWER SUPPLY

Despite this current comfortable capacity margin, public authorities expect reliability problems to arise in the coming years, due to the closure / mothballing of existing plants and lack of new investments to replace them and, more generally, due to an increasing uncertainty on whether sufficient flexibility options will be available in the future when demand peaks and renewables generation is low.

In several Member States, many power plants will approach the limit of their operational life, e.g. by 2020. Some coal-fired plants are to close due to stricter environmental policy (in the UK, with the application of

[8] https://ec.europa.eu/energy/sites/ener/files/documents/20140122_communication_energy_prices.pdf
[9] http://ec.europa.eu/competition/sectors/energy/capacity_mechanism_report_en.pdf
[10] DG COMP interim report of sector inquiry on capacity mechanisms, 2016
[11] ACER 2014 Market Monitoring Report, 2015

the Industrial Emissions Directive; in Poland as a consequence of an increased emission standards). Some countries have decided to reduced (France) or phase out (Germany) their nuclear fleet. And other countries (e.g. Belgium, Spain) phase important decision on whether to extend the operation life time of their old nuclear power park.

Even if most renewables generation units are the youngest in the generation mix, the question of their "repowering" and/or upgrading is also key if the EU wants to meet its at least 27% renewables energy target by 2030. Given the fact that the life span of a wind turbine is only 20 years, over half of today's wind farms are not going to be around at that time horizon unless additional investments are undertaken.

Finally, there might be specific adequacy problems arising at local level. This is the case for instance in Germany, where both the lack of transmission infrastructures from Northern to Southern regions together with the phasing out of nuclear power plants, have led to the introduction of a "grid reserve" which prevents power plants in the South from closing. This intervention creates an exit barrier and, hence, an additional "missing money" problem – the market is not allowed to rebalance by itself in order to create a scarcity expectation that justifies a reasonable opportunity for existing plants to cover their fixed costs.

The table here below shows selected countries and the opinion of stakeholders on whether they expect reliability problem to occur in the future.

The necessity of capacity mechanisms and actual reliability problems							
Country	Do Market Participants believe the mechanism is necessary?	Have reliability problems occurred in the last 5 years?	Are reliability problems expected in the future?	Country	Do Market Participants believe the mechanism is necessary?	Have reliability problems occurred in the last 5 years?	Are reliability problems expected in the future?
Belgium	Y	N	Y	Italy	Y	Y, in Sardinia and Sicily	Y
Denmark	Divided	N	Y	Poland	Y, but doubts as to appropriateness of the chosen mechanism	N	N
France	Y	N	Y	Portugal	Y	N	N
Germany	Y	N	N	Spain	Y	N	Y
Ireland	Y	N	Y	Sweden	Divided	N	Y

Figure 9 *The necessity of capacity mechanisms and actual reliability problems, European Commission DG COMP based on replies to sector inquiry*

ANNEX 2: OVERVIEW OF ADEQUACY ASSESSMENT PRACTICES

MOST COMMON PARAMETERS

Assessing resource adequacy[12] requires the definition of one or more scenarios that can affect generation and demand projections. These scenarios are elaborated according to different assumptions about load (typically high vs. low demand scenario), and type and amount of future installed capacity (e.g. conservative or baseline vs. RES penetration scenario). The scenarios can also differ on the basis of their time spell (short-, mid- and long-term), but most of them are based on a time horizon < 6 years[13].

A wide array of variables needs to be looked at when resource adequacy assessment is performed:

- **Regarding load forecast,** Member States base their projections on historical load curves, with assumptions on the evolution of specific parameters. These factors can take the form of macroeconomic, demographic, regulatory and policy drivers. The most common which are decisive to the sensitivity analysis usually are: demography, Gross Domestic Product (GDP) growth, fuel prices, power prices, inclusion of demand-side management, the influence of different level of energy efficiency, varying temperature levels and the development of electric vehicles and heat pumps. Often, consumers groups are classified to account for the fact that different consumer categories have separate consumption patterns (e.g. residential, industrial, commercial, agriculture etc.).
- **Regarding generation forecast,** the most important inputs are the information received by those intending to build new generation and rules on how to consider existing infrastructure (including interconnectors). All Member States take projected investments into account, although with heterogeneous sources and assumptions (i.e. generators, TSOs). Decommissioning (and mothballing) is only taken into account by half of the countries. In most cases, neither the contribution of variable generation (i.e. wind energy) and storage capacity is factored in, nor is information on demand-side response [see 2.2]. And despite ongoing developments, some assessments are still considering isolated systems and / or developing ways to include contribution from imports/exports.

[12] Today, most countries only assess generation adequacy, to wit the potential flexibility from demand side is not factor to ensure acceptable adequacy levels
[13] CEER 2014 report on generation adequacy assessment

Impact of extreme weather events

One of the main challenge in assessing adequacy is the inclusion of extreme conditions. Besides the obvious impact on in feed of wind and solar generation units, whether conditions deeply impact:

- Peak load, correlation with temperature (i.e. thermo-sensitivity). For instance in France, the highest value of instantaneous power demand climbed to a record 102 100 MW on February 8th 2012 because of the exceptional cold spell during this winter.

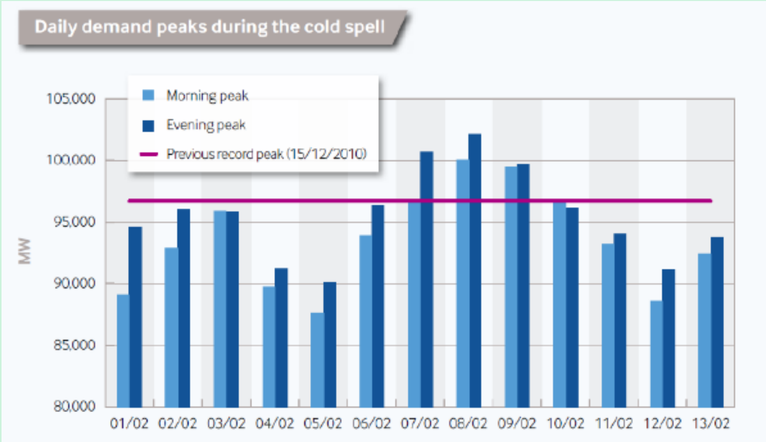

Figure 10 *Situation February 2012 in France, CEER/IEA*

- Hydro capacity, for which it is very difficult to define extreme years
- Possibility to withdrawn and return water from rivers for cooling down of power plants which can have severe impact on the availability of the thermal/nuclear generation fleet.

Several national adequacy reports (France, Norway, Estonia, Ireland, Sweden, and Denmark) include a specific study that can be described as an electricity system "stress test", i.e. assessing the ability of the resource fleet to supply electricity demand under extreme load conditions.

FROM DETERMINISTIC TO STOCHASTIC APPROACH

Member States carry out increasingly advanced adequacy assessments to cope with the growing complexity of the power system. The main reason is that it needs to take into account that both demand and supply vary considerably during the day, during the year and over the years, especially in power system with large proportion of decentralised energy resources. Moreover, it needs to be able to look far ahead, sometimes 10 years, which significantly increases uncertainty. Therefore, a majority of Member States have changed the way they assess resource adequacy from relatively simple "deterministic" assessment to highly sophisticated "stochastic" approaches, which are able to capture less predictable capacity sources, using state of the art weather forecasts for instance with hourly resolution for generation and demand.

The most simple deterministic method to assess adequacy is to calculate the **capacity margin**, which measures the amount of excess supply above peak demand, usually as a percentage. For instance, in 2016 France had 104,480 MW of production installed capacity whereas peak demand during winter 2015/2016 was 84,700 MW[14]; from that, one could say that France has approximately a 23% capacity margin. Of course, no form of generation can always output its full nameplate capacity with 100% reliability. Therefore, each sources of input needs to be applied a **de-rating factor** in order to reflect its likeliness to be technically available to generate at times of peak demand (e.g. in Ofgem's electricity capacity assessment, a combined cycle gas plant is assumed to be available 85% of the time). In 2014, CEER found that 6 Member States were using de-rated capacity margins: Estonia, Malta, Hungary, Belgium, Spain and Sweden.

Adequacy Assessments							
Country	Y/N	Who?	What?	Country	Y/N	Who?	What?
Belgium	Y	TSO	Probabilistic assessment based on LOLE	Italy	Y	TSO	EENS, LOLE, LOLP and Capacity Margin are calculated
Denmark	Y	TSO	EENS, LOLE and LOLP	Poland	Y	TSO	Capacity Margin
France	Y	TSO	LOLE	Portugal	Y	TSO + Gov	Load Supply Index (supply/demand per hour)
Germany	Y	TSOs + NRA	Calculation of EENS, LOLE, LOLP and Capacity Margin	Spain	Y	TSO	Capacity Margin
Ireland	Y	TSOs + NRA	Probabilistic assessment based primarily on LOLE	Sweden	Y	TSO	EENS, LOLE and LOLP are measured

Figure 11 *Member States practice in carrying out adequacy assessments, DG COMP sector enquiry on Capacity Mechanisms*

As shown in figure 11, a growing number of Member States now favour stochastic approach (or stochastic reliability methodology) that usually intends to quantify what is the **Loss of Load Probability (LOLP)**, i.e. the probability of a given level of unmet demand at any particular point in time, based on aspects such as temperatures, unforeseen unavailability of plants, variable generation etc..

This LOLP is often expressed in terms of **Loss of Load Expectation** (LOLE), i.e. the number of hours or days per annum in which, over the long-term, it is statistically expected that supply will not meet demand, thereby some customer disconnection is expected. For instance, French TSO RTE expects some customer disconnection to happen during 1h45 over winter 2016-2017[15]. It is important to note when interpreting this metric that a certain level of loss of load is not equivalent to the same amount of blackouts. In most cases, loss of load would be managed without significant impacts on consumers.

14 www.rte-france.com

15 Baseline demand scenario (assuming Fessenheim shut down in 2016), RTE 2016 generation adequacy report

However, LOLP/LOLE do not measure neither the size of the electricity shortfall (MWh) or capacity deficit (MW) that is expected not to be met by generation. It is the **Expected Energy Unserved or Not Served** (EEU or EENS), expressed in megawatt hours over a specific time period the indispensable indicator in order to determine the appropriate size of any future remedial measures [see 3.2].

ROLES AND RESPONSIBILITIES

Monitoring and assessing resource adequacy is a very complex process which s requires to define robust concepts, criteria and procedures in order to give a reference tool to decision-taking body if problems are encountered. In almost all EU countries, the body responsible for ultimately ensuring resource adequacy is the national government.

However, monitoring responsibilities are usually shared among the TSO, the NRA and the government. These responsibilities can evolve depending on the timeframe considered. According to the CEER[16], the responsibilities belong to:

- For the short term:
  - the TSOs in 13 countries;
  - the government in Belgium and Luxembourg; and
  - NRAs in Finland, Malta, Lithuania and Spain (together with the TSO in the latter case).
- For the medium and long term: the share of responsibility is similar with the exception of
  - Great Britain, where the responsibility shifts from TSO to NRA and government respectively;
  - Switzerland, where it shifts from TSO to NRA;
  - Estonia where the long term monitoring is managed by the government.

Hence, most of the short and medium term resource adequacy assessment is carried out by the TSO. In most cases, this assessment is performed yearly.

In addition, standard parameters are used to assess resource adequacy (most of the time expressed in LOLE hours). The responsibility of setting this reliability standard is not uniform: in some countries, it is the TSO while in others it is the government or the NRA. On average, those reliability standards range from 3 (France) to 8 hours (Ireland) in the EU. Importantly, those standards are not always binding (thresholds beyond which actions are to be taken), which leave room to the adoption of discretionary policies in most cases.

[16] CEER 2014 generation adequacy assessment report