BALANCING RESPONSIBILITY AND COSTS

of wind power plants

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EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

Executive summary

- Accurately defining and estimating the balancing cost of a single power generation technology, like wind power, is not a straightforward exercise. However, international comparisons of wind integration studies[1] suggest that in the EU**, increases in balancing costs due to wind variability and uncertainty amounts to approximately 1–4.5 €/MWh for wind energy penetrations of up to 20% of energy demand.** This is generally a marginal fraction of the wholesale value of wind energy (about 10% or less). In 2014, average wind energy penetration rate in the EU was 10.2%. EWEA expects this to increase to 14.9% by 2020, which suggests that in medium term, increases in balancing costs will not represent a significant share of total system cost.

- In most EU Member States where wind power has a share above 2% in annual generation (14 out of 18 Member States for which data was received) **wind power generators are already balancing responsible in financial or legal terms**. In these countries, wind power producers generally have the same balancing rules as conventional generation.

- Ranges of incurred balancing costs for wind power generators are 2-3 €/MWh on average. Compared to the balancing cost increase in the EU due to wind variability and uncertainty, this would mean that **in many cases wind power generators already bear the extra balancing costs they cause. In certain cases, this responsibility even exceeds the costs.**

- Worryingly, there are some notable exceptions. **In a few Member States, balancing costs borne by wind power generators seem to be arbitrarily high and possibly prohibitive for new installations.** In Bulgaria, the range is between 10 and 24€/MWh and in Romania, if not part of a large aggregator, wind power generators pay on average 8-10€/MWh.

- **Wind power generators are in most cases only partly allowed to participate in balancing markets and often only in providing replacement reserves.** Overall, balancing market arrangements seem to be applicable for conventional power generators mostly. With current technology, wind power plants can already provide ancillary services including balancing energy offering significant flexibility to the system. **Ongoing market reform and EU regulations in form of Network Codes should remove these barriers and provide for balancing market features and products apt for wind energy participation.**

- **Importantly, all future considerations by policy makers on balancing responsibilities by wind power generators need to take into account market maturity as well as the penetration level of wind power in the respective power system.** Market-specific boundary conditions under which balancing responsibility by wind power generators can be assumed include:

    - Existence of a functioning intraday and balancing market
    - Balancing market arrangements providing for the participation of wind power generators, as e.g. short bidding periods
    - Market mechanisms that properly value the provision of ancillary or grid support services for all market participants including wind power
    - A satisfactory level of market transparency and proper market monitoring
    - Sophisticated forecast methods in place in the power system
    - The necessary transmission infrastructure

[1] IEA Task 25, Wind Integration report, 2015

1. Introduction and scope of the paper

There are growing concerns about the extent to which variable power production impacts power system reliability, efficiency, and the ability to balance the power supply and demand. These concerns include the persisting misconception that wind power is still exempted from balancing responsibilities across the EU and the balancing cost they induce overall on the power system. This prompts a discussion on the best ways of exposing wind power generators to balancing responsibility and their participation in balancing markets.

Balancing responsibility is defined in a wide sense for the sake of this paper, namely the obligation of a power generator to match its forecasted electricity output in real-time. The aim of this paper is, therefore, to provide for:

- A detailed overview on balancing responsibility borne by wind power generators in selected EU including cost implications;
- Outline the terms and conditions related to national balancing markets at present;
- An overview on wind power specific features on national balancing markets, if existing;
- Policy guidance and recommendations to EU and national policy makers when considering balancing responsibility and market arrangements for wind power generators. This would be of particular relevance with regards to reference in State Aid Guidelines[2]: "RES generators shall be balancing responsible, where intraday and balancing markets exist" and its national implementation as well as in the upcoming Network Code on Electricity Balancing[3].

2. The balancing cost implication of adding wind energy to the power system

Calculating the uncertainty of adding wind to a system and extracting supplementary balancing costs is not a simple case of addition. For example, if the uncertainty in the demand forecast one hour ahead is 400 MW and the uncertainty in wind output is 150MW, the combined uncertainty is not simply 550MW (400+150). In this case, the TSO would carry out a more complex statistical calculation returning the lower uncertainty in a range of 420-430MW[4]. Equipped with this information, the TSO can assess how much extra reserve to schedule when their system includes wind. The cost of this extra reserve can then be quantified in such a simplistic way, usually using market rates for procuring these reserves[5].

It becomes more complex when defining the more accurate balancing cost which a single power plant induces over its life time. The term "balancing cost" generally refers to the increased cost of maintaining system balance that is caused by wind energy. It is important to recognise that in the base (no-wind) case the same energy must have been supplied by another resource. Thus, it is not the total cost of the balancing energy that is relevant, but the incremental cost of the balancing energy that is appropriate.

Integration cost studies generally attempt to capture the cost of the increased variability and uncertainty caused by wind energy, recognising some base level of variability and uncertainty that exist with no wind energy on the system. Methods to calculate this cost have evolved over the years, but there is currently no generally-accepted method in spite of there being general agreement that the variability and uncertainty from wind energy does have an additional cost element. The difficulty to correctly calculate the additional cost is an unresolved methodological issue that may not have a solution[6]. There are three main complications involved:
(1) Defining a suitable "non-wind" case;
(2) Extracting the highly nonlinear nature of these costs; and

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[2] Guidelines on State aid for environmental protection and energy 2014-2020

[3] See for an overview on this network code: https://www.entsoe.eu/major-projects/network-code-development/electricity-balancing/Pages/default.aspx

[4]Reserve requirements are determined by the aggregate uncertainty on the entire power system level. Because different sources of uncertainty are independent from each other (e.g. failure of a conventional power plant is generally not correlated with wind load or wind forecast errors), the aggregate uncertainty on system level is smaller than the sum of individual uncertainty factors.

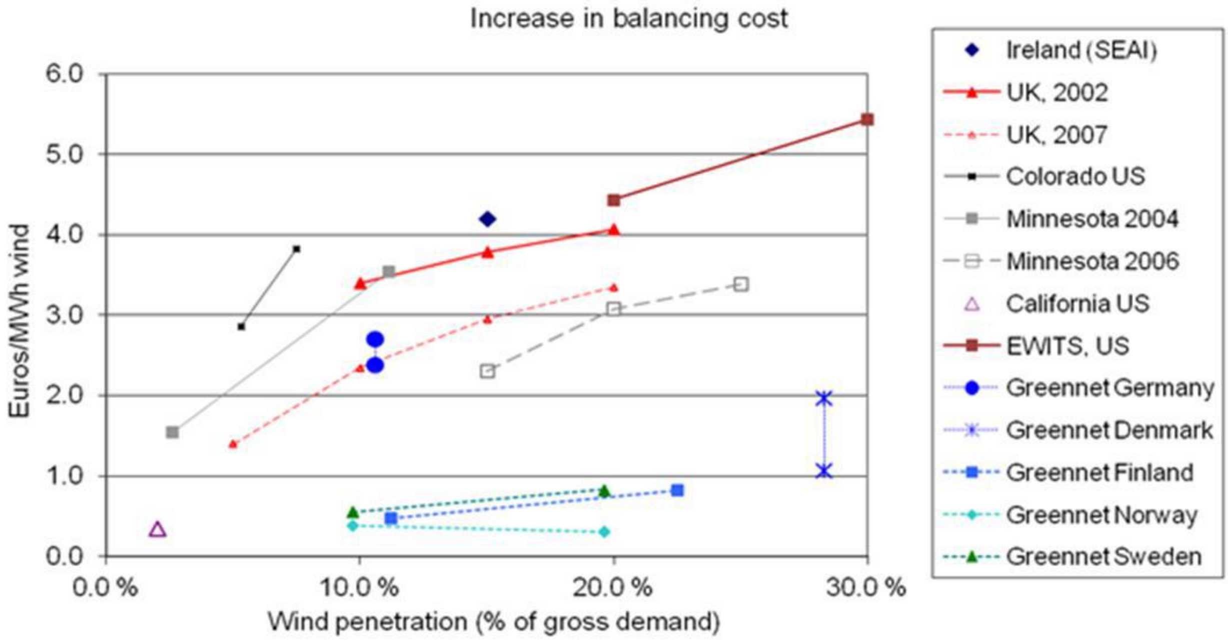
[5]D. Milborrow, "Balancing Act", Wind Power Monthly, 2012.

[6] IEA Task 25, Wind Integration report, 2015

(3) calculating wind balancing cost without doing comparable calculations for other types of generation that also impose balancing related costs[7].

Every power plant has certain capabilities and lacks others; this is why most power systems include a portfolio of plants with different characteristics. Interestingly, in the U.S. singling out one type of power plant for certain costs or impact without applying that to all plants is not an accepted policy practice. Accruing cost implications to single generator technologies is ruled-out by the Federal Energy Regulatory Commission (FERC) under the so-called “comparability rule” [8].
Not surprisingly, the estimates of increases and related costs in reserve requirements due to wind energy vary widely. Recent work under the IEA task 25 on wind power integration summarises current studies on the increase in reserve requirements resulting from higher shares of wind power.

Figure 1: Results from estimates for the increase in balancing costs due to wind power.



Source: IEA Task 25, Summary of studies on wind power integration, 2013

The above figure summarises the various national integration studies and finds that balancing cost increase in the EU due to wind variability and uncertainty amounts to approximately 1–4.5 €/MWh for wind penetrations of up to 20% of energy demand. This is usually about 10% or less of the wholesale value of the wind energy. In 2014, average wind energy penetration rate in the EU was 10.2%. EWEA expects this to increase to 14.9% by 2020, which suggests that in medium term, increases in balancing costs will not represent a significant share of total system cost. By 2030, EWEA expects that wind power would be able to cover 24.4% of electricity demand, which would require adapting electricity markets, including balancing arrangements, in order to minimise operational costs of the EU power system with large amounts of wind power.

3. State of play – Bearing balancing responsibility and financial implications for wind power

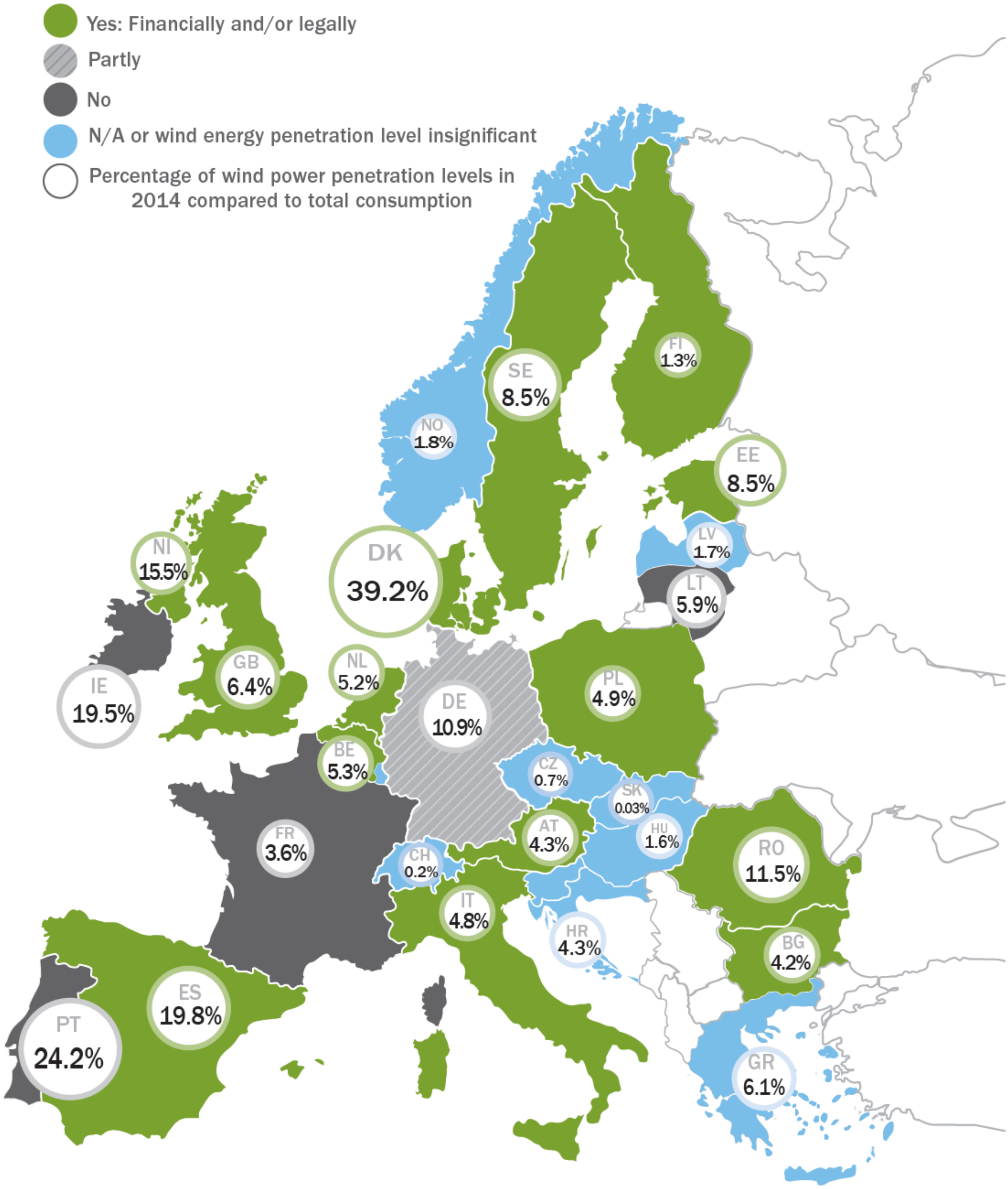
In order to provide a most detailed overview, EWEA has conducted an extensive consultation during Q1 2015 among its members on costs and balancing market arrangements for wind energy generators (see

[7] M.Milligan, NREL, 2013
[8] FERC, 1996, Order No. 888

annex I for more information about the entire data sheets). The following sections of the paper will provide the overview on the present state with regards to balancing responsibility borne by wind power generators.

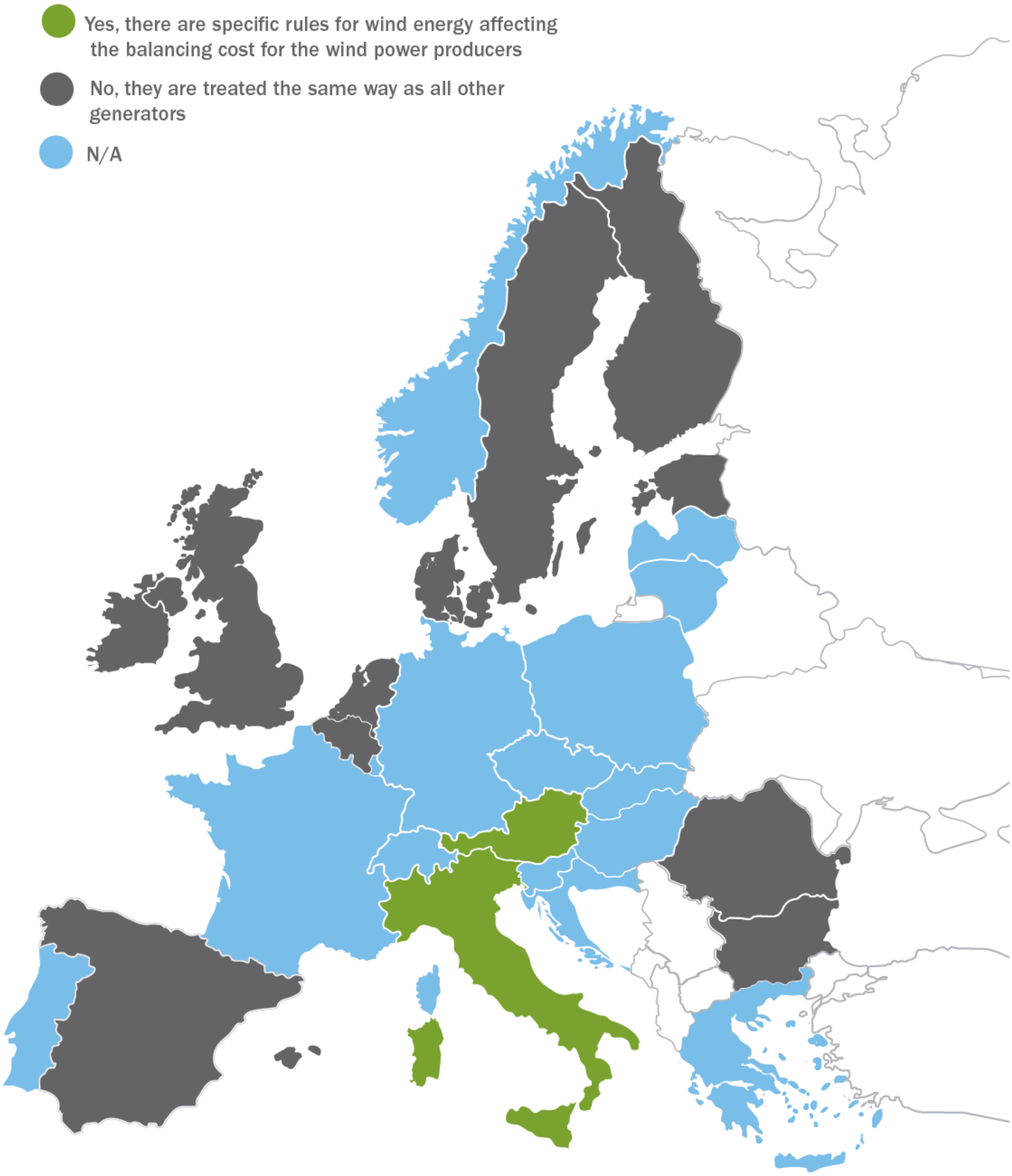
In addition, two country/region specific examples, Italy and the Nordic power market, are described in more detail to depict the differences of balancing regimes across the EU.

MAP 1: ARE WIND POWER GENERATORS BALANCING RESPONSIBLE?



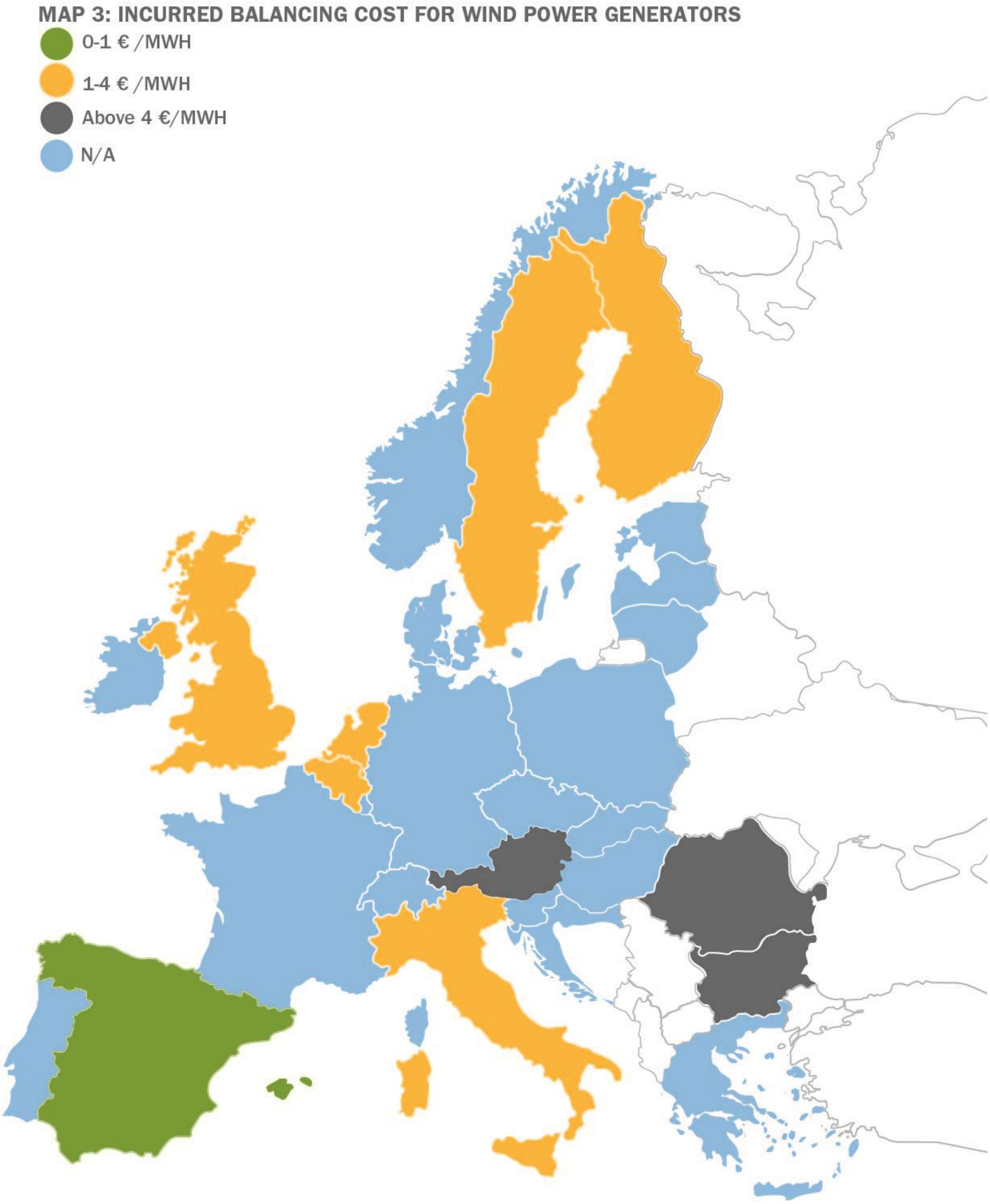
Main findings: In most EU Member States (14 out of 18 Member States surveyed) where wind power has a share above 2-3% in annual generation, wind power generators are already balancing responsible in some form[9].

MAP 2: ARE WIND POWER GENERATORS TREATED DIFFERENTLY COMPARED TO OTHER POWER GENERATION TECHNOLOGIES?



[9] Germany is a specific case as the balancing regime for renewables changed in 2012 and incentivises wind power generators to move towards the "Direct Marketing" scheme. In this scheme, they can bear a certain balancing responsibility depending on the arrangement with the BRP, see also report by TSO Transnet, in German, pages 21-22: http://enr-ee.com/fileadmin/user_upload/Downloads/Hintergrundpapiere/12_Strommarkt/150427_DFBEE_TransnetBW_Gefoerderte_Direktvermarktung_Deutschland_DE.pdf

Main findings: In most countries (except Italy and Austria) where data was available and wind power producers are balancing responsible, they are not treated differently than conventional generators.

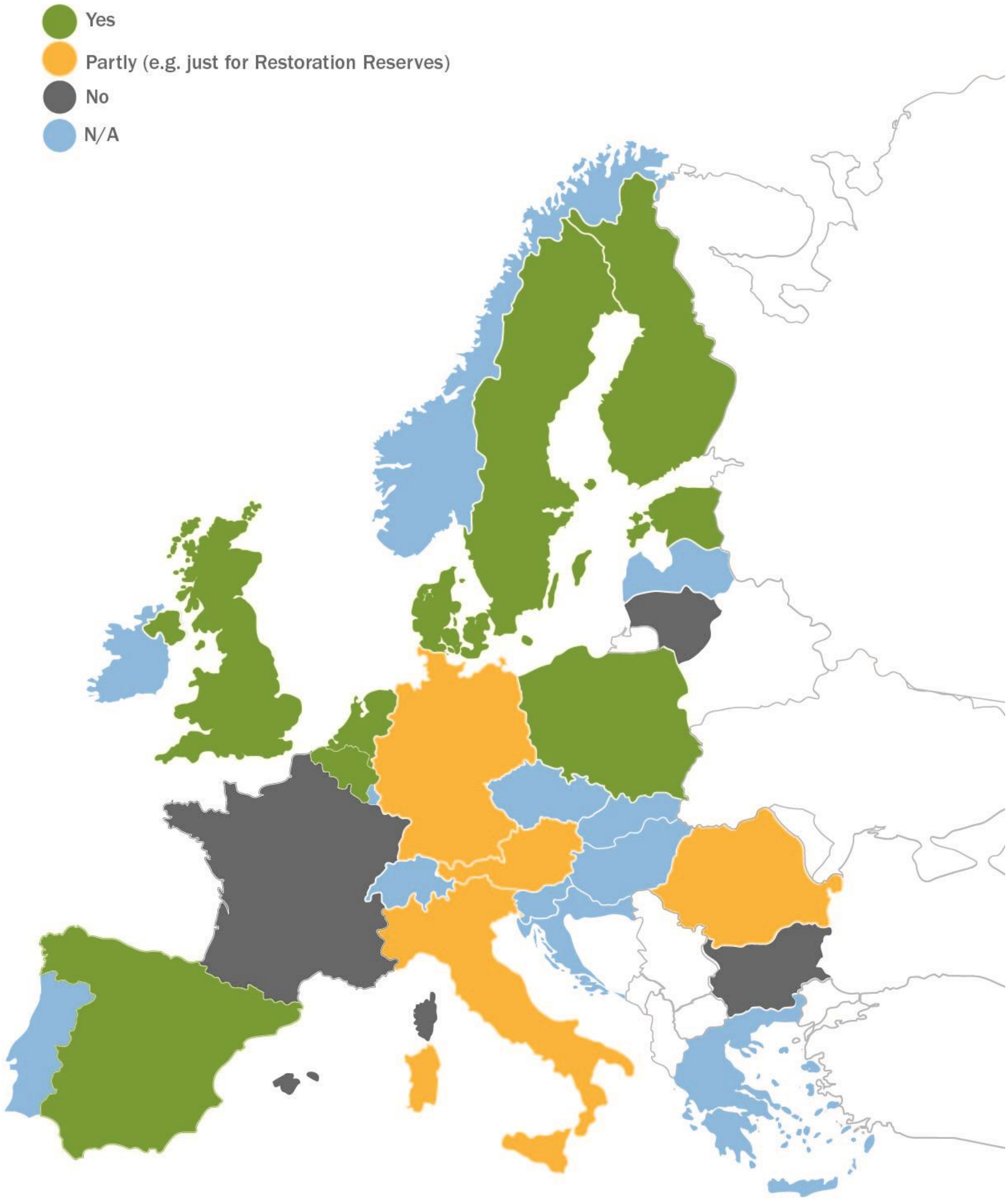


Main findings: Ranges of incurred balancing costs for wind power generators are 2-3 €/MWh on average with some notable exceptions:

- Bulgaria: between 10 and 24€/MWh; Romania: if not part of a large aggregator: 8-10€/MWh
- Austria and Spain: around 1€/MWh.

Balancing costs incurred by wind power generators today correspond to the EU averages found in the IEA Task 25 report mentioned in the previous section. This would mean that in many cases wind power generators bear already the extra balancing costs they cause, if not exceeding them. Worryingly, in Bulgaria and Romania balancing costs borne by wind power generators seem to be arbitrarily high and possibly prohibitive for new installations.

MAP 4: IS THE PROVISION OF BALANCING SERVICES ALLOWED BY WIND POWER GENERATORS OR ITS AGGREGATORS?



Main findings: Wind power generators are in most cases only partly allowed to participate in balancing markets and often only in providing replacement reserves. Even if wind power generators are allowed to participate, market entry barriers might be still high making it impossible for producers to offer balancing energy in practice. Overall, balancing market arrangements still seem to be applicable for conventional power generators mostly.

Balancing responsibility for wind power generators, country example: Italy

Starting from 1 January 2013 the Italian Regulatory Authority for Electricity has introduced the concept of balancing responsibility for wind generators (and in general for all variable renewables). The rule has established that wind generators have to pay penalties or receive revenues for the imbalances generated.

The rule has also defined for each variable renewables technology a percentage of error of the forecast for which the imbalances are not penalized through so-called "tolerance bands".

For the years 2013-2014 the tolerance bands for variable renewables units were set at 20% of the volume sold into the market. Starting from 1st January 2015 the tolerance bands are the following:

- Wind farms>10 MW: 49%
- PV units>10 MW: 31%
- Hydro units>10 MW: 8%
- Other units>10 MW: 1.5%

The variable renewables units under 10 MW are aggregated and the imbalance settlement is calculated at a portfolio level applying a tolerance band of 8%.

For new variable renewables units connected to the grid a period of no penalisation of the imbalances (at least 6 months) is expected, in order to guarantee a transitional period to fine tune forecasting activities. The imbalance settlement period is set to 1 hour, in order to support the compensation of the forecast errors and in accordance with the boundaries of the Day-Ahead and Intraday Market

The prices applied for imbalances generated are the weighted prices of balancing energy on each direction for each hour. If for an hour there is no need of balancing energy in one direction, the imbalance settlement price for it equals the spot price for the equivalent interval. The Italian market of the imbalances is divided in two areas: North and South. For each area the TSO calculate the imbalance prices according a single scheme represented in the table below:

		Imbalance Sign of the area	
		+	-
Imbalance sign of the unit	+	Unit receive the min (weighted Balancing energy Price Downward, Day Ahead Market Price)	Unit receive the max (weighted Balancing energy Price Upward, Day Ahead Market Price)
	–	Unit pay the min (weighted Balancing energy Price Downward, Day Ahead Market Price)	Unit pay the max (weighted Balancing energy Price Upward, Day Ahead Market Price)

The table showcases that in the green areas wind power generators receive an income for the unbalances generated, and in the red areas a penalty.

Balancing responsibility for wind power generators, example of the Nordic power market

On the Nordic power market, all generation and load are under financial balance responsibility towards the TSO, including wind power generators. Thus the same gate closure and rules to be balanced apply to all types of generation. The same imbalance prices apply to wind power as other generation.

On Day-ahead level, the Nord Pool Spot market is the centre piece for planning tomorrow's power generation. The market participant can choose to sell or buy in this voluntary spot market or trade bilaterally. The time resolution is one hour which equals the period currently used in the real time market and in the settlement of imbalances.

The Intraday market Elbas which is organised by Nord Pool Spot starts after the Day-ahead market has cleared and provide the actor the possibility to adjust the positions continuously until one hour ahead of delivery. The market is voluntary and the time resolution is one hour.

The balancing responsible party (BRP) plans towards the TSO are binding 45 min ahead of delivery. The Nordic Regulating Power market serves market actors in this delivery period to submit, amend or remove bids from 14 days prior to the commencement of the delivery day. Bids must always be submitted on an ongoing basis for the next 24 hours. Bids can be changed up until 45 minutes before the delivery hour, after which they are economically binding. The bids are activated in price order. In case there is no congestion in the Nordic market the price is equal in all bidding zones. The real time price is central in the settlement of imbalances and the marginal price (pay as clear) used as the price for the particular hour.

Overall, the Nordic case which is in accordance with the EU-wide target model for power market integration takes the approach of applying balancing responsibility for all generation without specific solutions for particular technologies.

4. Conditions under which balancing responsibility can be assumed

This section aims to outline policy recommendations in form of a general criteria catalogue under which balancing responsibility by wind power generators can be assumed. Importantly, **all recommendations for wind integration have to consider market maturities as well as the penetration level of wind power in the system.**

A one-size-fits-all solution is rarely the most cost-effective approach. Increased exposure to market risks applied in mature markets, while providing a valuable blueprint, cannot be translated in time and form to less mature markets where wind and other variable renewables penetration is less significant, and where neither physical, operational nor regulatory preconditions are met.

The EWEA country–specific survey which is the basis of the findings in this paper demonstrate that there are significant differences between national balancing market arrangements and different regimes applying to wind energy, regardless of its penetration level in the power mix.

In order to adequately outline the conditions under which balancing responsibility can be assumed, the following recommendations are separated in a generic part and a more country/region specific section in which we use the examples of Italy and the Nordic Power market. Albeit wind energy is bound to increase its share in both regions considerably, these two cases juxtapose two fundamentally different power system characteristics (Central dispatch versus self-dispatch model, less developed intraday market versus full regional market integration, etc.) resulting in a different set of country/region specific recommendations.

Policy recommendations derived from specific country cases

Case 1: Italy

Currently, wind generators are not able to provide for balancing services. Due to the increase of renewable energies in the last years and the necessity for TSO to have more flexible units to solve grid congestion, the Italian Regulatory Authority for Electricity published in 2014 a first consultation document in which three different models for the provision of balancing services from variable renewables units are suggested:

- **Model 1:** "Centralised Dispatching Extended": only the variable renewables units over 10 MW are able to provide global balancing services, the TSO has the centralized control of the balancing market;
- **Model 2:** "Local Dispatching of the DSO": all the variable renewables units are able to provide balancing services, the TSO coordinates a balancing market for the provision of global services and the DSO coordinates a secondary balancing market for the provision of local services to the TSO;
- **Model 3:** "Profile Exchange High/Medium voltage": all the variable renewables units are able to provide global and local balancing services, the TSO has the centralized control of the balancing market, and the DSO can supply local balancing services to the TSO entering bilateral contracts with administered tariffs.

For existing plants in the Italian power system, stakeholders recommend that:

- The participation to the balancing market for the existing plants has to be voluntary and remunerated on a market basis with no retroactivity;
- The investments for technology adjustments have to be supported with specific financial measures.

For all new plants, stakeholders recommend that:

- The participation to the balancing market is mandatory for the provision of the ancillary services provided for the security of the system, with the possible application of the clause "make-or-pay" (if you do not adjust the plant you are required to pay for the services not provided)
- The investments for technology adjustments do not have to be economically supported.

Case 2: The Nordic Power Market

The Nordic power market is on track in the implementation of the EU Target Model and it has enabled the participation of wind energy across all timeframes in the market[10]. Nonetheless, there are improvements in the balancing market that are important to enable proactive participation of wind generators:

- Splitting the market into availability (reserves) and activation (balancing energy) markets;
- The gate closure time for submission and activation of bids should be as close as possible to the operating hour for all power generators and demand;
- Activation bids should not be conditional to winning availability;
- Making the market asymmetric, allowing for only upward or downward power offerings;
- Improve transparency, consistency and predictability of balancing arrangements;
- Increase the integration with neighboring markets.

Experience from Denmark shows that using short-term forecasting of wind production and allowing BRPs aggregating power output of wind farms enable generators to participate more proactively in all market timeframes, including balancing markets[11].

General policy recommendations

Existence of a functioning intraday and balancing market

The implementation of the EU-wide target model is considered a no-regret option and should be a necessary precondition with wind power generators assuming balancing responsibility:

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[10] Specifically, in Western Denmark, in order to incentivize the participation of wind turbines in the balancing (regulating) market Energinet.dk changed its regulation in 2011 for handling notifications and procedures. Changes include requesting specific information from balancing responsible parties (BRPs) as well as the simplification of the imbalance settlement. Energinet.dk (2011) Regulation C3 – Handling of notifications and schedules – daily procedures. Rev 3.

[11] P. Sorknæs, et al. (2013) Market integration of wind power in electricity system balancing. Energy Strategy Reviews. Available at: http://www.sciencedirect.com/science/article/pii/S2211467X13000072

- Day-ahead market coupling throughout the EU and implementation of the flow-based capacity allocation method;
- Regional or at least national intraday and balancing markets are in place with sufficient liquidity in terms of market participants and amount of transactions.

Where these conditions are not provided, special temporary conditions should be granted to wind power generators. This would guarantee a level playing field for these new market entrants that otherwise would be disadvantaged compared to conventional generators.

Balancing market arrangements providing for the participation of wind power generators

Balancing responsibility is possible and desirable in systems that allow participation of wind generators through products and rules that take into account the intrinsic characteristics of their primary source. Rules - such as gate closure times as close as possible to delivery, aggregation of power output and harmonisation of imbalance prices - that incentivise balance responsibility are preconditions for wind generators to bear balancing responsibility. These criteria should be based solely on cost reflectiveness and not on arbitrary penalties imposed by TSOs.

In this context, policy makers should focus on creating liquidity in intraday markets ahead of balancing responsibility for variable RES. Once this is achieved, specific balancing market arrangements allowing for a non-discriminatory participation of wind power generators should be considered.

More in detail, this comprises[12]:

- Wind power generators' capability to provide balancing services, in particular Frequency Containment and Frequency Restoration Reserve (FCR and FRR), to the extent that it is beneficial (reliability vs. cost) to the system should be financially compensated;

- Clear procurement rules together with clear technical specifications are crucial. Characteristics of products such as low minimum bid sizes, separation of up- from downwards bids, inclusion of confidence intervals and aggregated bids and offers are essential to allow wind power generators to participate in balancing markets;

- Validation procedures to proof the delivery of balancing energy need to be adapted to the characteristics of wind power generation. To this end, a validation model based on a probabilistic approach should be considered. This would avoid a possible energy spillage by alloting very high probabilities to the balancing energy offer (e.g. a delivery likelihood of 99,994 % which would be acceptable to the buyer, the TSO) [13].

- Participation of wind power generators in such markets should always be voluntary as it is not cost-effective to require both market participation and balancing services capability from all generators. How much is needed and where, should be based on transparent system studies;

- For cost-efficient balancing services to be provided with the highest degree of certainty, the market design should encourage wind power generators to offer reserve products from aggregated portfolios of several wind power plants, which can be spread across wider areas and even across borders. Also, the uncertainty can be aggregated over all units participating in the reserve provision. This could be facilitated by the system operator and would reduce the need for overlapping safety margins due to forecast inaccuracy or unexpected power plant failure.

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[12] See also Economic grid support services by wind and solar PV, REServices project recommendations, September 2014: http://www.reservices-project.eu/wp-content/uploads/REserviceS-project-recommendations-EN.pdf

[13] This validation model would better enable wind power generators to participate in balancing markets than a "firm feed in" model assuming a constant delivery of balancing power which effectively means a continuous power output reduction of the wind power plant bidding. It would also decrease balancing settlement costs. See M.Jansen, Fraunhofer IWES, 2014, wind power participation on control reserve markets:http://www.energiesystemtechnik.iwes.fraunhofer.de/en/presse-infothek/publications/list_of_publication/2014/regelenergie-durch-windkraftanlagen.html

A satisfactory level of transparency, both in identification of system needs and corresponding market arrangements

Balancing market arrangements and corresponding costs are to be assessed in a transparent manner for all stakeholders. To this end, system studies should constitute the principal basis for market arrangements (and corresponding EU-wide network codes and national grid codes) in their formulation of requirements for wind power generators. The studies and their implementation in both grid codes and market arrangements should consider balancing services needs at the appropriate system level (system wide and cross-border versus localised needs). Moreover, any last resort decisions such as curtailments must be well explained by the TSO and the calculation method of any corresponding costs must be accessible and clear.

Proper market monitoring

An independent market monitoring entity must be set up (e.g. the national regulatory authority) in order to prevent and scrutinise any possible market distortive behaviours in the power sector stemming from structural market inefficiencies such as market concentration.

Sophisticated forecast methods in place in the power system

Wind power generation forecasts should take place 1 to 4 hours before real time and, ideally, aggregated from several sites. A shorter forecasting time horizon would not only help to set up a level playing field for balancing conventional and variable generation, but would also lower overall system operation costs. TSOs should improve their forecasting utilising state of the art methods during operations, while increasing cross-border cooperation to reduce unexpected situations due to forecast errors.

The necessary transmission infrastructure

Assessing a minimum level of grid reinforcements as power systems differ and grid development needs can be substantially different between transmission and distribution grids. The only current EU-wide benchmark available are the investment projects (“projects of Pan-European significance”) in the ENTSO-E 10-year network development plan 2014 which overlap with the current draft list of so-called “Projects of common Interest” (PCIs). However, this benchmark could only serve as a first indicator and would need to be amended by key national grid development projects on both transmission and distribution level.

Annex

I. Country overview table on balancing market arrangements for the EU 28

The country overview table with all country specific data is at disposal for all EWEA members on our members lounge:

http://www.ewea.org/members-area/policy-information/ewea-policy-priorities/grids-infrastructure-internal-electricity-market/

II. Imbalances in the power system and the role of markets

One of the main tasks of the Transmission System Operators (TSOs) in the EU is maintaining a real-time balance between electricity generation and consumption which is essential for safeguarding system security[14]. With the ongoing liberalisation of the energy sector TSOs not only plan and organise, but increasingly procure and deploy balancing services obtained from Balancing Service Providers (BSPs).

The main reasons for the occurrence of imbalances in power systems are[15]:

- A "Not N-1" disturbance: Unplanned outage of generation or load or a HVDC interconnector, which affects the "N-1" system security threshold on the transmission grid.
- Random imbalances in normal operation, typically due to a load forecast error or a production forecast error.
- Imbalances driven by specific market rules[16].
- Network splitting due to transmission bottlenecks, which effectively requires balancing within separate zones.

Since the start of electrification in the late 19th century, variability and uncertainty have been a constant feature of power systems. TSOs have to deal not only with the variability of the supply side, but the joint variability and uncertainty of the entire system – all generators and power demand combined. With any shares above 2-3% in annual generation, variable RES such as wind energy is likely to lead to an increase in supply-side variability and uncertainty, depending on the specificities of the respective power system in question[17]. Therefore, balancing services are key to activate cost-efficiently available flexibility resources of the power system. This will allow mitigating variability and uncertainty, regardless of the amount of wind energy installed.

Across Europe balancing services products and the arrangements by which they are produced are very diverse. This is mainly due to historical reasons as each TSO individually designed their balancing "market" according to national specificities, such as generation portfolios, presence of internal congestions and interconnectivity levels[18]. Interestingly, not all TSOs in the EU procure balancing services in a commercial way as in some EU Member States the provision by BSPs is obligatory.

With ongoing liberalisation efforts in the energy sector, an increasing number of Member States introduce organised markets for the provision of balancing services. However, most cases follow historical pathways along the characteristics of the respective power system. This diversity not only

[14] Article 12 of Internal market in electricity Directive 72/2009/EC

[15] Impact assessment on European Electricity Balancing Markets, Mott MacDonald/Sweco, 2013, page 6: https://ec.europa.eu/energy/sites/ener/files/documents/20130610_eu_balancing_master.pdf

[16] E.g. caused by ramping at the hour shift of settlement periods, which can be already observed in liquid markets with hourly settlement periods: Generators try to optimise their portfolio with frequent "shifts" near the round hours resulting in increased needs for reserves. This is less acute when the settlement periods become more granular – 30 or 15 minutes.

[17] IEA, the Power of Transformation, 2014, page 22

[18] IEA, the Power of Transformation, 2014, page 22.

stands in contrast to the market integration process in the EU, but also precludes vast cost savings that the possibility of procuring balancing services outside of a TSO's control zone would offer[19].

Finally, the integration of ever increasing shares of wind energy is further facilitated through well-functioning balancing markets across borders, next to improving system operation and overall market efficiency. By balancing wind power on a regional level, reserves will be optimised, requiring fewer balancing capacity being available. In this way, wider geographical areas will reduce balancing costs. This is due to the smoothing effect of aggregating wind power and other power output reducing its variability. Wind integration in the US and the Nordic region has shown how operational costs can be cut, by sharing balancing power with neighboring countries through adjacent markets.

Functional balancing markets that are integrated across borders also improve intraday markets' liquidity and create incentives for all generators to reduce their power imbalances. Last, but not least, a better understanding of the potential for wind power plants to participate in balancing markets is needed. With current technology, wind power plants can already provide ancillary services including balancing energy, offering significant flexibility to the system. However, market mechanisms that properly value the provision of these services for all market participants including wind power are still in their infancy.

[19] Ibid. integration of balancing markets and sharing of reserves provides operational cost savings of € 3bn/year and up to 40% less requirements for reserve capacity.