EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

Creating the Internal Energy Market in Europe

A report by the European Wind Energy Association - September 2012

Creating the Internal Energy Market

a report by the European Wind Energy Association

Text and analysis: Iván Pineda, Paul Wilczek (European Wind Energy Association-EWEA)
Data collection and data analysis: EWEA
Contributing author: Jacopo Moccia, Stephane Bourgeois, Justin Wilkes (EWEA)
Revision and editing: Zoë Casey (EWEA)
Design coordination: Jesús Quesada (EWEA)
Cover photo: Markus Haslinger - Winner Global Wind Day photo contest 2012
Design: Giselinde Vandevelde
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EXECUTIVE SUMMARY

This EWEA report serves two main purposes:

- Contribute to the debate on the completion of an Internal Energy Market (IEM) by 2014 and provide views on present electricity market integration approaches and the development of a future flexible power system with a large scale uptake of wind power.
- Place the current regulatory frameworks for wind power integration in the context of developing a single EU market for energy. To this end, it compares the impact of wind energy deployment with the major obstacles blocking and integrated internal market.

Wind power is capable of supplying a share of European electricity demand comparable to the levels currently being met by conventional technologies such as fossil fuels, nuclear and large hydro power. The envisaged share of around 14% of electricity demand (up from some 6.5% currently) met by wind in 2020[1], and the 2050 scenarios from the European Commission showing wind energy as the key generating technology – providing between 31.6% and 48.7% of electricity production[2] – require market rules to adapt to the generation mix of the future. The envisaged level of wind energy penetration will require cooperation among decision makers and stakeholders in the electricity sector, to make the necessary changes to a European energy market that has been developed with traditional centralised power plants in mind.

Main findings

1. ***Structural market distortions remain the main obstacle to creating an internal energy market and integrating wind energy.*** The level of liberalisation of European electricity markets remains low while large incumbents, high market concentration, continued massive subsidies to fossil fuels and nuclear energy and regulated prices remain the rule rather than the exception.
2. ***Integration of large amounts of wind energy in a cost efficient manner requires changing the current market arrangements.*** Market rules are not currently designed to facilitate the integration of wind energy. This creates significant challenges for its cost efficient integration into the market. Integration costs are not a consequence of the technology capability itself, but due to existing rigid market rules and institutional frameworks that were never designed with wind power, or other variable generation technologies, in mind. This prevents the full and cost-efficient exploitation of their capabilities.
3. ***The 2009 Renewable Energy Directive is based on the rationale that a positive framework for renewable energy development is necessary due to a number of market and regulatory failures or imperfections[3]. Thus, support mechanisms for wind power and other renewables should be seen in the context of an unfinished liberalisation and as compensation for the numerous market failures that arise from an internal market that is fragmented, dysfunctional and far from fully developed.*** Prevailing market distortions – in the forms of continued massive subsidies to fossil fuels and nuclear energy, market concentration and regulated prices - together with market rules that do not consider wind energy characteristics create increased market risks for wind energy generators.
4. ***Logically, full exposure of wind energy generators to market risks can only take place under the preconditions that markets are functional, competitive, liquid and transparent and that all technologies are exposed to the same conditions on a level playing field.*** As long as this is not the case in the fragmented European electricity markets, exposing wind generators to market risks, while other power technologies are shielded from those risks, will affect wind power deployment and delay the benefits of its large scale penetration for society and the environment and, in the end, make electricity more expensive than necessary for the consumer.

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[1] According to the National Renewable Energy Action Plans (NREAPs) from Member States

[2] European Commission 2050 Roadmap (21)

[3] European Commission, Renewable Energy Strategy Impact Assessment (24)

5. ***The EU Target Model (TM) does not effectively enable optimal wind energy integration into the European power markets.*** Whilst the TM is an important step towards increased cross-border trading, and consequently, towards the completion of the IEM, it does not sufficiently emphasise provisions that integrate wind energy into the power system to the degree communicated by the 27 Members States in their National Renewable Energy Action Plans (NREAPs)[4]. Nor are the provisions sufficient to move towards effective competition and a fully integrated, flexible European power system. Specifically, the TM does not address fundamental features of intraday and balancing markets which should be cornerstones of a competitive market place and are essential for wind energy integration. These features include measures to improve their liquidity, harmonisation of rules across borders and the interactions between these markets.

6. ***The TM could unlock greater benefits for the power system by embracing large scale deployment of wind energy into the market integration process.*** These benefits go beyond the current vision of the TM. They include better and more efficient use of all generating assets and resources, as well as load management, ensuring long term security of supply and providing flexibility and increased system adequacy to the power system. Most importantly, EU market integration enabling wind energy deployment has the potential for maximising overall welfare – for generators by lowering market risks in a truly competitive market, for system operators by reducing operation costs of balancing and reserves, and for customers by lowering electricity prices – while reducing their exposure to fuel and carbon price risk.

7. ***Flexibility is the main feature of tomorrow's power system:*** With the introduction of wind energy and other variable renewables the market will push out inefficient and polluting high marginal costs producers, slow-ramping and inflexible power plants. This will make a better case for assets that allow investments to be recovered in a more flexible system, over fewer running hours.

8. ***Wind energy is able to contribute significantly to system operation and flexibility.*** This includes the capability to provide support services to the grid and contributing to system adequacy. These capabilities have a value in an integrated market; therefore they should be assessed using harmonised methods, to forge pan-European market design provisions and rules.

Policy recommendations

Creating a level playing field

- ***Tackle the structural electricity market distortions rather than almost exclusively focusing on renewable provisions:*** Remove regulated prices; market concentration; coal, gas and nuclear subsidies; and improve market transparency. Properly transpose and implement the 2nd and 3rd EU Liberalisation packages, encourage participation of new entrants and provide incentives for extensive use of commercial power exchanges for trading.

- ***Design market rules that recognise the intrinsic characteristics of wind energy.*** Specific market design and rules for wind integration require provisions and products that fully exploit wind energy capabilities. These include large control zones (for smoother output variability) and shorter trading time horizons (for improved forecast accuracy and reduced balancing needs). Functional intraday and balancing markets at Member State level are imperative as a first step to achieving this. Interconnectivity of short-term markets between Member States has to be encouraged for efficient trading of wind generated electricity.

- ***A functional, mature and competitive market should be seen as a pre-condition to exposing wind generators and other producers to market risks, included carbon and fuel price risks.*** Where this is the case, exposure to balancing risks could be considered as a first step as long as a functional regional wholesale market and application of advanced forecast

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[4] European Commission, (26)

tools and operational routines by TSOs are in place. In these cases, regulators should also ensure that costs are transparent and represent only the real cost of balancing.

Implementing the EU-wide Target Model with a large share of wind power

- ***Implementing the EU-wide Target Model as a minimum for achieving the IEM by 2014.*** Beyond providing day-ahead market integration across borders and improved transmission capacity allocation, a more ambitious vision of cross-border balancing markets should be developed as well as a more prescriptive design for intraday markets.

- ***Provide for integrated intraday and balancing markets.*** Functioning intraday markets are crucial for the efficient and cost effective integration of large amounts of wind energy and for cost efficient system operation. Proper design of intraday and balancing markets and much closer cooperation between Member States is required to enable European market integration.

- ***Make the best use of available transmission capacity and improve system operation routines.*** Moving away from static capacity transmission calculation methods is crucial when implementing the Target Model. Once capacity has been properly allocated, the incorporation of innovative grid management methods should be promoted to maximise the use of existing assets. These include regional control centres to help monitor power flows and RES performance and Dynamic Line Rating (DLR).

Assessing system adequacy properly in a renewable EU integrated power system

- ***TSOs must be encouraged to thoroughly analyse all aspects of firm capacity from wind power and other renewables in an integrated system at EU level.*** Despite the real physical capacity value of wind power and other renewables, they are not yet used for capacity planning to any significant extent. The development of a harmonised method for assessing wind power capacity credit is needed in order to properly evaluate its contribution to system adequacy at European level.

- ***Challenge the need for capacity payments and assess system adequacy from a pan-European perspective.*** As practice shows, capacity markets uptake is complex and might produce further market distortions, free riders and other externalities, while creating disincentives to invest in and apply more cost effective grid infrastructure and demand side management solutions.

Ensuring cost-effectiveness of the future power system: a market-based approach for ancillary grid services

- ***Grid codes in Europe should first consider market options for ancillary services instead of compulsory requirements to be fulfilled without specific remuneration.*** The compulsory technical requirements for all generators must, therefore, focus on the essential aspects of technical performances, leaving an opening for remunerated grid support services.

- ***Establish grid support services markets to create additional non-discriminatory revenue streams for all generators***. Commercial provision of grid support services as additional market-based revenue for all generators should be considered in view of lower average and more variable spot market prices on energy-only markets. This will ensure investors’ interest in power generation and tackle any potential generation gap in the electricity sector through a market-based mechanism, as opposed to regulatory intervention – for example, in the form of capacity payments.

Photo: Istock

1 INTEGRATING WIND ENERGY INTO THE MARKET

Wind energy integration into the electricity market has the potential to deliver significant benefits for society and the environment[5]. From ensuring security of supply, reducing electricity prices and fuel import bills, to driving economic growth, job creation and competitiveness, the value of wind energy goes well beyond producing GHG emissions-free electricity. However, the characteristics and current state of the European electricity "energy-only market" pose significant challenges for its efficient integration. Given the efforts to create a single European Internal Energy Market (IEM) by 2014, these challenges must be tackled urgently to fully reap the benefits that wind energy and other renewable technologies bring to the electricity system.

This chapter provides an overview of the existing electricity market arrangements in the EU focusing on the challenges surrounding wind power integration. The status of energy market liberalisation and the most critical market distortions in the European electricity sector are examined. Indeed, the combination of unfavourable market rules and incomplete liberalisation creates increased market risks for wind energy generators, and justifies current regulatory provisions for renewable energy promotion within the market integration process.

Main findings

1. ***Structural market distortions remain the main obstacle to creating an internal energy market and integrating wind energy.*** The level of liberalisation of European electricity markets remains low while large incumbents, high market concentration, continued massive subsidies to fossil fuels and nuclear energy and regulated prices remain the rule rather than the exception.

2. ***Integration of large amounts of wind energy in a cost efficient manner requires changing market arrangements.*** Market rules are not currently designed to facilitate the integration of wind energy. This creates significant challenges for its cost efficient integration into the market. Integration costs are not a consequence of the technology capability itself, but due to existing rigid market rules and institutional frameworks that were never designed with wind power, or other variable generation technologies, in mind. This prevents the full and cost efficient exploitation of their capabilities.

3. ***The 2009 Renewable Energy Directive is based on the rationale that a positive framework for renewable energy development is necessary due to a number of market and regulatory failures or imperfections[6]. Thus, support mechanisms for wind power and other renewables should be seen in the context of an unfinished liberalisation and as compensation for the numerous market failures that arise from an internal market that is fragmented, dysfunctional and far from fully developed.*** Prevailing market distortions – in the forms of continued massive subsidies to fossil fuels and nuclear energy, market concentration, regulated prices - together with market rules that do not consider wind energy characteristics - create increased market risks for wind energy generators.

4. ***Logically, full exposure of wind energy generators to market risks can only take place under the preconditions that markets are functional, competitive, liquid and transparent and that all technologies are exposed to the same conditions at a level playing field.*** As long as this is not the case in the fragmented European electricity markets, exposing wind generators to market risks, while other power technologies are shielded from those risks, will affect wind power deployment and delay the benefits of its large scale penetration for society and the environment and, in the end, make electricity more expensive than necessary for the consumer.

Policy recommendations

Creating a level playing field

- ***Tackle the structural electricity market distortions rather than almost exclusively focusing on renewable provisions:*** Remove regulated prices, market concentration; coal, gas and nuclear subsidies; and improve market transparency. Properly transpose and implement the 2nd and 3rd EU Liberalisation

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[5] See EWEA reports "Green Growth", "Wind Energy and Electricity Prices" and "Wind Energy and EU Climate Policy". Available on www.ewea.org

[6] European Commission, Renewable Energy Strategy Impact Assessment (24)

packages, encourage participation of new entrants and provide incentives for extensive use of commercial power exchanges for trading.

- ***Design market rules that recognise the intrinsic characteristics of wind energy.*** Specific market design and rules for wind integration require provisions and products that fully exploit wind energy capabilities. These include large control zones (for smoother output variability) and shorter trading time horizons (for improved forecast accuracy and reduced balancing needs). Functional intraday and balancing markets at Member State level are imperative as a first step to achieving this. Interconnectivity of short term markets between Member States has to be encouraged for efficient trading of wind-generated electricity.

- ***A functional, mature and competitive market should be seen as a pre-condition to exposing wind generators and other producers to market risks, included carbon and fuel price risks.*** Where this is the case, exposure to balancing risks could be considered as a first step as long as a functional regional wholesale market and application of advanced forecast tools and operational routines by TSOs are in place. In these cases, regulators should also ensure that costs are transparent and represent only the real cost of balancing.

1.1 The European energy-only market for electricity

The market that emerged from the EU energy sector liberalisation – a process which started more than 15 years ago – is predominantly an “energy-only” model, in which generators’ revenues depend solely on the electricity they can sell to the market without receiving any additional income for their installed capacity. In this way, electricity could be treated as any other commodity, with price determined purely by supply and demand. Thus, price signals will establish the optimum level of generation capacity by creating the incentives for all participants to either invest in new power plants or voluntarily curtail their demand in times of scarcity.

In today’s liberalised market, these participants are both large and small generators (using a variety of technologies), transmission and distribution operators, suppliers, retailers, non-physical traders[7] and customers. They all interact in organised markets in which electricity is traded. However, the particular physics of electricity supply poses various challenges for their commercial interactions.

Electricity is generated, transported, delivered and used in real-time. Electricity cannot be stored and supply must always match an almost inflexible demand. Despite this real time feature, for the purpose of trading, participants carry out commercial activities during designated periods ahead of real-time use. There are two main markets where trade takes place: the wholesale market where the bulk of electricity is sold and purchased between suppliers, generators, non-physical traders and large end users; and the retail market where electricity is finally sold to the end consumer.

Trading is undertaken in a relatively standard form: an amount of energy is agreed for delivery over a specified period in the future and at a certain price per unit delivered. For each period, suppliers assess demand in advance and sign contracts with generators for the given volume of electricity. During the contracted period, generators are expected to produce and deliver the contracted volume of electricity and suppliers are expected to use their contracted volume of electricity.

1.1.1 Bilateral agreements and power exchanges

Trading electricity takes place either via bilateral agreements or via a commercial power exchange.

Bilateral contracts represent the greatest volume of electricity traded in most countries, as seen in Figure 1.1. Bilateral trading comprises mostly

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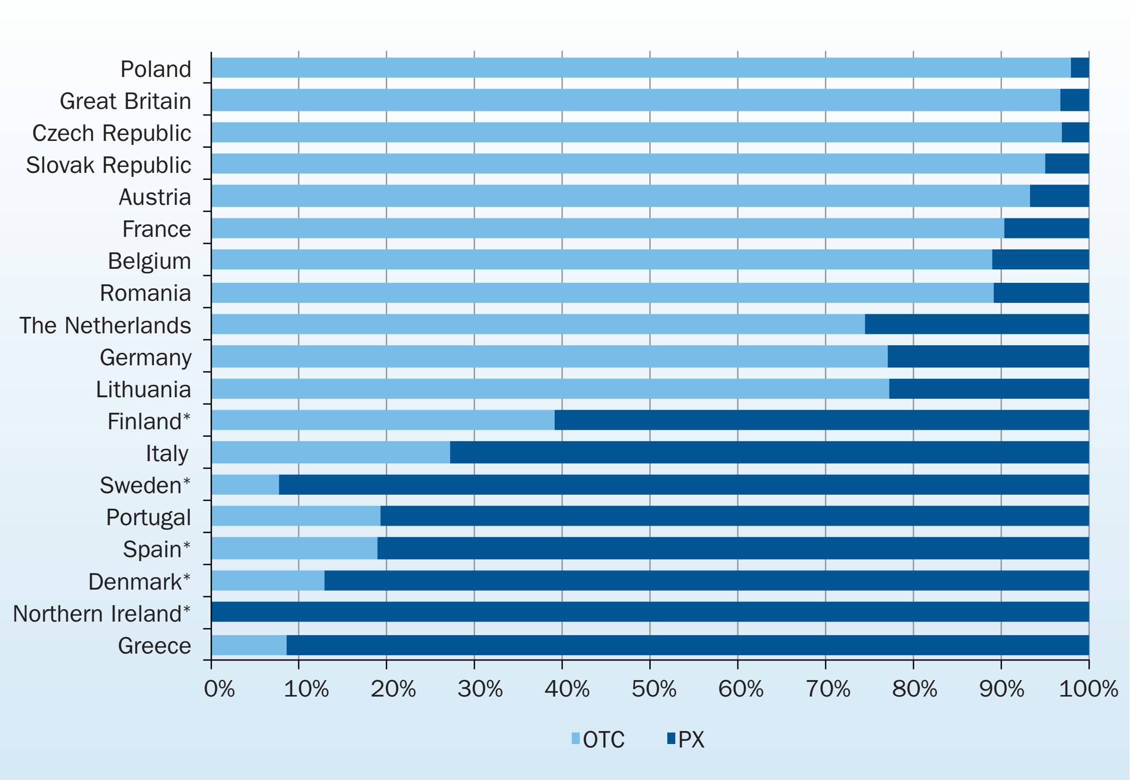
[7] Non-physical traders are market participants without physical demand for electricity or any means of generating it, e.g. banks

so-called "over the counter" (OTC) contracts, in which a broker anonymously facilitates transactions between two counterparties, or the counterparties contact each other directly. Contracts can trade energy months or even years before delivery.

Power exchanges often trade lower volumes of electricity compared to what is traded bilaterally. This is done through auctions, where bids and offers are gathered and a market clearing price is struck according to the principles of supply and demand (see Box 1). Therefore, the energy price in power exchanges is particularly relevant as it serves as a reference point for bilateral trading. Power exchanges are generally used for trading medium (months) to short term supply (up to the day prior to delivery or even a few hours before real time).

Trading in power exchanges can be voluntary or mandatory depending on the regulatory framework. Power exchanges aim to incentivise trading among participants more transparently than via bilateral trading. Generally, countries with incentives to participate in power exchanges benefit from higher trade volumes than those without incentives[8] (see countries marked with an asterisk, in Figure 1.1).

FIGURE 1.1 ELECTRICITY VOLUME TRADED DAY-AHEAD IN POWER EXCHANGES (PX) VS. FORWARD BILATERAL CONTRACTS (OTC). [MW AS PERCENTAGE OF NATIONAL GROSS ELECTRICITY PRODUCTION], 2009 DATA



Sources: European Parliament (1), Cornwall, N (2006) (2)

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[8] For example, in Northern Ireland and Spain TSOs were mandated by the regulator to create the power exchange for trading electricity, scheduling plants and allocating transmission capacity. Also, trade in Nordic countries has to go through the power exchange, NordPool, in order to get access to transmission capacity. (Cornwall, N. 2006 (2), Meeus, L., 2010 (18))

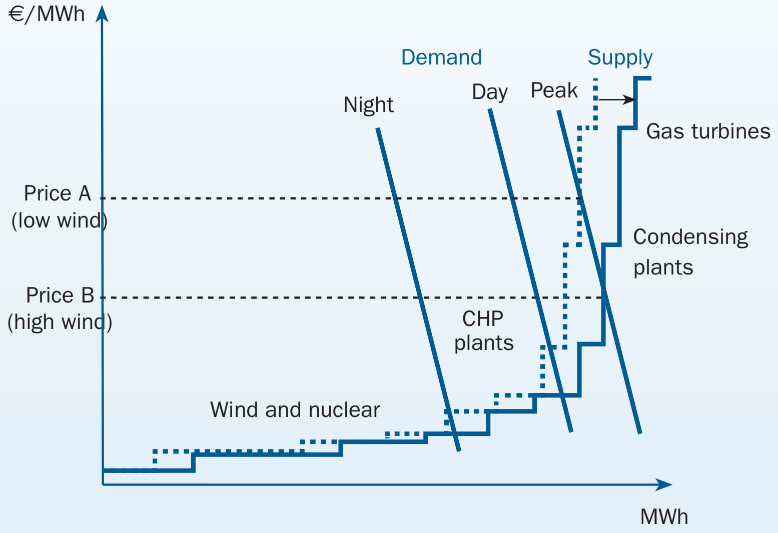
BOX 1 HOW WIND POWER INFLUENCES THE POWER SPOT PRICE AT DIFFERENT TIMES OF THE DAY THROUGH THE SO-CALLED "MERIT ORDER EFFECT"

Merit order effect in the electricity spot market

Under the merit order principle plants with the lowest short-run marginal costs - mainly fuel, carbon and operating costs - are used first to meet demand and more costly plants are brought on line later as needed. The merit order principle is the guiding principle of an electricity market in which the lowest bids will be served first, but where all bids up to the point where supply equals demand receive the price established by the intersection of the supply and demand curves. It refers to the day-ahead or spot power price and is based exclusively on short-term marginal costs of power generation (which do not include capital costs of a power plant).

Technologies with the lowest marginal costs enter near the bottom of the supply curve shifting it to the right, resulting in a lower power price depending on the elasticity of the demand. For example, in the figure below the electricity price is reduced from Price A to Price B when wind power supply increases. In general, the price of power is expected to be lower during periods with high wind than in periods with low wind. This is called the "merit order effect".

When wind power reduces the spot power price, it has a significant influence on the price of power for consumers. When the spot price is lowered, this is beneficial to all power consumers, since the reduction in price applies to all electricity traded – not only to electricity generated by wind power.



Source: Risø DTU

1.1.2 Power trading time frames

Electricity can be traded across different time scales. However, trading arrangements are designed in a way that, at a set point before real-time delivery, contracts are fixed. This set point in time is called gate closure. In real time delivery, the gate closure allows generators to finalise their physical outputs according to their contracted volumes and to notify their expected output for each of the next contracted periods to the transmission system operator (TSO).

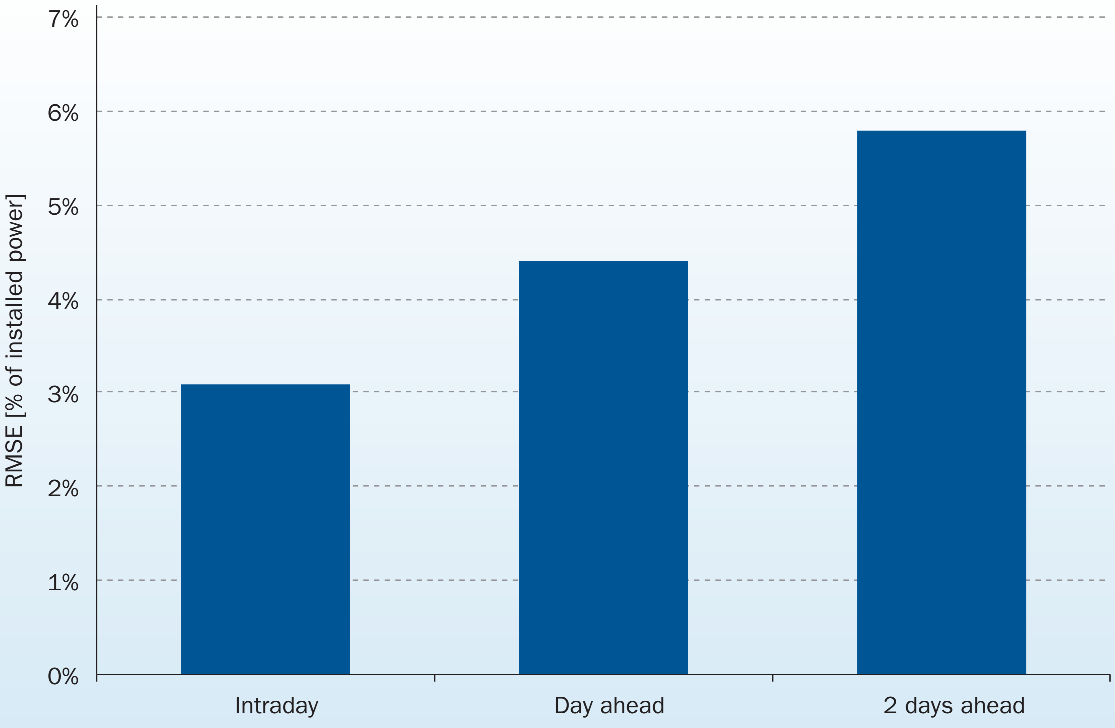
Day-ahead

The most important gate closure for trading is the day-ahead of delivery. Nevertheless, even after this gate closure, plans may need to be updated. One of the following events could occur: suppliers or non-physical traders may have forecast their production incorrectly, an updated weather forecast might be available, or there may be an unforeseen downtime of a transmission line or an unscheduled outage of a large power plant.

Traditionally, the day-ahead trading time frame suited most power generators as their production could be scheduled more accurately according to revised demand forecasts and updated plant conditions. As the day-ahead market is closer to delivery than a forward market, trading months or even years in advance, it provides better signals to participants about current market conditions and more detailed information about demand and supply.

However, in contrast to conventional power generation, which is demand driven, wind energy is mainly supply driven according to the availability of its energy source. This availability is more accurately forecast at shorter time scales than day-ahead. Specifically, for wind energy there are clear improvements in forecast accuracy as the time horizon decreases, as seen in Figure 1.2.

FIGURE 1.2 INCREASING WIND FORECAST ERROR (ROOT MEAN SQUARE ERROR) AS TIME HORIZON INCREASES. RESULTS FROM REGIONAL WIND POWER PRODUCTION FROM GERMANY



Source: IEA Wind Task 25 (3)

Trading wind energy only on day-ahead markets prevents the possibility of delivering more accurate power generation, and leads to greater mismatches between scheduling and delivery of energy (also called imbalances). These imbalances then need to be corrected during the day of operation if markets allow for it, or more often in real-time by the TSO, which creates unnecessary system operation costs. Therefore, day-ahead gate closures without the possibility of adjustments in the market make the system overly reliant on real-time balancing, and consequently more costly.

Intraday

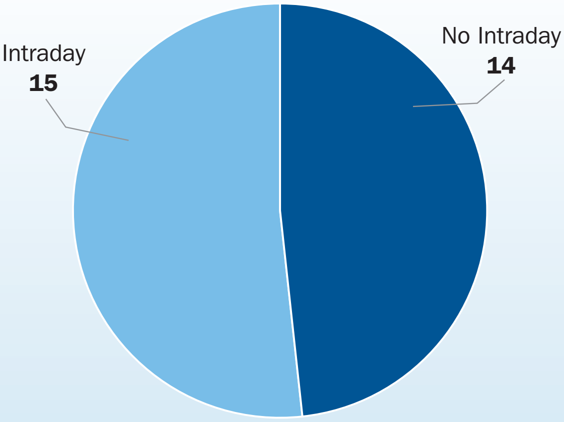
Adjustments needed after day-ahead gate closure can be made much more economically and efficiently in intraday markets. In some EU countries, intraday markets have been set up recently to fine-tune trading positions closer to real time delivery. Participants undertake this fine-tuning to ensure that they have exploited all profitable opportunities for trading, that their contracted position is closer to their expected physical energy position and, in some countries, to adjust unfeasible schedules[9].

Intraday markets have positive impacts not only on generators but also on the operation of power systems. By allowing generators to adjust their trade position using more accurate and close to delivery data, real-time balancing volume and price are reduced, allowing electricity markets to benefit from the integration of wind energy (see Chapters 2 and 3 for further details).

However, despite these advantages, there are only 15 Member States with intraday markets, as seen in Figure 1.3. Moreover, intraday markets, when available, have very low trade volumes and liquidity. Table 1.1 indicates the volume of traded electricity and share of electricity consumption of five power exchanges. Only the Spanish power exchange trades significant volumes, the others are all below 1% of consumption.

Low liquidity in intraday markets results in the use of more expensive resources in real-time delivery for making adjustments, such as fast ramping conventional power plants. In addition, markets with low trade activity are characterised by less transparent prices than those with high liquidity where individual actors have greater impacts on the price formation.

FIGURE 1.3 INTRADAY MARKETS IN THE EU (2011)



	Market operator	Intraday
Austria	EXAA	x
Belgium	BELPEX	√
Bulgaria	TSO	x
Cyprus	TSO	x
Czech Republic	EPX	x
Denmark	NordPool Spot	√
Estonia	NordPool Spot	√
Finland	NordPool Spot	√
France	APX-ENDEX	√
Germany	APX-ENDEX	√
Great Britain	N2X	√
Greece	HTSO	x
Hungary	HUPX	x
Ireland	SEMO	x
Italy	GME	√
Latvia	NordPool Spot	x
Lithuania	BaltPool	x
Luxembourg	BELPEX	x
Malta		x
Northern Ireland	SEMO	x
Norway	NordPool Spot	√
Poland	POLPX	√
Portugal	OMIE	√
Romania	OPCOM	√
Slovakia	OKTE	x
Slovenia	Borzen*	x
Spain	OMIE	√
Sweden	NordPool Spot	√
Netherlands	APX-ENDEX	√
	Intraday	15
	No intraday	14

Source: EWEA

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[9] Frontier Economics, 2005 (19), Weber, C., 2010 (2)

TABLE 1.1 VOLUME OF ELECTRICITY TRADED IN INTRADAY MARKETS, 2011 AND 2010* DATA

Country/ Region	Market Operator	Volume traded	Share of consumption
France	APX-EPEX	0.2 TWh	0.1%
Germany	APX-EPEX	1.4 TWh	0.2%
Nordic	NordPool	2.7 TWh	0.7%
Belgium	BELPEX	0.2 TWh*	0.2%*
Spain	OMIE	45.6 TWh	15.3%

Sources: EPEXSPOT (4), CREG (5), NordPool (6), OMIE (7)

Real-time balancing

With real-time balancing, after gate closure, when all trading ceases among participants, the TSO takes full control of the power system and corrects any imbalance created by the difference between supply and demand in real-time. As the latter is not currently controllable, the TSO requires production reserves in the system to inject or withdraw energy as necessary. To do this, it uses special trading arrangements to procure a wide range of services (including energy) in order to balance the system (see Box 2).

During real-time operation specifically, the reserves are dispatched via a balancing mechanism managed by the TSO in which market participants can place bids for up- or downward balancing power. Such a balancing market is the last opportunity for commercial transactions in the system and as such, normally trades at higher energy prices than forward, day-ahead and intraday markets.

TSOs incur costs for procuring reserves as well as for energy used to cover imbalances. Therefore, an imbalance mechanism is applied to recover all associated costs from the market participants that deviate from their submitted schedules. The TSO determines these costs either by the marginal price or by the average price of all accepted offers during the balancing period. In addition to this cost, the TSO could charge imbalances differently depending on whether they are positive (more production than forecast) or negative (less production than forecast). It could even add penalties as disincentives for future imbalances.

The design of the imbalance mechanism has important consequences on the interactions between balancing and day-ahead markets. A single price imbalance mechanism applies the penalty only when generators deliver less energy than the one contracted day-ahead. A dual price mechanism applies when generators deliver more and less energy than contracted. A dual imbalance price mechanism is supposed to give stronger incentives to deliver schedules as submitted, but it could also incentivise strategic gaming behaviour and may excessively penalise wind energy generators, as wind forecasting can deviate up or down. Such balancing provisions put them at a disadvantage compared to conventional generators as their forecasts become more accurate closer to electricity delivery, but they have few or no opportunities to use them in real time operation.

Until very recently, balancing the system was deemed to be limited to national or control zone borders for which a given TSO is responsible. This was justified as a way of avoiding unnecessary flows of electricity over larger distances, thus reducing transmission losses. It also reflected the complexity of predicting and monitoring such flows throughout the highly meshed European grid. Last, but not least, markets were initially developed nationally with a lack of, or poor, market integration vision and little cross-border coordination. This created a variety of different rules and procedures for balancing services and reserves procurement across Europe, which today is a significant challenge – not only for regional and pan-European market integration, but also for enabling large deployment of wind energy and other renewables.

In particular for wind energy, balancing within specific limited or national control zones hinders the possibility of smoothing its variability. The aggregation of wind power output across larger geographical areas enables the smoothing-out of its variability, thus reducing the need for relatively costly real-time balancin[10]. This means the more wind power plants in operation over a larger geographical area, the smaller the impact of variability on system operation.

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[10] IEA Wind Task 25 (3) and TradeWind Project (14)

BOX 2 BALANCING SERVICES

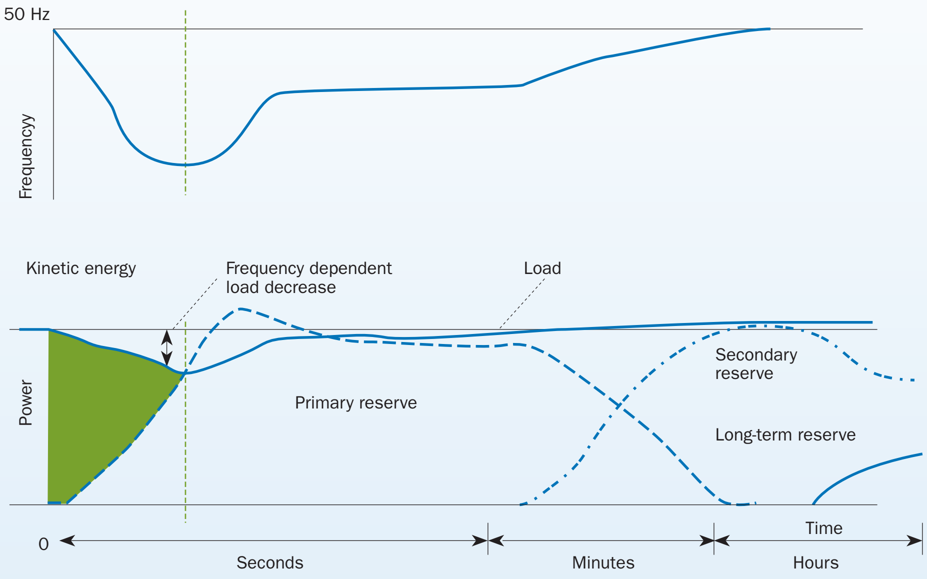
Balancing Services

Balancing refers to the situation after markets have closed and in which TSOs ensure that supply is equal to demand in real time. It includes all the services associated with power system operation that ensure quality and short-term security of supply.

These can be broadly classified as follows:

- Frequency control: Services automatically and instantly delivered to correct small or sudden variations in production and consumption that cause frequency deviations of the system. (See upper section of Figure 1.4)
- Reserves and energy balancing services: Services manually instructed by TSOs generally cater for plant loss and significant demand or supply forecast error. These are further classified[11] according to the time frame from dispatch to full service delivery: minutes to hours. (See lower section of Figure 1.4)

FIGURE 1.4 BALANCING SERVICES TIME FRAME ACTIVATION



Sources: ETSO (8) and EWEA (9)

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[11] ENTSO-E Network Codes on "Load Frequency Control and Reserves" and "Electricity Balancing" refer to reserves as Frequency Containment (primary), Frequency Restoration (secondary) and Replacement Reserves (long-term)

1.1.3 Congestion management and transmission capacity allocation

Given the finite transmission infrastructure, physical flows of traded electricity can cause congestion in the grid. This happens when the desired transfers of electricity exceed the transmission grid capacity. As these situations have negative consequences for system stability and security of supply, TSOs use special methods and trading mechanisms to alleviate congestion and manage network constraints. These include transmission capacity calculation and allocation methods, dispatch optimisation decisions, redirecting electricity flows between congested areas either by direct trading (counter-trade) or splitting same-priced congested areas into two or more areas with different prices (market splitting) or even curtailing electricity flows.

Transmission capacity is generally traded as a separate product from electricity and according to the control areas for which each TSO is responsible. This is done through explicit (separate) auctions[12] that allocate capacity across different timescales and for cross-border trading, for each border individually at the time. Generators sign long-term contracts with TSOs to secure transmission rights, which can be physical or financial[13].

This forward market implies that transmission capacity is determined before final energy flows are known. In fact, in the day-ahead timescale, before energy trading takes place, TSOs have to predict flows during the day of operation and place the Available Transmission Capacity (ATC) on the market for each of their control zones[14]. Whilst this predictive method provides indicative flows of electricity, it hardly captures the real electricity flow behaviour in the network[15].

This method has consequences for cross-border trading as transmission capacity is bilaterally agreed exclusively between the zones where trading takes place without considering interactions with neighbouring systems. Unscheduled flows can go through other control zones causing TSOs to take additional steps to control congestion. Consequently, the capacity transmission calculation generally includes unilateral high security margins significantly constraining cross-border flows, as effective congestion management methods across borders are not well developed.

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[12] In Nordic countries, implicit auctions have been used since 2000. In North-Western Europe, these have been used since 2006 through the Trilateral Market Coupling initiative. (see Figure 2.5)

[13] The former entitles the holder to use the transmission capacity or trade it (use-it-or-sell-it, or in some cases use-it-or-lose-it) while the latter only entitles the holder to receive a payment when price differences arise between zones in which the transmission capacity was acquired.

[14] Available Transfer Capacity (ATC) is calculated by subtracting the Notified Transmission Flows (NTF) of the forward market from the Net Transfer Capacity (NTC). NTC is determined statistically from historical flows and each TSO's security margins (16).

[15] Electricity flowing between any two points distributes itself along all possible parallel paths in an interconnected network according to Kirchhoff's laws. Therefore, transmission capacities calculations would have to consider all possible paths in which electricity will flow. Considering all these interdependencies in large networks requires specialised algorithms and the detailed topology model of the grid, which, to date, are not available to TSOs.

Myth 1: Wind energy is the root cause for loop flows in the network

The so-called loop flows are unscheduled electricity flows mainly resulting from commercial transactions between control zones that affect neighbouring power systems, either from other countries (cross-border flows) and/or from other TSOs' control zones.

In a highly meshed network – such as the European one – electricity flowing from one zone to another does not follow a 'direct' path. It distributes along all possible connected paths according to the physical laws of electricity flow. Therefore, unscheduled flows are the consequence of a flawed calculation method and a lack of coordination between adjacent control zones for scheduling them appropriately.

Specifically, unscheduled flows are caused by the current method of allocating cross-border transmission capacity and inappropriate definition of bidding zones in the market. Currently, cross-border transmission capacity is traded bilaterally without considering the effects of power flows in adjacent zones. Moreover, these cross-border flows may be within a common market zone, which would not be nominated (declared) as cross-border even if using international interconnectors affecting neighbouring countries. This contributes to failing to consider them in the regular scheduled flows when trading occurs.

Unscheduled flows have been noted in high wind/low demand situations. Nevertheless, these flows are not linked to a specific generation technology, but are the combination of several factors, and most importantly a symptom of a lack of grid capacity, lack of TSO cooperation and the sub-optimal use of existing transmission lines. If more investments were made in the internal grid and the use of the neighbouring grids coordinated (most of the time they are not optimally utilised either), loop flows would be reduced.

1.2 State of play of electricity market liberalisation

The liberalisation of European energy markets promised many benefits to Europe's citizens and industry: more choice, increased competition pushing prices down, better service and improved security of supply. The opening of a previously closed sector to the EU single market was planned to be achieved through effective ownership unbundling of power generation and supply assets, free choice of supplier and enhanced market monitoring and transparency.

However, the way in which markets were liberalised and recently integrated has created many difficulties for integrating wind energy. The original voluntary character of initiatives for electricity market integration achieved progressive but limited national market convergence within a region and created divergences between regions. This made it difficult to take full advantage of renewables, particularly wind. Differences in gate closure times, cross-border trading and congestion management methods were not thoroughly addressed or coordinated and, eventually, more top-down regulatory intervention at European level was required.

The 3rd Liberalisation Package, which came into force in March 2011, changed the context of such voluntary and intergovernmental market integration, notably through the provision of binding Framework Guidelines and Network Codes. These set the legal framework for cross-border transmission management and market integration. However, the legislation only contains a few specifics on how integration of EU electricity markets is to be achieved.

In practice, the main problem is that national markets have not been, and are still not, ready. Currently, Member States are at different stages of implementing common electricity market rules. The numerous elements of the 3rd Liberalisation Package (adopted in 2009) and even the 2nd Liberalisation Package (adopted in 2003), have not been effectively transposed and implemented. Despite a clear timetable for transposition of EU directives and regulations for the energy sector (see Table 1.2), gaps persist and national market rules continue to diverge, in contradiction to EU market rules. In its 2010 progress report on the internal market, the European Commission suggests that market rules have responded to national interests and regulation of electricity prices for consumers[16], largely ignoring the Internal Energy Market (IEM) vision.

Regulated consumer prices are a significant obstacle to efficient and fair competition and hinder market entry and infrastructure development. They do not allow a transparent comparison between generating technologies and they distort markets. Unfortunately, regulated prices are common in Europe as seen in Figure 1.5.

Moreover, energy markets in the EU continue to be highly concentrated with national incumbents exerting significant market power, as illustrated in Figure 1.6. It is more difficult for small and medium-sized (wind energy) companies to enter the market and compete on a level playing field. Thus, structural market distortions remain the main challenge to the internal energy market, including wind energy market integration.

Furthermore, the liberalisation process has not yet achieved a competitive market, and the new liberalised market rules have been developed with established conventional large scale power generators in mind, with little reference to the increasing amount of renewables foreseen by the 2020 Renewable Energy Directive and limited recognition of their technical nature. In fact, these rules hardly differ from those created for vertically integrated utilities before any significant cross-border trading and liberalisation took place.

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[16] European Commission, 2009-2010 Report on progress in creating the internal gas and electricity market (1)

TABLE 1.2 RELEVANT EU DIRECTIVES AND REGULATIONS IN ELECTRICITY

	Publication date	Transposition deadline	Directive /Regulation
First Package	19/Dec/96	19/Feb/99	Directive 96/92EC[17] concerning common rules for the internal market of electricity
Second package	15/Jul/03	01/Apr/04	Directive 2003/54EC[18] concerning common rules for the internal market of electricity
	26/Jun/03	01/Jul/04	Regulation (EC) 1228/2003 on conditions for access to the network for cross-border exchanges of electricity
	9/Nov/06		Commission Decision 2006/770/EC amending the annex ("Congestion Management Guidelines") for regulation 1228/2003
Third package	13/Jul/09	03/Mar/11	Directive 2009/72/EC[19] concerning common rules for the internal market of electricity
			Regulation (EC) 714/2009 on conditions for access to the network for cross-border exchanges of electricity
			Regulation (EC) 713/2009 on establishing an Agency for the Cooperation of Energy Regulators (ACER)

Source: Adapted from REKK & KEMA (10), EC, DG Energy

The predominance of forward energy markets in which power is mainly traded via long-term bilateral contracts and explicit transmission capacity allocation is evidence of a market design tailored for dominant incumbent participants. Similarly, the absence of intraday markets – and, where they exist, their low liquidity – is further proof of a market designed for large, slow-ramping, must-run inflexible power plants. Intraday markets would allow the possibility of re-planning and trading closer to real-time delivery, which is more suitable for the kind of flexible generators that are needed in a future internal market for electricity.

In particular, wind energy characteristics are fundamentally different: variable availability, limited predictability and very low marginal cost of electricity production. These characteristics must be taken into account when establishing market rules to efficiently integrate wind energy. Furthermore, wind energy should be used whenever it is available as it decreases electricity prices via the merit order effect and provides electricity without any CO_2 emissions. Curtailing wind power is not the most economic option as no fuel or carbon cost savings are made. Similarly there are very little operating cost savings.

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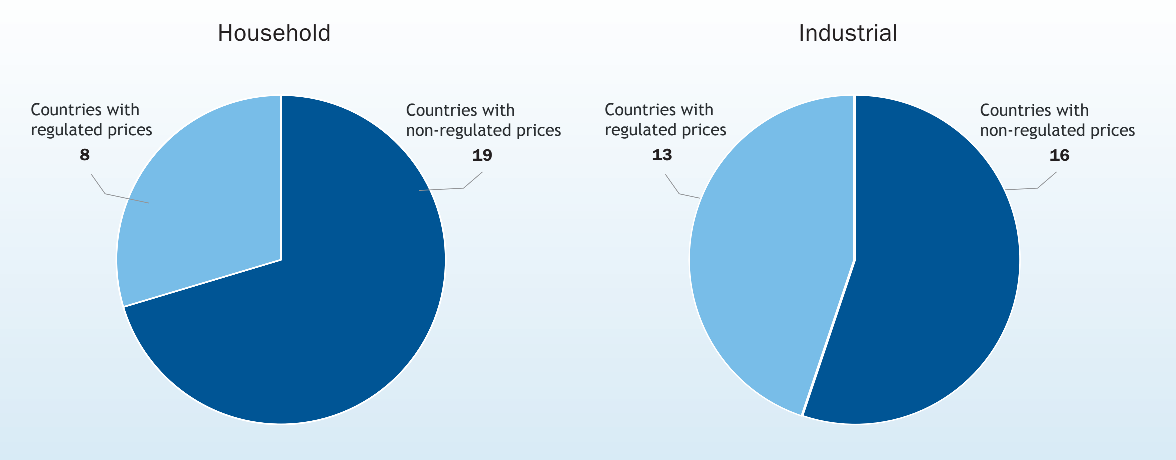
[17] Directive 96/92EC established the minimum requirements of generation and transmission unbundling for accounting and management activities.

[18] The 2nd Liberalisation package aimed at legal unbundling and required management staff of the TSO not to take decisions in other parts of the vertically integrated company. This included DSOs, except those serving fewer than 100,000 clients or operating in isolated systems.

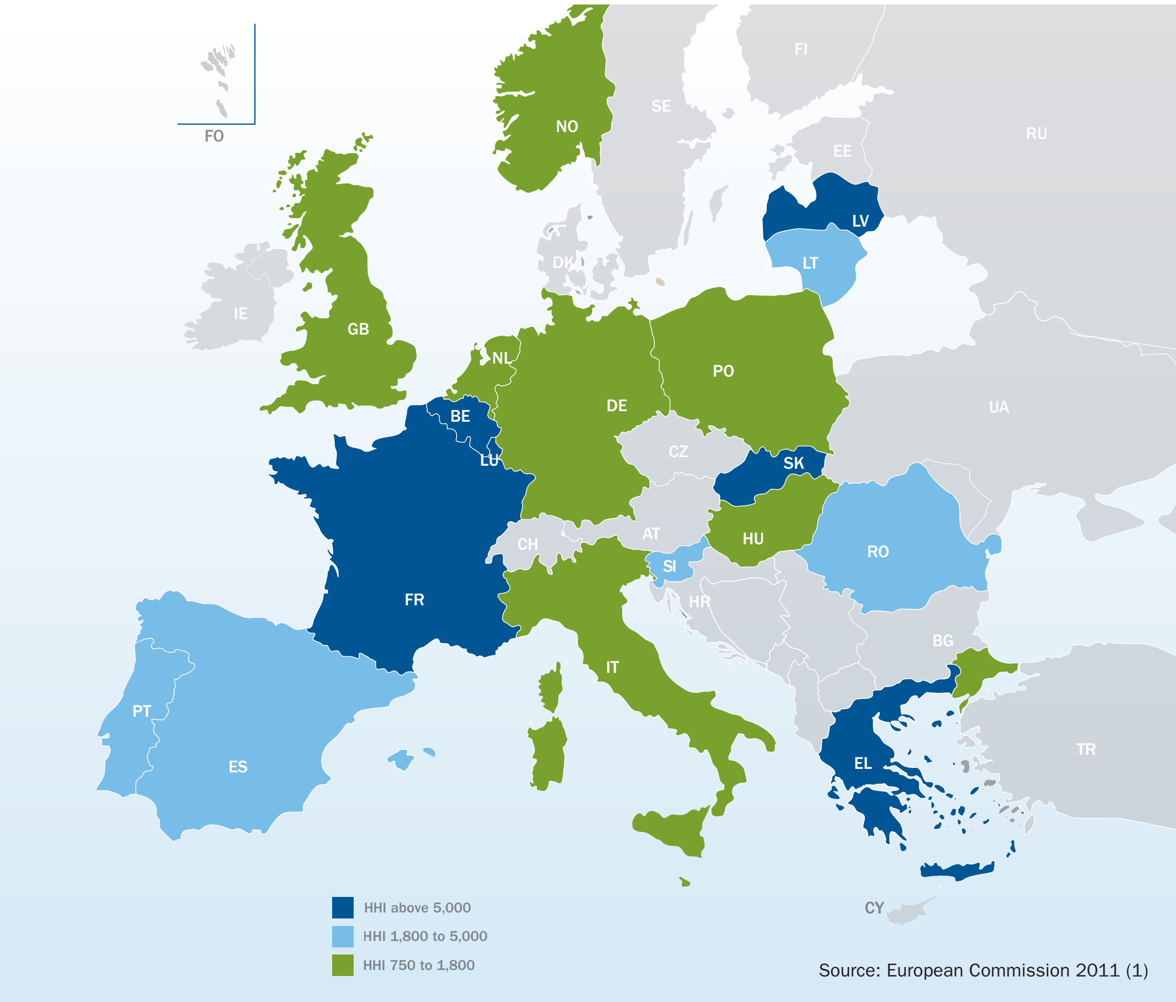
[19] The 3rd Liberalisation package provided for full ownership unbundling (complementing the ITO and ISO model), the establishment of the Agency for Cooperation of Energy Regulators (ACER) and the European Network of Transmission System Operators for electricity and gas (ENTSO), binding rules for cross-border network management and market design as well as additional rules on transparency of retail markets. (27)

FIGURE 1.5 NUMBER OF COUNTRIES WITH REGULATED ELECTRICITY PRICES (2009) EU-27



Source: European Commission 2011 (1)

FIGURE 1.6 DEGREE OF MARKET CONCENTRATION[20] IN THE EU POWER SECTOR



Source: European Commission 2011 (1)

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[20] HHI is the Herfindahl-Hirschman Index which measures market concentration by capacity. It is calculated as the sum of the squares of market shares of individual companies.

1.3 Risks in the market for wind power producers

Prevailing market distortions and discriminatory rules create increased risks for new entrants, particularly for wind energy generators. Therefore, existing support mechanisms for these generators have to be seen in this context. If new renewable generators were faced with full risks under these distorting and discriminatory circumstances, they would require a higher level of financial support to stimulate the development of their technology[21].

Despite this, it is increasingly claimed that as future large penetration of wind will change the power system structure, wind generators should not neglect existing market signals and operational rules. Therefore they should be fully exposed to risks in the market to improve their efficiency and limit costs to society. These risks include price, volume and balancing risks[22].

However, because wind energy is variable and unable to influence the availability of its primary source, it reacts differently from conventional generation to market signals. This is especially true in forward markets, where wind power has limited control of its future output, but also for shorter time scales, such as day-ahead, where market signals have different impacts on wind generators' ability to manage risks.

Firstly, generator's revenues depend on the spot price and the volume of electricity they can sell to the market. Wind generator revenues have, so far, been guaranteed through support mechanisms combined with priority dispatch. The former hedges wind generators from price risks, while the latter protects them against volume risks.

Secondly, generator revenues also depend on the balancing risk they are exposed to. This has a price risk component, determined from the spot market, and an imbalance price component, determined by the mechanism used by the TSO for recovering balancing costs. As the selection between single and dual mechanism (see section 1.1.2) can put wind generation at a disadvantage, in many systems they are exempt from this balancing responsibility.

At low levels of penetration, support mechanisms ensure that wind generators receive a stream of revenues even when prices are very low or drop to zero, thus securing their return on investment in the long-term. On the one hand, zero prices are a consequence of lack of transmission capacity and demand response, which are both structural distortions of the European power market. Also, low electricity prices are a consequence of the merit order effect that low marginal cost technologies produce (see Box 1). However, because today's energy-only market does not provide revenue streams that recognise their true value, low average prices reduce return on investment from wind energy assets, The average energy price is lower when the turbines produce the most, therefore, support mechanisms are based on generation output in order to compensate this.

Similarly, priority of dispatch, instead of being seen as a preferential treatment, protects wind generators from unjustified curtailments caused by inefficient operational procedures, thus encouraging TSOs to improve their power system routines, when coping with variable renewables.

As wind power output predictability improves with shorter time horizons, the development of liquid intraday markets is fundamental if renewable energy generators are to be exposed to balancing risks. Intraday markets take advantage of wind energy's very low marginal cost, using wind power whenever it is available through the merit order effect and the improved output predictability at shorter time horizons, thus reducing balancing and volume risks. Moreover, not only is the creation of intraday markets a prerequisite for cost effective integration of wind power, it is also vital for liquidity and integration of these markets across borders (see Chapter 2).

If wind energy generators are exposed to market risks, balancing responsibility could be considered as a first step provided there is a functioning and liquid intraday market and sufficient level of cross-border interconnectivity. These preconditions, together with the extensive use of short-term forecasts as close to real time as possible, must be met in order to give wind generators the possibility of matching their forecast power output with a minimised forecast error. The application of state-of-the-art forecast tools

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[21] Klessman, C., et al., 2008 (20)

[22] Jirouš, F. et al, 2011 (30)

together with larger balancing areas are crucial in regimes where balancing costs must be borne by the wind farm operator.

The benefit to society of exposing wind power producers to risks in the market depends heavily on the level of penetration, prevailing market distortions, and whether market rules enable the intrinsic characteristics of the technology to succeed in the long-term. Preconditions to full exposure are that markets are functional, competitive, liquid and have a significant level of transparency and that all market actors are treated equally. This ensures better risk management and reduces the need for regulatory intervention in the form of support schemes. As long as this is not the case in the European electricity market, exposing wind generators to market risks will impact on their deployment, delaying the benefits they deliver to society and the environment.

Myth 2: Alleged market distortion due to RES support schemes

It is often stated that 27 different national RES support mechanisms hamper the creation and efficient functioning of a future single electricity market. There is also a tendency among stakeholders and policy makers to exclusively focus on the support mechanisms for renewables. These cannot and should not be viewed in isolation from the rest of the power market, which is already highly distorted. If structural risks are addressed effectively, the need to support newer, flexible renewable energy technologies would significantly decrease or completely disappear for the most mature renewable technologies, such as onshore wind power in good locations.

In 2009 the European Commission initiated infringement procedures against 25 out of 27 Member States for failing to transpose the 2nd Liberalisation Package. Legal action is currently being pursued against 20 of them. Furthermore, no Member State has yet implemented provisions from the 3rd Package despite the March 2011 deadline. It seems that in over 15 years of liberalisation efforts, results have been piecemeal, at best.

Dedicated RES support mechanisms and related regulatory provisions should be seen in the context of this incomplete liberalisation and lack of competition in the energy sector. RES support, harmonised or not, as well as priority grid access and dispatch are not a market distortion in themselves, but they are a guarantee for new entrants given the structural risks and lack of a functioning internal energy market. Dedicated renewable energy support is necessary in the absence of effective competition and in view of the historical development of power generation. Vertically integrated companies have developed their power generation portfolio enjoying the advantages of a natural monopoly, decades of fossil fuel and nuclear subsidies which continue today and passing on costs and risks to consumers via electricity bills or tax revenue.

Photo: Jose Ramon Luna de la Ossa

2 EU TARGET MODEL AND ROADMAP FOR ELECTRICITY MARKET INTEGRATION

The completion of the Internal Energy Market needs to respond to the challenges of energy affordability, security of supply, fuel import dependence and climate change. Firstly, a more cost efficient power supply is needed through increased competition and a reduction of market concentration that generates competitive prices for consumers. Secondly, cross-border markets are fundamental to increase security of supply and to ensure adequate levels of capacity and flexibility in the power system. Thirdly, integration of wind energy and other renewable energy technologies is vital for meeting Europe's GHG reduction targets in order to contribute to climate change mitigation efforts.

This chapter summarises the latest developments towards the completion of the Internal Electricity Market (IEM). In particular, it analyses the EU Target Model (TM) and its roadmap for 2014. It assesses the extent to which it will facilitate the integration of wind energy in the power system and the benefits that could be unlocked by embracing large scale penetration of wind energy.

Main findings

- ***The EU Target Model does not effectively enable optimal wind energy integration into the European power markets.*** Whilst the TM is an important step towards increased cross-border trading, and consequently, towards the completion of the IEM, it does not sufficiently emphasise provisions that integrate wind energy into the power system to the degree communicated by the 27 Members States in their National Renewable Energy Action Plans (NREAPs)[23]. Nor are the provisions sufficient to move towards effective competition and a fully integrated, flexible European power system. Specifically, the TM does not address fundamental features of intraday and balancing markets, which should be cornerstones of a competitive market place and are essential for wind energy integration. These features include measures to improve their liquidity, harmonisation of rules across borders and the interactions between these markets.

1. ***The TM could unlock greater benefits for the power system by embracing large scale deployment of wind energy into the market integration process.*** These benefits go beyond the current vision of the TM. They include better and more efficient use of all generating assets and resources, as well as load management, ensuring long-term security of supply and providing flexibility and increased system adequacy to the power system. Most importantly, EU market integration enabling wind energy deployment has the potential for maximising overall welfare - for generators by lowering market risks in a truly competitive market, for system operators by reducing operation costs of balancing and reserves and for customers by lowering electricity prices - while reducing their exposure to fuel and carbon price risk.

Policy recommendations

Implementing the EU-wide Target Model with a large share of wind power

- ***Implementing the EU-wide Target Model is the minimum required for achieving the IEM by 2014.*** Beyond providing day-ahead market integration across borders and improved transmission capacity allocation, a more ambitious vision of cross-border balancing markets should be developed, as well as a more prescriptive design for intraday markets.

- ***Provide for integrated intraday and balancing markets.*** Functioning intraday markets are crucial for the efficient and cost effective integration of large amounts of wind energy and for cost efficient system operation. Proper design of intraday and balancing markets and much closer cooperation between Member States is required to enable European market integration.

- ***Make the best use of available transmission capacity and improve system operation routines.*** Moving away from static capacity transmission calculation methods is crucial when implementing the Target Model. Once capacity has been properly allocated, the incorporation of innovative grid management methods should be promoted to maximise the use of existing assets. These include regional control centres to help monitor power flows and RES performance and Dynamic Line Rating (DLR).

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[23] European Commission, 2010 (26)

2.1 The EU-wide Target Model for electricity market integration

As described in the previous chapter, a truly competitive pan-European electricity market with more flexible trading arrangements would facilitate the deployment of large amounts of wind energy. The development of the IEM has the potential to pave the way, by designing market rules that take the characteristics of wind – and other renewables – into account.

The European Electricity Regulatory Forum (Florence Forum) decided in November 2008 to establish a Project Coordination Group of experts drawn from the European Commission, regulators, and relevant stakeholders, to develop an EU-wide Target Model and a roadmap for the integration of electricity markets across regions. The tasks were to develop a practical and achievable model for the harmonisation of co-ordinated EU-wide transmission capacity allocation, to manage congestions and to propose a roadmap with concrete measures for the integration of forward, day-ahead, intraday and balancing markets – including governance issues.

The main areas of work to achieve the TM were:

- A flow-based transmission capacity allocation method in highly meshed networks
- A single European platform for the allocation and nomination of long-term transmission rights
- A single European price market coupling
- Implementation of continuous implicit cross-border trading
- Pilot projects for the implementation of balancing markets

The importance of the measures outlined in the TM was underlined by the EU Heads of State meeting at the European Council on 4 February 2011[24]. It agreed to achieve the IEM with all necessary regulatory measures by 2014, and made this a top priority for the European Commission (see Figure 2.2 for the roadmap).

Nevertheless, the impact of the TM will go beyond 2014, as it could be an enabler (or an obstacle) for achieving the 2020 climate and renewable energy targets. While some provisions in the TM are positive – such as enhanced transmission capacity calculation and allocation, as well as day-ahead market coupling – others will have to be improved to enable larger amounts of renewable energy to be deployed more cost efficiently.

The following section describes aspects of the TM for wind energy integration[25].

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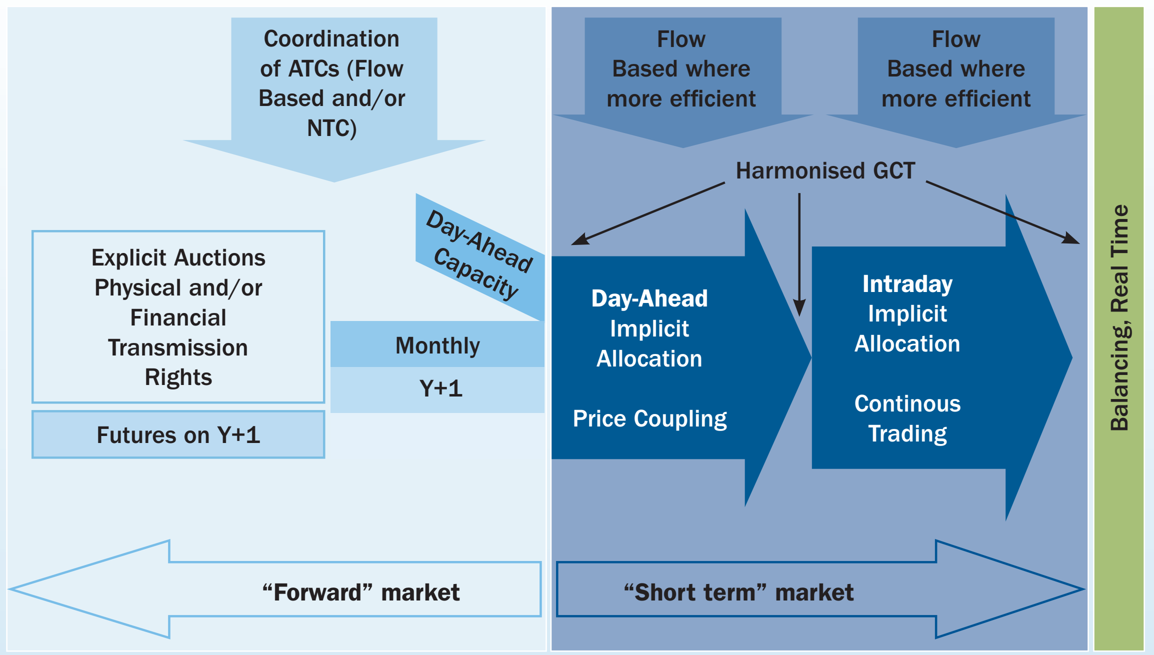
[24] European Council conclusions, 4 of February 2011 (25)

[25] Certain features from the TM, specifically those from forward markets and governance, are omitted from this assessment. This is because their impact on large deployment of wind energy is considered less relevant as the provisions stand, at the time of publication of this report.

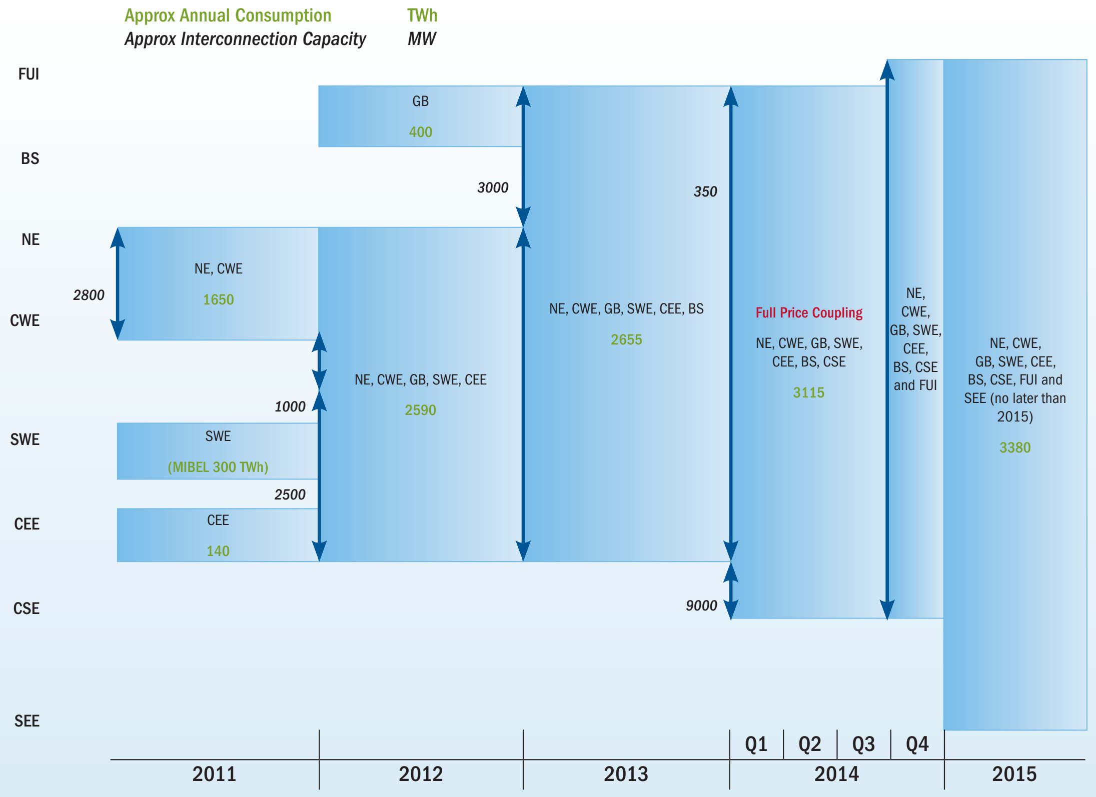
FIGURE 2.1 THE EU TARGET MODEL (TM) FOR ELECTRICITY TRADING



ATC – Available Transmission Capacity **NTC** – Net Transfer Capacity **GCT** – Gate Closure Time

Source: Florence Forum, Project Coordination Group (PGC), 2009

FIGURE 2.2 ROADMAP FOR DAY-AHEAD MARKET COUPLING AS PER TM



FUI – France, UK, Ireland	**NE** – North Europe	**SWE** – South West Europe	**CSE** – Central South Europe
BS – Baltic States	**CWE** – Central West Europe	**CEE** – Central East Europe	**SEE** – South East Europe

2.1.1 Flow-based transmission capacity allocation

The starting point for a pan-European market where electricity can move freely across borders is to define the available transmission capacity for trading. As explained in Chapter 1, cross-border transmission capacity has traditionally been calculated before final flows are known, one border at a time and without considering bilateral trading impacts on neighbouring systems. This causes TSOs to frequently restrict flows across borders under different security standards, even when restrictions are not justified by the physical flows of power.

For this reason, the TM prescribes the harmonisation of transmission capacity calculation and allocation methods by using a Common European Grid Model (CGM) in which Flow-Based transmission capacity Allocation (FBA) can be carried out. The FBA method builds on technical power flow optimisation models that take into account the relationships between all interconnectors of a network, following the physical laws of electricity flow and maximising the capacity utilisation of assets.

A common grid model and flow-based transmission allocation are significant steps towards enhanced, harmonised and more transparent congestion management across borders. Their use maximises the capacity available to the market under common technical security criteria, opening up the possibility of accommodating additional power flows for trading.

While CGM and FBA do not replace infrastructure upgrades, their implementation can secure short-term transmission capacity expansion across borders, particularly when wind generation is high and curtailment of wind farms may take place. This increased interconnection capacity could be used for balancing purposes. In addition to taking advantage of the availability of wind and its lowering effect on electricity prices, there is evidence that when sufficient interconnection capacity is available for balancing in high wind power penetration levels, balancing costs for the power system[26] are reduced.

Moreover, by considering electricity flows behaviour in the interconnected network when trading across borders, the FBA method will significantly reduce unscheduled power flows (loop flows) through neighbouring systems which, today, are mistakenly attributed almost exclusively to increased wind and solar power penetration.

Finally, the CGM and FBA methods open up the possibility of linking dynamic grid management with the market to maximise the use of new and existing assets. For example, the use of regional control centres[27] and other dynamic grid management tools such as Dynamic Line Rating (DLR) should be promoted in the market. DLR can increase transmission capacity at high wind power penetration levels by taking into account the cooling effect of weather conditions in the cable temperature, minimising curtailment and increasing firmness of market arrangements[28].

2.1.2 Day-ahead market coupling

The TM establishes day-ahead electricity markets integration through a market coupling mechanism. This aims to lower average prices across the EU by synchronising day-ahead operations of different markets in terms of gate closure times, operational procedures, type of products available for trading and transmission capacity allocation across borders.

This harmonisation enables joint market clearing, making available all cross-border supply and demand bids for trading at the same time, which can be matched automatically with the available cross-border transmission capacity. In this way, transmission capacity can be procured implicitly, together with energy trading, as opposed to traditional explicit auctions. This enables parties to obtain automatic

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[26] IEA Wind Task 25 (3)

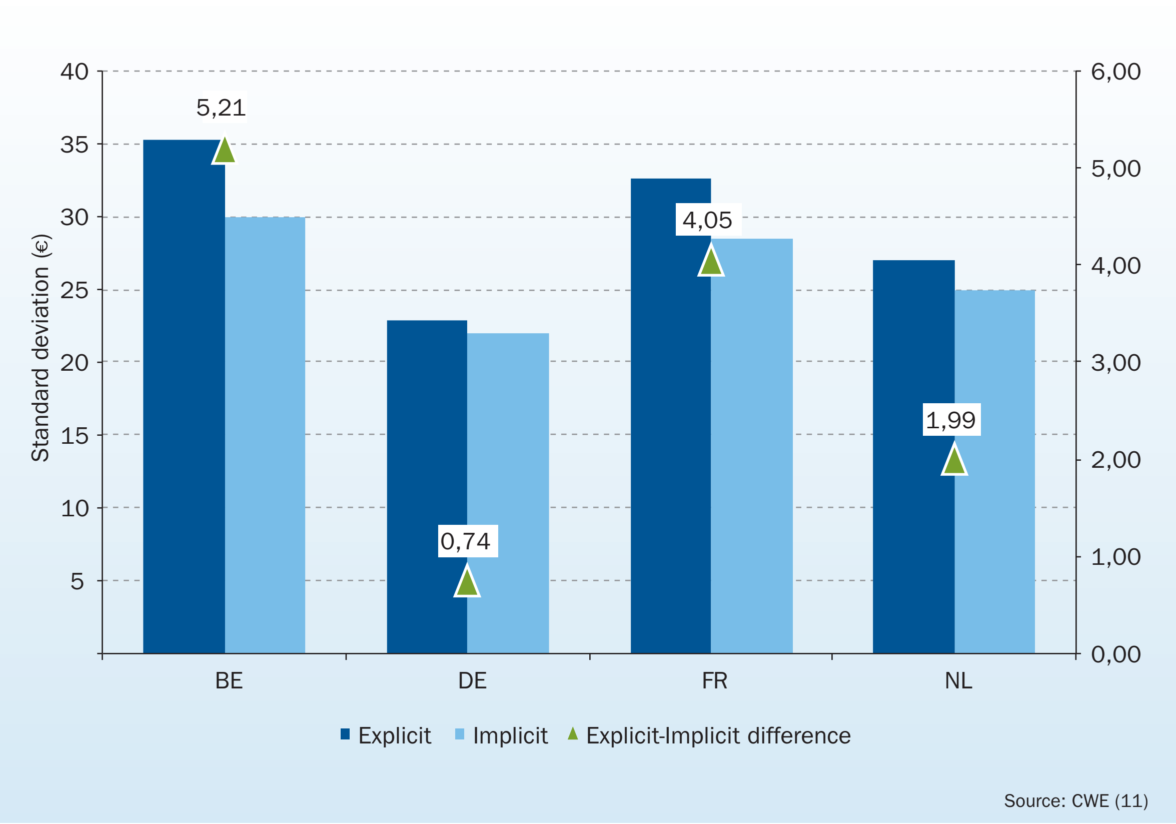
[27] Control centres such as CORESO which monitors grids from Belgium, France, Italy, Great Britain, North and East of Germany or CECRE which oversees the Spanish grid.

[28] Schell et al. 2011 (22)

access to cross-border energy and capacity without having to procure them from separate markets.

Thus, market coupling increases electricity flows across borders, which contributes to creating price convergence and to reducing price volatility. So far, this has been successful – as seen in Figure 2.3, which shows the reduction in electricity price variation between explicit (no coupling) and implicit (coupling) auctions.

FIGURE 2.3 MARKET COUPLING EFFECTS ON VOLATILITY OF ENERGY PRICES



Source: CWE (11)

BOX 3 MARKET COUPLING AND MARKET SPLITTING

Market coupling

Market coupling is a mechanism for enabling trade between two or more power exchanges using implicit auctioning of cross-border transmission capacity.

When power exchanges are integrated, trading is subject to capacity constraints set by TSOs, which may limit electricity flows between markets. The coupling mechanism uses a central algorithm. It simultaneously optimises all profitable deals resulting from the matching of bids and offers between power exchanges with available capacities defined by TSOs.

The main objective of the optimisation is to maximise the total economic surplus of all participants and to determine the flows that lead to a levelling of prices across markets. This means that cheaper electricity offered in one country can meet demand and reduce prices in another country. Prices will level out whenever there is sufficient transmission capacity. When congestion occurs, prices between zones differ and the mechanism ensures that power flows from the lower price zone to the higher price zone.

In practice, market coupling has been implemented in two ways, depending on how price is calculated:

1. ***Price coupling*** determines both prices and flows centrally by the coupling algorithm in an iterative two step process. First transmission capacity is optimised at national level without considering cross-border trading. Then, a second optimisation considering imports, exports and national flows is undertaken and the resulting prices and optimised power flows are determined.

2. ***Volume coupling*** determines only power flows with the central algorithm, whereas price calculation is done independently by each power exchange involved in the coupling. This has advantages for power exchanges as they introduce the coupling without significant changes to their existing market procedures. They keep the control of price calculation, minimising implementation costs.

Market splitting

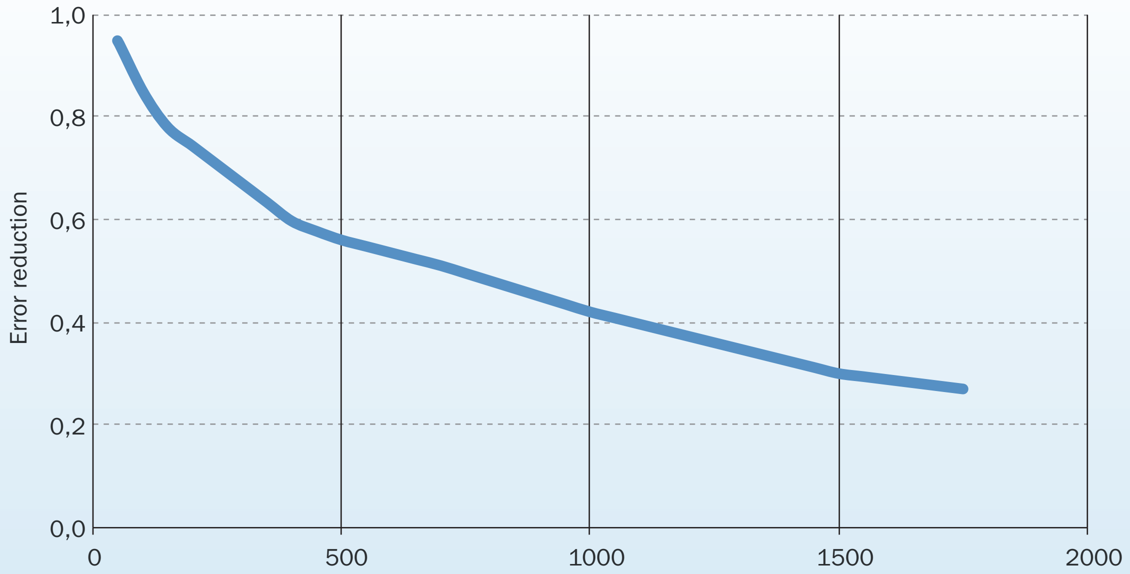
Market splitting is a congestion management mechanism that splits a power exchange into geographical bid areas of different electricity prices and limited capacities of exchange, when congestion occurs. It also uses implicit auctioning for transmission capacity allocation between areas, ensuring the balance between supply and demand automatically.

Sources: ELIA (28), EMCC (29) and CWE (11)

The main effect of day-ahead market coupling on wind power integration is that wind energy can be more easily aggregated and procured across larger geographical areas. The aggregation of wind power forecasts from different control zones will help to reduce the forecast error and will alleviate price spikes in low or high wind situations across regions. Figure 2.4 illustrates such forecast improvement as a function of region size.

Moreover, the integration efforts on day-ahead level are positive for all generators. The market coupling mechanism also optimises trading opportunities for power plants that would otherwise face shorter running times due to wind energy integration, giving them access to trade in different zones and markets.

FIGURE 2.4 DECREASE OF FORECAST ERROR PREDICTION FOR AGGREGATED WIND POWER PRODUCTION DUE TO SPATIAL SMOOTHING EFFECTS. ERROR REDUCTION = RATIO OF RMSE REGIONAL AND RMSE OF A SINGLE SITE. RESULTS BASED ON 40 GERMAN WIND FARMS

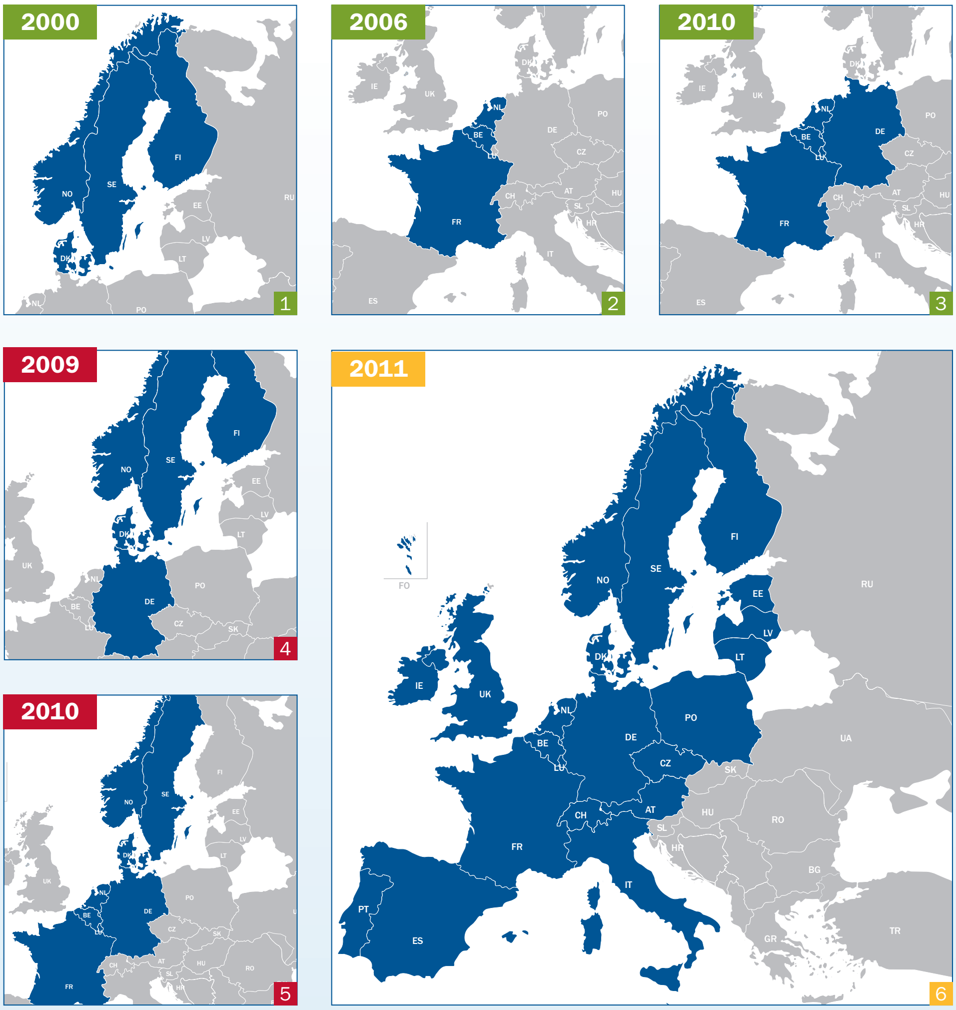


Source: Energy and Meteo Systems in IEA Wind Task 25 (3)

Market coupling status in the EU

A major step towards day-ahead market integration was achieved on 9 November 2010, with the launch of market coupling in Central West Europe (known as CWE) covering Belgium, The Netherlands, Luxembourg, France and Germany. In parallel, CWE was volume coupled in November 2010 with the Nordic market region via the Interim Tight Volume Coupling[29]. The integration of the UK and Irish electricity market is scheduled for the end of 2012 (see also the roadmap for market coupling at the end of this chapter) with the goal of complete market integration of all EU regions by 2014.

FIGURE 2.5 MARKET COUPLING MECHANISMS USED IN THE EU. *ONGOING INITIATIVE



	Market integration mechanism	Region /countries
1	Price Coupling	2000 - Nordic Market integration: Norway, Sweden, Finland and Denmark
2		2006 - Trilateral Market Coupling: France, Belgium and The Netherlands
3		2010 - Market Coupling Mechanism Central West Europe (CWE): Germany, Belgium, France, Luxembourg, Netherlands
4	Tight Volume Coupling	2009 - European Market Coupling Company (EMCC): Nordic region and Germany
5		2010 - CWE and Nordic region
6	Price Coupling of Regions	2011* CWE, Nordic and SWE regions. (Portugal, Spain, Italy, Belgium, the Netherlands, Great Britain, France, Germany, Austria, Switzerland, Denmark, Norway, Sweden, Finland and the Baltic, including the price coupling on SwePol-link to Poland)

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[29] 'Tight' in this context means that the volume (flow) traded is calculated on the same basis as price coupling but prices are not optimised centrally (see Box 1). Tight volume coupling is meant to be an interim solution towards price coupling.

2.1.3 Intraday continuous implicit cross-border trading

The TM foresees intraday cross-border market functioning as ‘continuous trading’ rather than fixed auctions with gate closures at pre-determined times during the day[30]. As the purpose of these markets is to allow for faster adjustments within the day of operation, continuous trading is considered to be more suitable than fixed auctions. In continuous trading bids and offers can be submitted to power exchanges at any time. This is intended to provide greater flexibility for participants to perform short-term adjustments.

Nevertheless, there is little progress in the development of intraday markets across Europe. Eastern and new Member States show the least progress (see Figure 1.3), but functionality in Western and older Member States remains a challenge, even where intraday markets exist. In this sense, the TM does not address the lack of liquidity of intraday markets highlighted in the previous chapter. This hinders not only wind power integration but also a more efficient use of the power generation fleet overall. Whilst continuous trading allows greater flexibility, it is not clear how it will encourage greater transaction volumes.

Currently, short-term adjustments are mostly made using expensive resources from balancing markets. Intraday markets could change this and yield cost savings. To achieve this, their design features must be further improved in the TM. Moreover, the TM must clearly address the strong interplay of intraday and balancing markets and their overall impact on cross-border trading. So far, this has not been the case.

A functioning intraday market will increase the efficiency of the balancing market. It will allow better deployment of resources if unit commitment can be rescheduled and balancing resources used only when needed. For example, the TradeWind project found that allowing for unit commitment rescheduling intraday leads to savings in operational costs of power generation[31]. By accepting wind power forecasts up to three hours before delivery, a reduction of reserves demand of €260 million/year could be achieved. Such benefits are even larger when considering intraday rescheduling of cross-border exchanges. Savings range between €1 billion and €2 billion per year, compared with cross-border exchange scheduled day-ahead.

Also, combining predictions over larger areas with reduced forecast horizons has a positive effect on forecast accuracy (Table 2.1). Consequently, intraday trading across borders aggregating wind power production from several control zones has a positive effect on market functioning as well as on wind power integration.

TABLE 2.1 LEVEL OF ACCURACY OF WIND POWER PREDICTIONS FOR LARGER AREAS AND SHORTER TIME SCALES

NRMSE (%)	Germany (all four control zones) ~1,000 km	One control zone ~350 km
Day-ahead	5.7	6.8
4h ahead	3.6	4.7
2h-ahead	5.7	6.8

Source: Rorhig, K. in IEA Wind Task 25 (3)

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[30] For example, OMIE, the Iberian power exchange, has six fixed energy auctions in which participants can trade intraday, while BELPEX, the Belgian power exchange, allows participants to submit bids and offers continuously every five minutes.

[31] Van Hulle, F. TradeWind Project (14)

Continuous intraday trading has the potential to accommodate forecast updates of wind power production that might occur within one hour. These are already applied in some countries with auctions and products in less than one hour (as in Germany with 15 minute contracts available for trading[32]), but could be supported by stricter provisions in the TM. For example, intraday gate closure times could be harmonised, ideally up to 15 minutes before real-time – or even less. Also, the balance between continuous and fixed auctions should be carefully analysed: some market participants may consider fixed auction gate closures more convenient. The aggregation of bids and offers at a single point in time gives a better indication of prices than transactions spread over the day. However, in order to retain the flexibility of continuous trading, auctions should be offered as additional products, to increase liquidity in the markets.

As explained above, intraday markets are key to creating well-functioning power markets and integrating wind energy and other variable renewables into the electricity market. These allow generators to adjust their trading position using more accurate short-term forecasts for their generation output. It is imperative that well-designed and functioning intraday markets are set up on a national and regional basis. This must firstly be a Member States driven process, as in day-ahead market uptake and integration.

2.1.4 Balancing market

The TM is not as prescriptive for the balancing market as for other markets. In fact, there is no clear path or model towards European market integration. The TM only proposes cross-border trading of manually activated reserves (also known as replacement reserves) and establishes that pilot projects are tested on a case-by-case basis under close TSO supervision.

Various balancing market models are proposed, according to the degree of harmonisation between markets and TSO cooperation required. These range from cross-border extension of national balancing mechanisms to bilateral or multilateral TSO-TSO exchanges. The latter require the greatest level of harmonisation and cooperation.

Balancing markets face a high level of complexity for integration. First, the variety of operational and market rules across Member States is a significant problem. Second, the impact of balancing and reserves changes for system stability and security of supply is critical. Therefore, there is a conservative approach to cross-border cooperation in developing these markets beyond national borders.

If electricity market and wind power benefits are to be fully exploited, more ambitious provisions in the TM for regional and pan-European balancing markets are needed. Harmonisation of gate closure times and technical characteristics are necessary first steps. Then, cross border integration needs to be encouraged across all time frames and activation modes – not only on replacement reserves, as required by the TM. The Nordic market can be taken as a reference point. There, even primary reserves can be exchanged across borders through its “Regulating Power Market”[33].

Balancing markets across borders will enable cost-efficient integration of wind energy and will improve power system operation and overall market efficiency. By balancing wind power on a regional level, reserves will be optimised, requiring fewer real-time assets online. In this way, large geographical areas will reduce balancing costs. This is due to the smoothing effect of aggregating wind power and other power outputon reducing its variability. Wind integration in the US and the Nordic region has shown how operational costs can be cut, by balancing power exchange with neighbouring countries and markets[34].

Functional balancing markets that are integrated across borders also improve intraday markets' liquidity and create incentives for all generators to reduce their power imbalances. In a well-designed balancing market, prices will be higher than on day-ahead and intraday markets, encouraging the use of the latter to avoid high costs of imbalances.

If imbalances occur, imbalance exchange between countries or systems is possible, when functional cross-border balancing markets are in place. This has the benefit of decreasing the reserves needed in the system. The principle is explained in Figure

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[32] EPEX Spot (17)

[33] Nordpool Spot (15)

[34] IEA Wind Task 25 (3)

2.6, in which two countries exchange their opposite imbalances to reduce the amount of balancing power needed in their respective systems. The chart on the left shows the imbalances of the countries over a day before being exchanged (current market situation) and the chart on the right shows the net imbalances after opposite imbalances have been exchanged (cross-border balancing markets in place).

Finally, a better understanding of the potential for wind power plants to participate in balancing and providing reserves to the system is needed. With current technology, wind power plants can already provide grid support services including balancing. Advanced control techniques allow them to ramp up or down as required by the system, depending on the availability of wind at the specific moment. This could offer significant flexibility to the system, allowing TSOs to make use of inexpensive balancing resources. Nevertheless, market mechanisms that properly value the provision of these services for all market participants have to be put in place (see Chapter 3).

FIGURE 2.6 OPPOSITE IMBALANCE EXCHANGE OF TWO COUNTRIES

Source: Andersen & Detlefsen, 2011 (31)

2.2 Benefits of wind power in an integrated electricity market

A more complete TM would have the potential to unlock significant benefits for the power system by bringing large scale deployment of wind energy into the market integration process. These benefits go beyond the current vision of the TM and include better and more efficient use of assets and resources, ensuring long-term security of supply, providing flexibility and increasing the adequacy of the power system while reducing consumer cost.

An integrated electricity market that recognises the specifics of the various power production technologies is key to increasing wind energy competitiveness. With markets more adapted to variability and better integrated, wind would be the most competitive energy source, providing zero CO_2 energy at the lowest price and risk for consumers.

Large amounts of wind power in an integrated electricity market provide:

1. Smoother and steadier power generation by aggregating wind and other power output across greater geographical areas. Also, aggregating wind energy production from multiple countries strongly increases the firm capacity of wind energy. The wider the TSO's control zones, the higher the resulting capacity credit of wind, i.e. wind energy contribution to the guaranteed capacity in relation to peak load[35] (see Chapter 3 for details).

2. Savings in operational costs of power generation and more stable power prices, through the uptake and integration of intra-day markets. These would allow unit commitment rescheduling as close as possible to real-time delivery leading to savings in balancing and reserves, as documented by the TradeWind project[36]. These benefits are even more marked when considering intraday rescheduling of cross-border exchanges.

3. Increased flexibility in the power system. Wind power plant capabilities can offer grid support services. Advanced control techniques allow them to ramp up or down as required by the system, depending on the availability of the wind resource at the specific moment. This offers significant additional flexibility for TSOs.

4. Increased cross-border electricity flows, creating greater trading opportunities across borders of energy and reserves, to enhance security of supply. Specifically, the cross-border trading of balancing services can make efficient use of inexpensive resources such as wind power.

Most importantly, EU market integration enabling wind energy deployment has the potential to maximise overall welfare – for generators by lowering market risks in a truly competitive market, for system operators by reducing operational costs of balancing and reserves and for customers by lowering electricity prices. Last, but not least, wind energy integration into the market will not only hedge against supply disruptions and fossil fuel dependency but will improve overall regional competitiveness and promote economic growth, at the same time as reducing CO_2 emissions.

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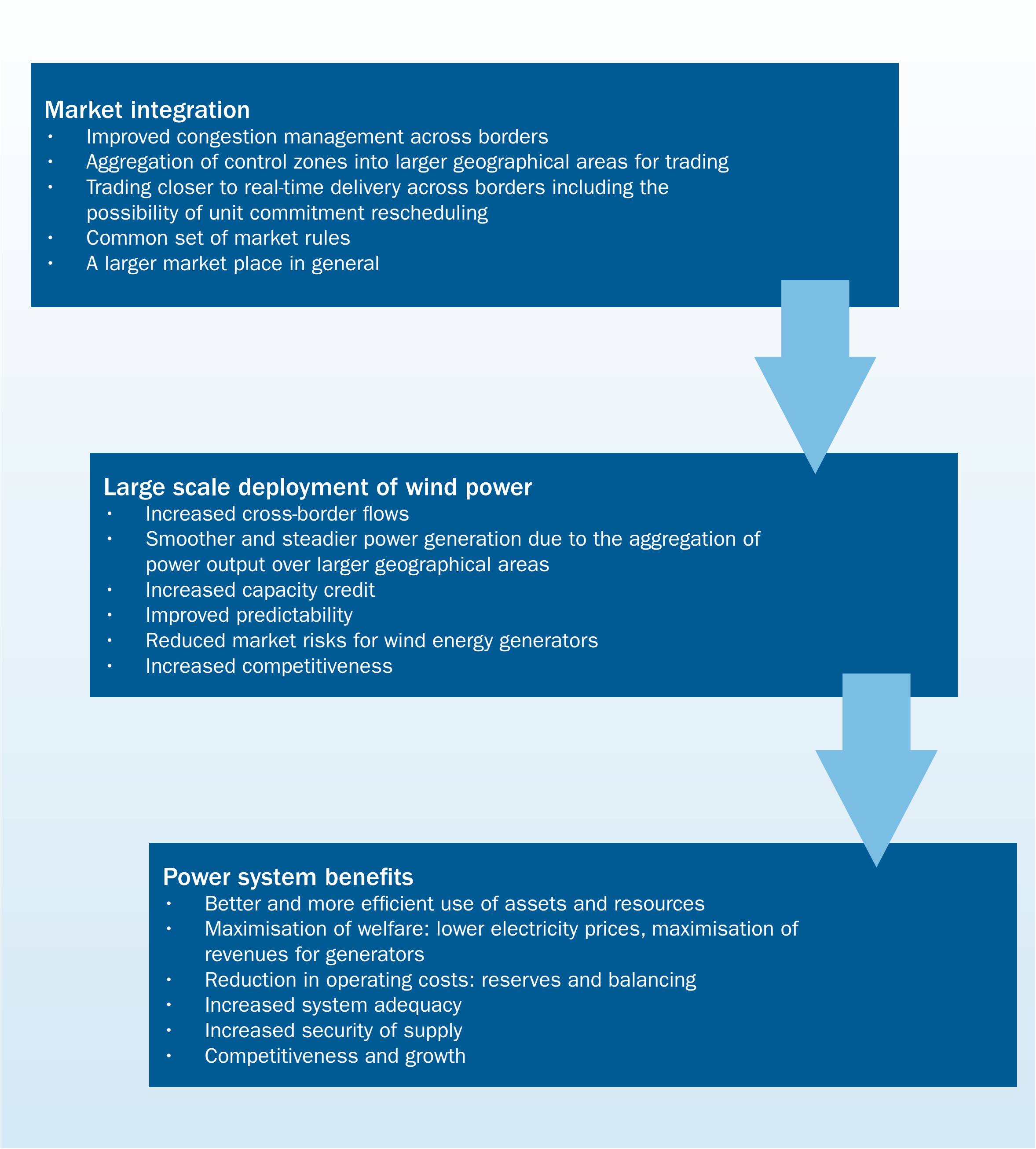
[35] EWEA. Powering Europe: Wind energy and the electricity grid (9)

[36] Van Hulle, F. TradeWind Project (14)

FIGURE 2.7 MARKET INTEGRATION AND WIND POWER DEPLOYMENT BENEFITS



Market integration

- Improved congestion management across borders
- Aggregation of control zones into larger geographical areas for trading
- Trading closer to real-time delivery across borders including the possibility of unit commitment rescheduling
- Common set of market rules
- A larger market place in general

Large scale deployment of wind power

- Increased cross-border flows
- Smoother and steadier power generation due to the aggregation of power output over larger geographical areas
- Increased capacity credit
- Improved predictability
- Reduced market risks for wind energy generators
- Increased competitiveness

Power system benefits

- Better and more efficient use of assets and resources
- Maximisation of welfare: lower electricity prices, maximisation of revenues for generators
- Reduction in operating costs: reserves and balancing
- Increased system adequacy
- Increased security of supply
- Competitiveness and growth

Photo: Vestas

3 POST TARGET MODEL – THE DEVELOPMENT OF A FUTURE FLEXIBLE POWER SYSTEM

Once the IEM is completed and a level playing field is achieved, the true value of wind power for the power system will be fully realised. Flexibility and contribution to system adequacy will be the basis for delivering the far reaching benefits of wind power to the electricity market.

Main findings

1. ***Flexibility as the main feature of tomorrow's power system.*** With the introduction of wind energy and other variable renewables, the market will push out inefficient and polluting high marginal costs producers, slow-ramping and inflexible power plants. This will make a better case for assets that allow investments to be recovered in a more flexible system over fewer running hours.

2. ***Wind energy is able to contribute significantly to system operation and flexibility.*** This includes the capability to provide support services to the grid and contributing to system adequacy. These capabilities have a value in an integrated market; therefore they should be assessed using harmonised methods to forge pan-European market design provisions and rules.

Policy recommendations

Assessing system adequacy properly in a renewable EU integrated power system

- ***TSOs must be encouraged to thoroughly analyse all aspects of firm capacity from wind power and other renewables in an integrated system at EU level.*** Despite the real physical capacity value of wind power and other renewables, they are not yet regularly used for capacity planning to any significant extent. The development of a harmonised method for assessing wind power capacity credit is needed in order to properly evaluate its contribution to system adequacy at European level.

- ***Challenge the need for capacity payments and assess system adequacy from a pan-European perspective.*** As practice shows, capacity markets uptake is complex and might produce further market distortions, free riders and other externalities, while creating disincentives to invest in and apply more cost effective grid infrastructure and demand side management solutions.

Ensuring cost-effectiveness of the future power system: a market-based approach for ancillary services

- ***Grid codes in Europe should first consider market options for ancillary services instead of compulsory requirements to be fulfilled without specific remuneration.*** The compulsory technical requirements for all generators must, therefore, focus on the essential aspects of technical performances, leaving an opening for remunerated grid support services.

- ***Establish grid support services markets to create additional non-discriminatory revenue streams for all generators.*** Commercial provision of grid support services as additional market-based revenue for all generators should be considered in view of lower average and more variable spot market prices on energy-only markets. This will ensure investors' interest in power generation and tackle any potential generation gap in the electricity sector through market-based mechanisms, as opposed to regulatory intervention – for example, in the form of capacity payments.

3.1 Wind energy's contribution to system adequacy

The design of an integrated electricity market with large amounts of wind power needs to go beyond commercial arrangements for cross-border trading. It has to provide incentives for future flexibility whilst ensuring system adequacy.

In an energy-only market, generation adequacy is determined by market dynamics. Under truly liberalised and competitive arrangements, these will create the incentives for investment in new power generation assets – when needed – or will allow demand to curtail consumption at the price of the available adequacy. However, in a situation of inflexible demand, such as currently with European markets, adequacy is determined on the supply side only. More specifically, it is determined by incentives generators are given for investment in new capacity.

Wind power changes these incentives in the market. As wind power reduces spot market price levels via the merit order effect and reduces the number of hours of production from conventional generators (load duration curve), it lowers their load factor or capacity utilisation. This makes costs and investment recovery more challenging.

Nevertheless, this is a feature of market dynamics. Incumbent participants have to compete under different terms when new participants enter the market. Specifically, conventional power plants have to compete in a more flexible manner, with more frequent and faster ramp-ups and fewer running hours if they are to stay in the market.

Moreover, wind power can contribute to system adequacy. It has the potential to replace conventional capacity at a high degree of reliability. The capacity credit of wind power[37] can be up to 40% if high wind energy production is combined with high loads, and it can be as low as 5% in extreme cases with

Myth 3: Capacity payments are necessary to maintain system adequacy

In recent years there has been a renewed interest in generation capacity mechanisms. Several EU countries have set up or are discussing alternative models that remunerate generators for their installed capacity. It is frequently claimed these guarantee system adequacy. But assessment is not always transparent and generally results in protecting market incumbents' revenues.

While it is clear that they provide a certain amount of guaranteed income to certain power producers, capacity payments also lead to undesired externalities and market distortions. This perpetuates the need for regulatory interventions, which is clearly a retrograde step in efforts to create competitive conditions in liberalised markets.

Capacity payments distort price signals to consumers, undermining the development of demand response. They also lead to over-investment in national power generation capacity making generation mix unnecessarily expensive. Furthermore, this can trigger investment distortions in neighbouring countries as they create disincentives for investing in interconnectors and in future storage facilities.

In view of this, some issues should be clarified before establishing capacity payments. Is there a capacity problem in the EU, and if so, how big is it? How much firm capacity from variable renewables and other technologies can we count on, from a pan-European perspective?

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[37] Capacity credit of wind power is defined as the amount of conventional generation capacity that can be displaced by wind capacity while maintaining existing levels of supply security.

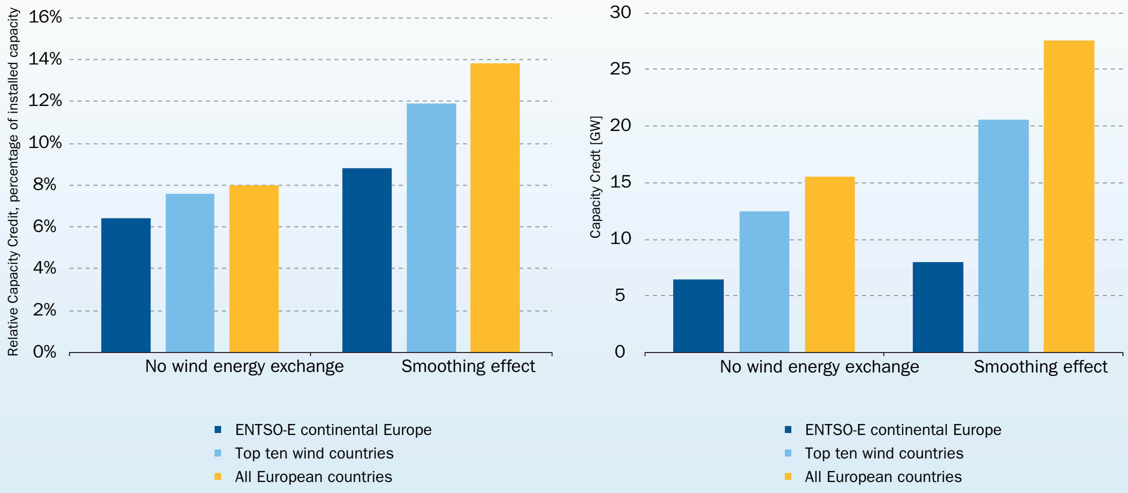
local wind characteristics correlating negatively with demand[38].

At low levels of wind penetration the capacity value is roughly equal to its load factor, which in 2011 was around 24% for onshore and 42% for offshore. At larger amounts of wind energy, its marginal contribution to system adequacy declines. Despite this, research has shown that aggregating wind energy production from multiple countries strongly increases its firm capacity (see Figure 3.1). This, of course, is a principle that applies to all technologies to different degrees.

The TradeWind study found that the effect of aggregating wind energy across multiple countries increases the average capacity credit by a factor of 1.7 compared with the capacity credit averaged over separate countries. Clearly, the completion of the IEM is instrumental for this benefit to be exploited. The wider the control zones are geographically, the higher the resulting capacity credit of wind.

The aggregated capacity credit of the wind farms in a system depends on many factors. Among them, the characteristics of the power system in question (reliability level, flexibility and composition of the

FIGURE 3.1 INCREASE IN CAPACITY CREDIT IN EUROPE DUE TO WIND EXCHANGE BETWEEN COUNTRIES IN 2020



Source: TradeWind project (14)

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[38] IEA Wind Task 25 (3)

total generation mix) 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. 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 individual national borders or 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 PV been considered. Such analysis could help mitigate variability from both, increasing their firm capacity share.

A better understanding of system adequacy in Europe is needed, and this requires further research. The capacity credit of wind power should be taken into account in generation adequacy forecast and planning – particularly in view of the trend towards establishing capacity mechanisms on the grounds that they ensure system adequacy.

From the methods available, determining the loss of load probability (LOLP) of the system for different load levels is the most rigorous methodology available. With this, it is crucial to use wind and load profiles from common weather drivers to calculate wind capacity credit. At least one year of hourly wind generation and load must be obtained from the same calendar year. Even with this data, wind generation profiles can vary from year to year, so multiple years of time synchronised wind and load data are required (minimum 10 years and ideally 30 years)[39].

To ensure investors' interest in power generation assets, the focus should be on alternative market-based revenue streams. This would tackle a potential generation gap in the electricity sector without significantly distorting the market. New markets for ancillary services could provide an additional source of income for all generators, including renewables.

3.2 Grid support services market

Ancillary services are all services required by the system operator to maintain the integrity and stability of the transmission or distribution system as well as the power quality[40]. Ancillary services can be broadly classified as:

- Services for maintaining frequency
- Services for maintaining voltage
- Services for emergency response

Ancillary services have always been part of the electricity industry, but their relevance has only been recognised recently due to unbundling and liberalisation efforts in the energy sector.

Markets for ancillary services remain underdeveloped in Europe. Instead, compulsory requirements without remuneration through grid connection requirements remain the most common form of provision. As generators are not paid directly for fulfilling compulsory requirements, they include these compliance costs in the calculation of their energy prices, which in the end, are paid by consumers.

If all generating facilities could fulfil minimum technical requirements for ancillary services at the same costs, there would be no impact on the consumer. But this is not the case. Generation technologies differ in their cost-effectiveness in delivering electrical energy and in providing ancillary services, due to their inherent capabilities. This leads to differences in costs between the various types of generation.

Consequently, grid connection requirements in Europe should firstly consider market options for ancillary services instead of compulsory non-remunerated requirements. These options are markets for grid support services and ideally they should be utilised as fully as possible because they lead to higher cost-effectiveness and hence to a reduction of electricity costs for users.

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[39] IEA Wind Task 25 (3)

[40] Eurelectric, 2004 (23)

3.2.1 Capabilities of wind power plants

Large amounts of wind energy in the market may change requirements for ancillary services in the power system. System impacts of wind power, at short time horizons (seconds to hours), are related to system stability, which is ensured by the provision of services such as frequency control and voltage management. Impacts can be positive or negative and depend on the specific time horizon and size of the geographical area that is analysed.

The wind energy industry has therefore adapted wind farm design to include capabilities to minimise its impact and to provide grid support services. State-of-the-art wind technology includes riding through voltage dips, supplying reactive power to the system, controlling terminal voltage and even participating in system operation through output and ramp rate control, as well as provision of real-time performance information. All these significantly improve system flexibility at large wind energy penetration levels.

In areas with limited penetration, system stability studies have shown that modern wind plants equipped with power electronic controls and dynamic voltage support capability can improve system performance by damping power swings and supporting post-fault voltage recovery[41].

However, these enhanced features involve significant investments for generators. Compulsory requirements applicable to all generators affect wind and other renewable energy generators in particular. They fail to acknowledge that this type of power generator can provide ancillary services, but in a different way than conventional power plants. Grid support services markets allow wind power, as supply driven technology according to the availability of its energy source, to fully exploit the flexibility it can offer to the power system.

High penetration levels of variable renewables will require a change in strategy for procuring ancillary services. Such a strategy should strike the right balance between technical and economic considerations. It needs to make optimal use of the specific characteristics of different generation technologies, and acknowledge that wind technologies provide grid support services in a different way.

In the medium to long term, technological progress and further market development should enable wider participation of renewable energy and other generators and provide another revenue stream in addition to energy-only markets. Grid support services markets will deliver benefits similar to those provided by capacity markets in a broader and less discriminatory and distortive manner. In a truly liberalised setting, regional trading of grid support services could also be encouraged when technically feasible. One solution is a market for grid support services with prices high enough to influence investment decisions. This would encourage the construction of power plants able to provide certain grid support services, incentivise demand-side solutions and ultimately trigger innovations.

The development of a future power system requires thinking beyond the Target Model for 2014. A post Target Model should provide additional products and markets in which flexibility can be truly procured and valued. Markets for grid support services with a variety of products for real time delivery could be the way forward. These would include services for normal system operation and emergency states, as well as services for system stability, for balancing and even for future system adequacy.

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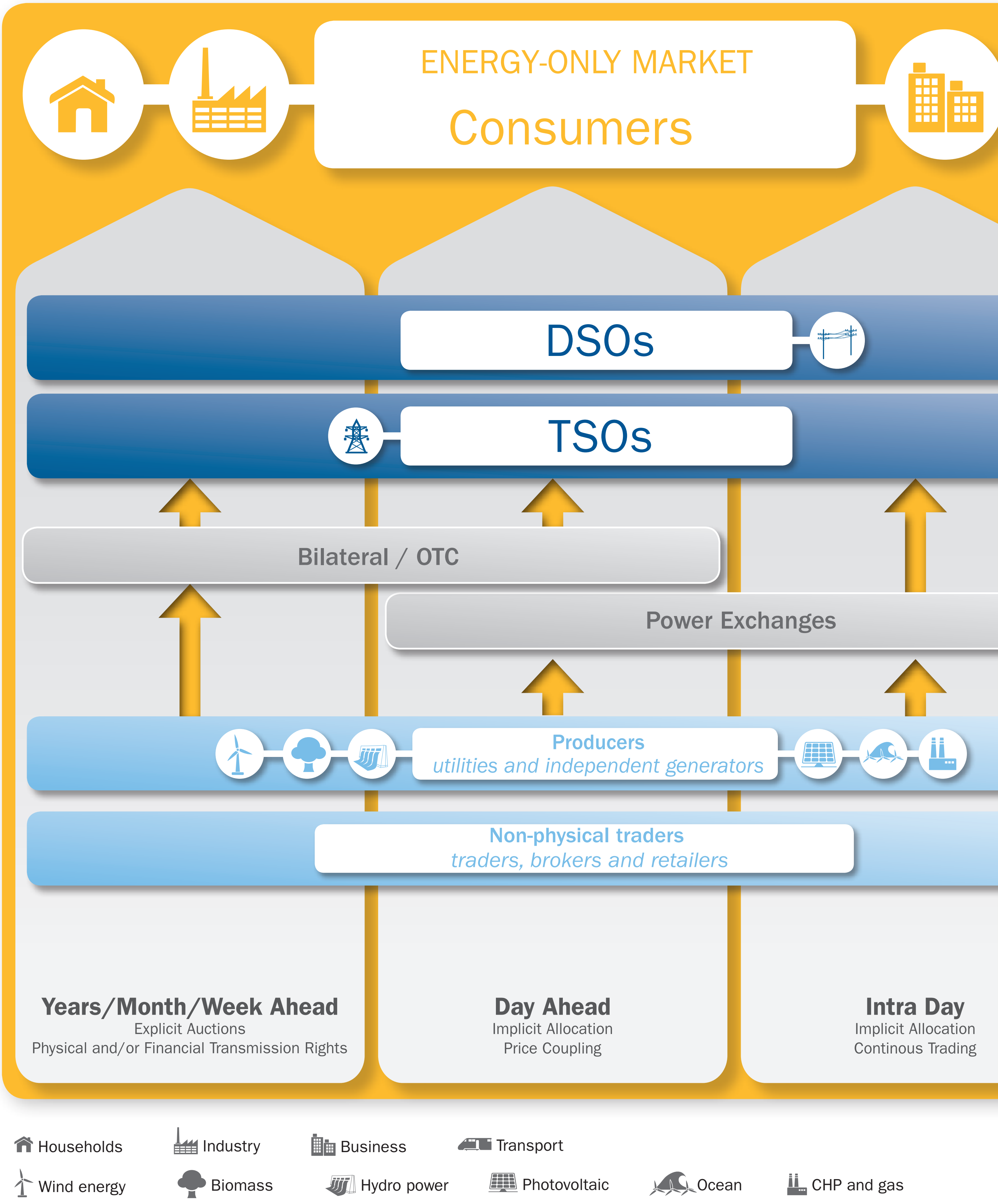
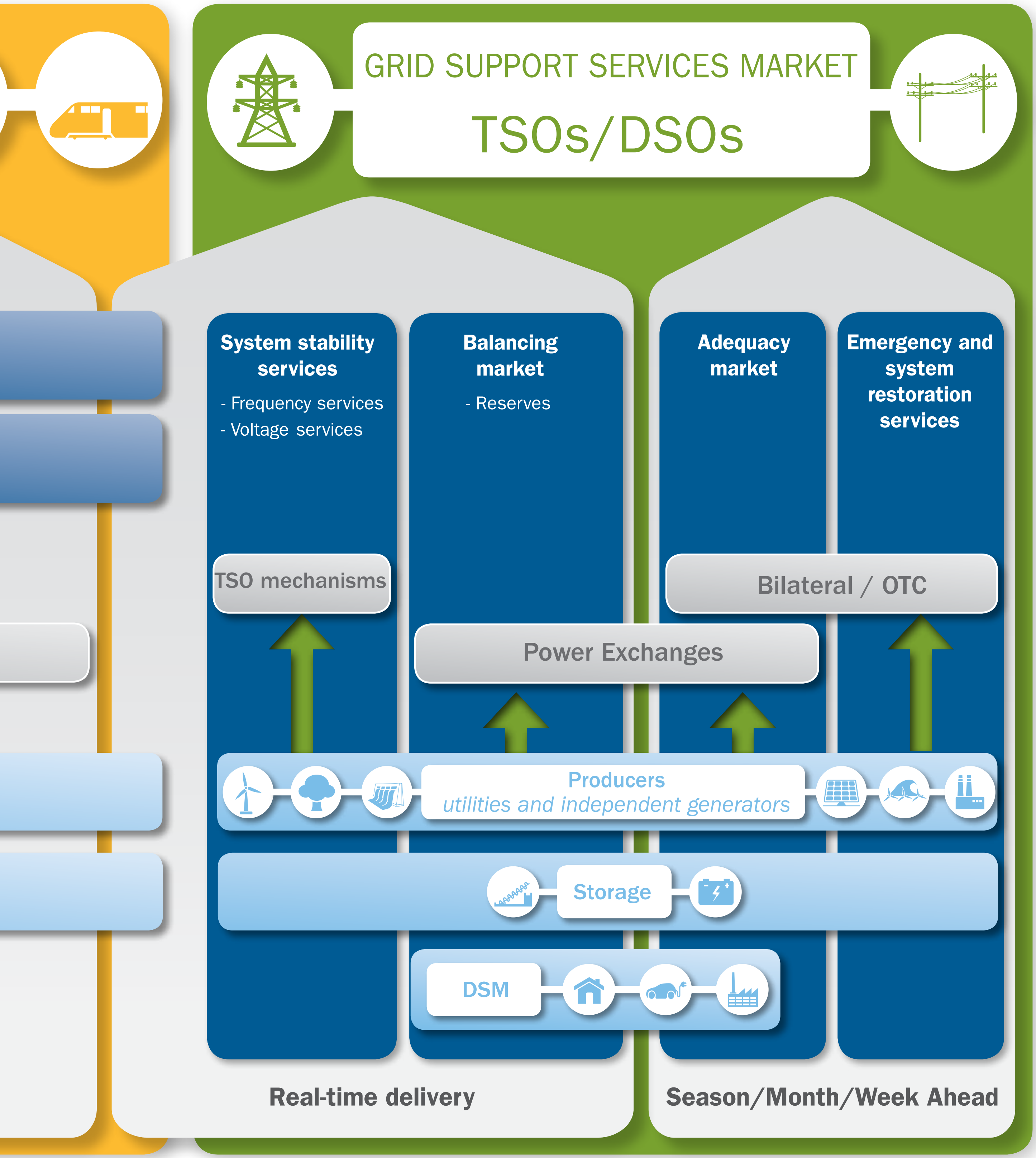
[41] IEA Wind Task 25 (3)


ENERGY-ONLY MARKET
Consumers
DSOs
TSOs
Bilateral / OTC
Power Exchanges
Producers
utilities and independent generators
Non-physical traders
traders, brokers and retailers
Years/Month/Week Ahead
Explicit Auctions
Physical and/or Financial Transmission Rights
Day Ahead
Implicit Allocation
Price Coupling
Intra Day
Implicit Allocation
Continous Trading
Households
Industry
Business
Transport
Wind energy
Biomass
Hydro power
Photovoltaic
Ocean
CHP and gas



GRID SUPPORT SERVICES MARKET

TSOs/DSOs

System stability services

- Frequency services
- Voltage services

Balancing market

- Reserves

Adequacy market

Emergency and system restoration services

TSO mechanisms

Power Exchanges

Bilateral / OTC

Producers

utilities and independent generators

Storage

DSM

Real-time delivery

Season/Month/Week Ahead

OTC: Over The Counter trading

Wind energy
Biomass
Hydro power
Photovoltaic
Ocean
CHP and gas

Hydro pump storage
Batteries

DSM: Demand Side Mangement
Households
Electric car
Industry

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