Danish Energy Agency

ELECTRICITY MARKET DESIGN

Integrating renewables at low cost

August 2020

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Electricity Market Design: Integrating renewables at low cost

Electricity markets are one of the most important tools for system operators, producers and consumers to ensure efficient dispatch of electricity to efficiently achieve security of supply, operational control and planning of production and consumption. When designed appropriately, they can provide meaningful price signals, foster competition and transparency for operation and investments, and are an effective tool to integrate renewables.

Multiple markets with multiple time horizons

The Danish electricity market consists of three short-term markets with different time horizons: the day-ahead market, the intraday market (XBID) and the balancing market (manual Frequency Restoration Reserves (mFRR) for the reserves and Regulating Power Market (RPM) for activation). In Denmark, the day-ahead and intraday markets is part of European electricity market coupling and run by a number of private owned power exchanges, whereas the balancing market is the common responsibility of the Transmission System Operators (TSOs). The Distribution System Operator (DSO) is responsible for the distribution grid and metering electricity demand and is not described at length in this factsheet. Long-term financial risk management is supported by the forward market, which offers monthly, quarterly and annual forward prices. This market is run by a financial exchange (NASDAQ).

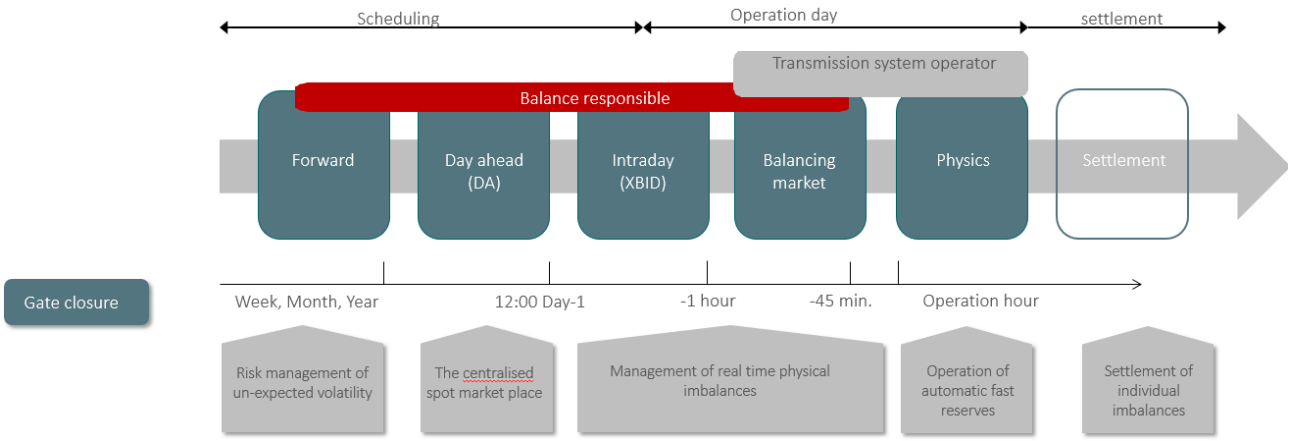


Figure 1: Different markets in the Nordic system operate together, with different time horizons

The electricity spot market, known as the Day Ahead Market, has proven instrumental in integrating a high share of variable renewable energy (VRE) in Denmark. Nordpool is the main day-ahead power exchange (NP-DAM) in Denmark and Operating over Nordic and Baltic countries, NP-DAM had a 382 TWh turnover in 2019 and an average system price in the Nordics of 38.9 EUR/MWh, more than 92% of the total volume of electricity consumed.

In the Nordic power market, the vast majority of the physical power trade takes place day-ahead. However, even though the volume traded at the intraday market accounts only for 3%, this market is rapidly growing: its volume has almost doubled from 8.3 TWh in 2018 to 15.8 TWh in 2019 as a consequence of European market coupling. The intraday market opens after the hourly day-ahead priced are published and closes 1 hour before the operational hour. It is a market with a continuous trade through pay-as-bid, incentivizing generators and consumers to reduce their own imbalances and to utilize flexibility.

The Nordic regulating power market is designed using a combination of daily and monthly capacity (in the mFRR market) and hourly activation payments (in the RPM). A capacity payment received by a supplier imposes an obligation to submit a bid for activation in the hourly regulating power market and have the agreed capacity available. The mFRR market and the RPM have two important features: firstly, they are both cleared by marginal prices; secondly, in the RPM, the voluntary bids are allowed for providers that are not paid in the mFRR reserve market and volume in the RPM are much higher than the minimum reserve capacity and at lower activation prices. The mFRR is dimensioned at "N-1 criterion", but if it is not available, to ensure security of supply, TSOs can choose to by capacity reserves through voluntary bids and/or use interconnectors.

To hedge financial risk for generators and consumers, the forward market can provide an opportunity to hedge against long-term price risk. These are purely financial markets, meaning no power is physically exchanged, but only money. These financial markets are very important in combination with the day-ahead market, for VRE generators to hedge risk and secure a sufficient return on their investment.

Key elements of the market

The day-ahead market is effective at integrating VRE mainly because it is built around the concept of merit order dispatch and marginal pricing, where generators bid their short-run marginal cost, and are dispatched in order from the least to most expensive, until the demand is met. With merit order dispatch, the day-ahead market is designed to minimize the cost of energy. This leads to a maximization of social welfare, which is the sum of consumer surplus and producer surplus. The market-clearing price is the price of the most expensive dispatched generator, and is the price that all dispatched generators receive. Ideally, if there is no congestion in the system, the system price is the same as the market-clearing price. On the other hand, in case of a congestion, different prices in areas on either side of the congestion will occur.

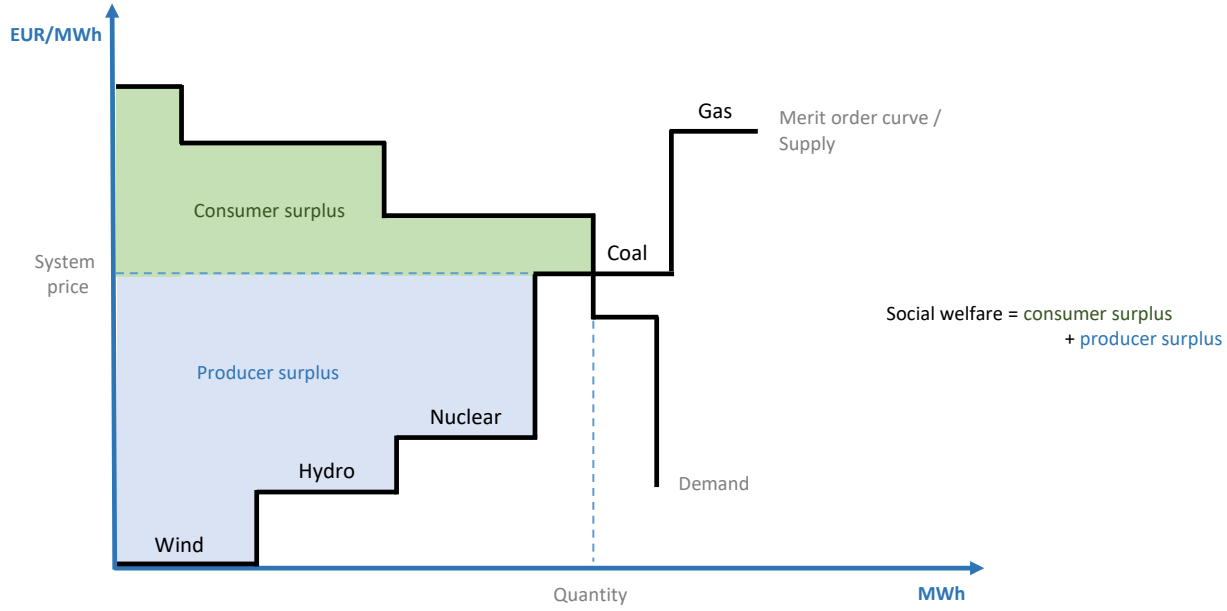


Figure 2: An illustrative representation of market clearing with simplified bids. The merit order curve determines which generators are dispatched and is a fundamental mechanism behind the day ahead market. Social welfare is defined as the sum of consumer surplus and producer surplus, as shown in the figure.

The market is open to participation from any technology (renewable or not), ensuring sufficient competition to keep prices down. Since VRE generators typically have marginal costs of effectively zero, it also ensures that these VRE generators are dispatched at a higher priority than generators with higher marginal costs.

A key feature of the day-ahead market is price discovery, where the market clearing process results in a market clearing price. Transparency and high liquidity is essential to ensure an efficient price formation. The benefit of this price signal is that it reflects the time-dependent value of electricity for the consumer, and offers incentives for both consumers and generators to act flexibly and to bid their marginal costs. Electricity market prices are designed with either a zonal (for example as in Europe) or nodal (for example as in ERCOT in Texas or CAISO in California) pricing approach, as described below:

Zonal pricing approach	Nodal pricing approach
The electricity price is the same in the whole bidding zone	Reflects the locational marginal prices at a given transmission node
Bidding zones are generally designed to physically reflect the grid infrastructure and/or geographical boundaries and to ensure that there are no congestions within a bidding zone	It implicitly includes the impact of grid losses and transmission congestion and can increase dispatch efficiency and help isolate some price spikes in the market
Countries can be divided into several bidding zones (e.g. Denmark or Sweden) or they can have only one bidding zone that corresponds to national borders (e.g. Germany).	Calculation is more complex and requires more computational power
Increased space granularity in electricity markets can lower dispatch costs and drive investments where the prices are highest	It can also decrease the liquidity and the competition in the market

An element of the electricity market that will become increasingly important in the future is the participation of flexible consumers such as electric boilers, heat pumps and electric vehicles. In Denmark, already now, several technologies in the district heating sector, such as turbine bypass, heat pumps and electric boilers, are coupled to the power sector, and can thus provide flexibility in case of very high or very low electricity prices.

European market coupling

In Europe, electricity markets are getting more integrated – they are continuously being harmonized according to common European standards. The market coupling between different power exchanges allows bids to cross borders, as long as there is capacity available on the interconnectors. It implies that the lowest cost of energy production required to satisfy the demand is guaranteed across borders. Therefore, the connection of markets leads to an overall positive socioeconomic impact.

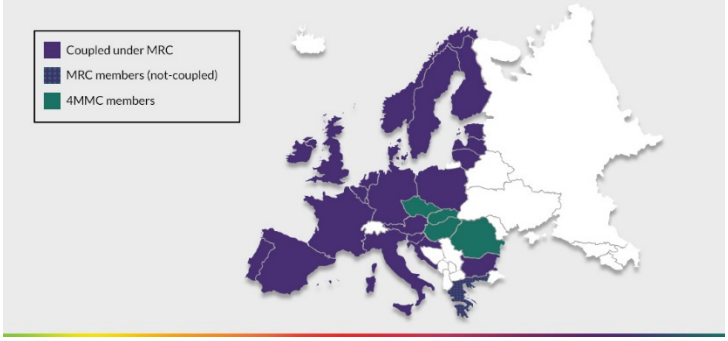


Figure 3: Single day-ahead coupling. 21 countries in Europe are fully coupled under the Multi Regional Coupling (MRC). In November 2014, four 4MMC countries, Czech Republic, Hungary, Romania and Slovakia, went live using the Price Coupling of Regions solution. By the end of 2020, the MRC coupling shall be extended to Greece. Source: http://www.nemo-committee.eu/sdac

The aim of Single Day-ahead Coupling (SDAC) and Single Intraday Coupling (SIDC) is to create a single pan-European cross zonal day-ahead and single cross zonal intraday electricity market. This will improve the overall efficiency of trading by increasing competition and liquidity and enabling a better use of generation across Europe. The security of supply in Denmark is the best in Europe (followed by Switzerland and Luxembourg in terms of minutes of annual outage, 2010-2016) and one of the reasons is the large interconnector capacity and, in continuation, the ability to trade across borders, enabling a geographically larger balancing area. This brings benefits from both the different mix of production technologies and consumption profiles. A European market coupling of the balancing markets is also being implemented from 2022.

Maintaining balance in the power system

A balance responsible party (BRP) is a market participant or its chosen representative responsible for its imbalances. In Denmark, the BRP must enter into an agreement on balance responsibility with the Danish TSO.

The BRP is responsible for the deviations between reported trading schedules and actual consumption/production, as well as the costs related to the purchase of balancing power which the Danish TSO must make in order to uphold the balance. The competition between BRPs should lead to improved forecasting systems and better balancing strategies, which in turn should reduce balancing costs.

In the operational hour a proactive approach to reserves is used in the Nordic countries compared to a reactive approach. In a proactive reserves approach, the TSO foresees the imbalances and is responsible for procuring and activating necessary reserves before the imbalance appears. Meanwhile, in a reactive reserves approach, each market participant is able to balance its positions close to the operational hour. Because of the proactive balancing in the Nordics and well functioning balancing markets, the importance of the intraday market is lower comparing to the reactive balancing approach.

The capacity adequacy can be maintained using strategic reserves or capacity markets. Payment to strategic reserves is focused on a small amount of capacity while in the capacity market every provider of capacity receives remuneration. In Denmark, the capacity markets and strategic reserve procurement has never been needed.

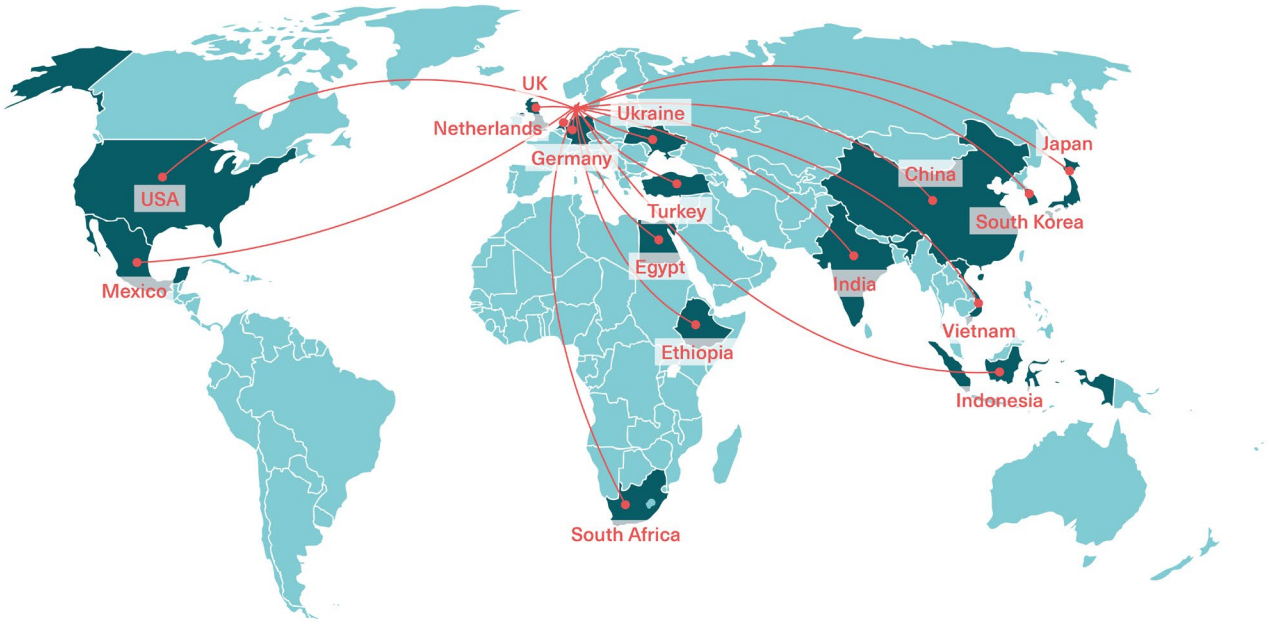
Transparency

Europe has a high level of market transparency enforced through the European legislation and independent regulatory authorities. Transparency increases trust and reduces risks for market participants. At the same time, transparency is linked to market surveillance and reduces the opportunity for market participants to engage in non-competitive behavior. The Regulation on wholesale Energy Market Integrity and Transparency (REMIT), which defines a framework for identifying and penalizing such actions, was introduced in 2011. According to REMIT, all market participants have to disclose market information related to production, consumption and transmission outages along with other market information through urgent market messages (UMMs), ensuring all actors have access to equal information.

In Denmark, the Danish Utility Regulator (DUR) must ensure strong and efficient supervision of the electricity market. DUR is a member of the EU wide Agency for the Cooperation of Energy Regulators (ACER). On the European level, the ENTSO-E transparency platform provides data from most of Europe in compliance with the European transparency regulation. However, some information about specific bids is considered confidential and cannot be made public, as such information might be beneficial to competitors and can lead to distortions in the competition.

Global Cooperation

The Danish experience has returned valuable lessons learned in designing efficient electricity markets, and this experience is shared with partner countries through the Centre for Global Cooperation. The Centre for Global Cooperation has 16 bilateral partnerships around the world, as shown in the map below. A non-comprehensive list of collaborations within electricity markets includes China, India, Mexico, Vietnam, South Africa, Ukraine and Egypt.



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