HydroBalance Policy Brief 3/2016

Evolving European electricity markets, and possibilities for flexible hydropower

This policy brief describes the integration process for electricity markets in the EU. New regulation (partly adopted, partly in process) exist for various electricity market types. Studies within the HydroBalance project have shown that both electric energy and ancillary services are important when considering the utilization Norwegian hydropower for balancing of variability of European wind- and solar-power generation.

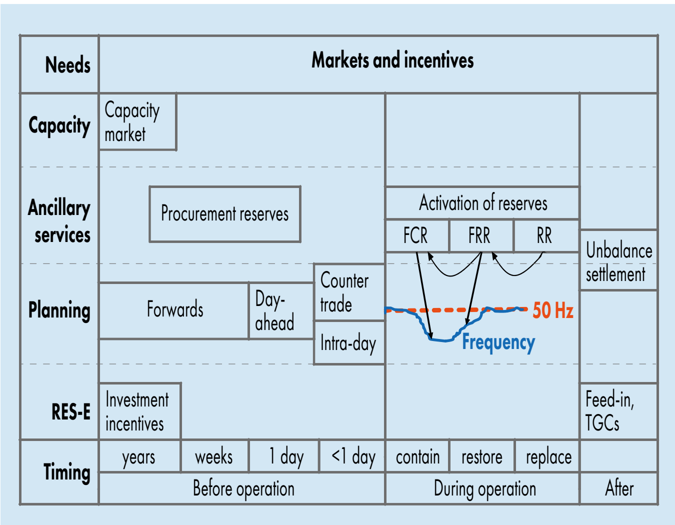
In the following we start by giving a brief introduction to why we need the different electricity product types. Thereafter we shortly introduce the corresponding EU-processes in the evolution of new regulation, and we discuss specific regulation. Finally we discuss possibilities of utilizing hydropower for new value-creation, and which factors that are important for the realization of this.

Needs, products and markets for electricity

In a modern society we are totally dependent on the availability to electricity in our everyday lives. Its price is far below the welfare it provides, thus the consumer surplus is enormous. The most important task for the institutional arrangements of any electricity system is therefore to provide a stable supply to the consumers. This is probably the reason why the deregulation of Europe's power markets started as late as the 1990s, with the forerunners in the Nordic area and GB. This aspect is still important when considering the evolution of market structures for electricity in Europe:

"..., the most important objective in developing integrated Balancing Markets is to keep the lights on while facilitating market integration."[1]

Figure 1. *Electricity market types.*



Other special characteristics of the electricity commodity is that it is transported from producers to consumers in an electrical grid at the speed of light. The in-feed and outtake from the grid must be balanced at all times. If not, the electrical frequency will deviate from tolerance of various electrical equipment, and supply can be disrupted and component damaged. Because of this, it is sometimes important to differentiate between the balance of demand/supply vs. consumption/production. Whereas the former describes a market equilibrium, the latter describes the physical balance in the grid. We take it if for granted nowadays, but it was an important institutional achievement to connect them, i.e. applying market instruments to enhance cost-efficiency - and still having a system to ensure the physical balance at all times. **Figure 1** gives a non-exhaustive overview of different electricity market types and incentives; facilitating needs both for planning and for securing the physical balance. **Figure 2** is an illustration of the timeframes for some of the markets, i.e. the time lag between the gate closure time and the corresponding real-time operation hour for traded products.

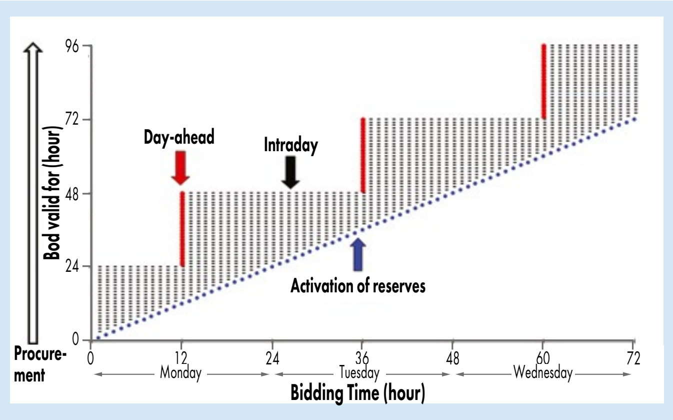


***Figure 2**. Sequence for bids and operation.*

Central markets for electricity:

- **Day-ahead**
- **Intraday**
- **Reserves (procurement and activation)**

Day-ahead market

The day-ahead markets are typically the main markets for electric energy, which are mostly organized by PXs. The gate closure, for instance for Nord Pool Spot, is 12:00 (midday). Thereafter the PXs calculate the price that balances demand and supply each hour the following day – account taking also for limitations in the transmission grid between countries and areas, which can lead to differences in prices. In many countries (e.g. Germany) there are only one domestic day-ahead price even though the capacity of the transmission grid sometimes cannot facilitate the outcome of the single day-ahead market. Then, TSOs typically carry out bilateral counter-trade (also called re-dispatch) after the day-ahead timeframe to improve the geographical distribution of planned generation.

By 2016, day-ahead markets in 19 countries constituting 85% of the total European market are connected by the price coupling algorithm EUPHEMIA. This algorithm was developed through the so-called PCR initiative of seven PXs, and builds further on existing market structures. Whereas the development of EU regulation can be seen as a top-down approach, the PCR initiative is one of several bottom-up approaches / stakeholder initiatives that are crucial for the practical implementation of new regulation.

Intraday market

Both producers (such as Statkraft) and consumers (or rather their corresponding power supplier such as Norgesenergi) may want to change their position taken day-ahead e.g. because new weather forecasts affects expected production from renewables or consumption. This is dealt with in **the intraday market**, such as Nord Pool's Elbas trading platform. Typically, this is continuous trading based on pay-as-bid where PXs matches bids that are feasible given the remaining capacity on interconnectors. Intraday trading stop e.g. 1 hour before real time operations. Notice that nothing is actually produced day-ahead nor in the intraday timeframes. Those markets are set up for planning purposes, notably to ensure that the planned generation matches expected demand cost-efficiently.

The liquidity of many intraday markets have traditionally been low, even with the increasing shares of renewable generation in Europe. One reason for this is the use of so-called feed-in tariffs and priority dispatch for renewable generation, which reduces RES-E producers' incentive for having balanced positions, as they are guaranteed market access and a predefined price. However, under the new EU regulation that has been adopted[2], all producers shall be balancing responsible parties (conditional on the existence of well-functioning intraday markets), and this can possibly be a game changer for the importance of intraday markets.

For the intraday timeframe, a new PX initiative (XBID Market Project), where Nord Pool participates, are developing a common IT solution for trading throughout Europe, again linking the local trading systems already operated by PXs. It is expected to go live during 2017.

Reserve markets

Reserves are **procured** by TSOs such as Statnett, and corresponding capacity (MW) is **activated** only if the TSO needs it during the real time operations. The providers of reserves are typically remunerated by the TSO both for procurement and activation – if any. There are several products defined – among other things based on how fast the capacity can be activated – and many national dialects regarding the set of products applied has evolved.[3] Following recent EU terminology, Frequency Containment Reserves (FCR) are used for containing the deviation in frequency following any disturbance (cf. **Figure 1**), Frequency Restoration Reserves (FRR) restores the frequency and replaces applied FCRs so they are ready to deal with further disturbances, whereas Replacement Reserves (RR) replaces FRR. Some of those products are automatically provided e.g. on basis of the frequency in the system, whereas others are activated manually. The term ancillary services includes additional services for the upkeep of power system stability.

EU regulation

Developement of EU regulation

At the European Electricity Regulatory Forum (Florence Forum) in 2008, it was decided to establish an expert group of stakeholders to develop an EU-wide Target Model (TM) as a tool for harmonization and increased cross-border competition. A roadmap for electricity market integration including forward, day-ahead, intraday, and balancing markets where developed. Through the 3rd Liberalisation Package, which came into force in 2011, the Agency for the Cooperation of Energy Regulators (ACER) and the European Network of Transmission System Operators (ENTSO-E) where established. They were given legal mandates for the development of regulation, through so-called network codes (NC) and guidelines – which typically have EEA relevance. With this, the integration process changed from being voluntary and intergovernmental to becoming legally binding for all member states.

Network codes

The formal process for the development of a new network code is started when the European Commission ask ACER to develop so-called framework guidelines for new legislation on a topic[4]. ACER then ask ENTSO-E to draft network codes on basis the framework guidelines, in a process involving national experts and different stakeholder such as producers in EURELECTRIC and exchanges in EUROPEX. A first draft for the network code is submitted to ACER, which then states their opinion, and specifies need for further developments. On this basis, ENTSO-E prepares a revised draft, whereas ACER state their opinion on it. Finally, a comitology procedure involving member states and the European Commission is carried out, and regulation is finally adopted after the approval of the Council of the European Union and the European Parliament.

Central network codes for markets

Capacity Allocation & Congestion Management (CACM) is a guideline for the set-up of common and connected European markets in the day-ahead and intraday timeframes. It describes how different regional markets and price zones shall be coupled and coordinated. It also prescribes how TSOs shall contribute to establish a common European grid model, which shall be used to calculate so-called flow-based constraints for electricity trade. The flow-based constraints more accurately describe the real constraints in the transmission grid compared to applying the traditional net transfer capacity (NTC) for individual interconnectors. As a consequence, a higher utilization of the transmission grid can be planned e.g. in the day-ahead timeframe.

Electricity Balancing (EB) possibly adopted at the end of 2016 or beginning of 2017 deals with TSO cooperation, ancillary services, and corresponding markets including procurement and activation of reserves (FCR, FRR, and RR). EB only deals with aspects of cross-border trade, and it mostly describes the further processes to develop and implement a future cooperation between TSOs. This will be a process which to a large degree will be based on consensus between involved TSOs. A step-by-step approach is described, starting with careful integration at a regional level.

Capacity markets

Capacity remuneration mechanisms including capacity markets provides a premium for MW flexibility rather than MWh generated. Higher shares of varying renewable generation combined with low investment in firm capacity have led to concerns about the security of supply in many European countries. Several countries have already implemented capacity markets, and some countries are in the process of implementing them. The European Commission is in general in favor of energy only market. However, they give guidance for when capacity markets still can be accepted.

Value creation by hydropower through balancing of renewables

With its flexibility, reservoir hydropower can bid into all kinds of markets for electric energy (day-ahead, intraday) and contribute with ancillary services. This is illustrated by **Figure 3**, whereas **Figure 4** is one possible mind-map for which factors that are important for the profitability and operation of Norwegian hydropower.

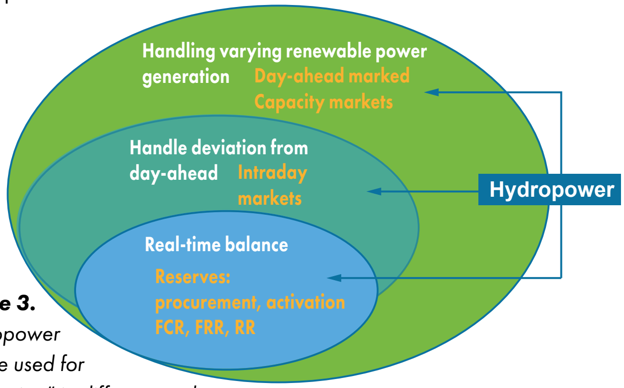


Figure 3. *Hydropower can be used for "balancing" in different markets.*

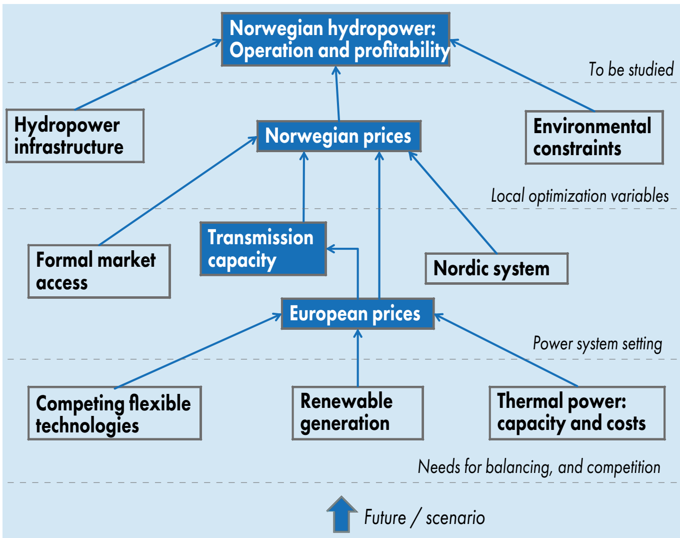


Figure 4. *A mind-map for determinants of operation and profitability for hydropower.*

It is mostly the Norwegian prices that are important for hydropower located in Norway, especially since NC EB favours TSO-TSO cooperation for balancing services. Norwegian prices will be affected by formal access to European markets, but this impact is limited by the available capacity on transmission cables – which again could be affected by European prices through investment decisions for cables. The degree to which Norwegian hydropower producers are able to respond to prices is affected by their production system (e.g. installed capacity), and possible environmental constraints on the operation. Moreover, European prices in the different timeframes are impacted by the share of generation that comes from varying renewable generation, other flexible options installed in the system (storages, demand response, gas turbines etc.), and in general the capacity and costs of thermal power generation (including fuel costs and CO_2 permit prices).

Within the Hydrobalance project we have studied the profitability and cost-effectiveness of utilizing Norwegian hydropower for proving balancing services to Europe from different perspectives. The competitiveness (measured as levelized costs of peaking capacity) of investing in extra hydropower capacity plus needed investments in transmission grids, compared to other flexibility options for Europe, have been published[5] and presented in a previous policy brief. University of Achen carried out a system simulation for a future European power system in line with Hydrobalance scenarios, and made a cost/benefit assessment of additional Norwegian hydropower capacity and corresponding capacity in transmission cables.[6] **Both studies concluded that it is cost-effective for Europe to invest in extra hydropower capacity in Norway, including corresponding transmission cables.**

With more liquid intraday markets and increased cross-border trade on ancillary service products, **it will be more important to take into account incomes in the markets subsequent to the day-ahead timeframe when considering upgrading hydropower capacity.** In the project we have studied the profitability seen from the perspective of Norwegian investors in extra capacity, notably a pumped storage project in Otravassdraget in Southern Norway. That study concluded that the project was not profitable at historical prices, but it is profitable at future prices in Hydrobalance scenario as calculated by University of Achen if the producer participate in the market for balancing energy (e.g. RR) in addition to the day-ahead market. To carry out this study, we developed one of our traditionally one-market optimization models for a single watercourse – PRODRISK – to become a multi-market model. In the new model, the producer supplies to the day-ahead market as-if it was the only market. However, for each hour the producer respond to new prices in the different timeframes by adjusting its position. Thus, the new model is a simulator for possible income and operation in a multi-market setting, rather than a multi-market optimization model.[7] An iterative algorithm does however search for the best strategy with respect to the share of capacity set as reserve.

Based on our understanding, at least the following elements will be central to fully utilize the flexibility of Norwegian hydropower in value creation by providing balancing services in all timeframes for Europe in the future:

- Norwegian government, regulator and TSO must be involved in the development of network codes, e.g. to promote solutions and products facilitating overall cost-effectiveness for Europe.
- The transmission capacity towards Europe needs to be sufficiently large, i.e. somehow based on cost/benefit assessments, and institutional arrangements or procedures should be in place to realize profitable projects.
- The domestic transmission grid and other electricity system elements must be adopted to facilitate higher balancing volumes and faster changes. The cost of this must be included in cost/benefits assessments.
- Regulation of hydropower generation should probably deal more explicitly with the supply of balancing services, e.g. how to deal with possibly environmental impacts thereof, and one should work actively to get public acceptance locally, cf. policy brief of WP5. If large amounts of balancing power shall be provided from Norway in the future, there is a need for more research on all these aspects.

Facts about the HydroBalance project
The project addresses key questions regarding the increasing need for balancing variable generation from renewable energy sources and providing flexibility by the use of Norwegian hydropower including deployment of pumped storage. These key questions are investigated in the research tasks of five work packages. The interdisciplinary project integrates perspectives on the topic according to CEDREN's vision: technology, nature and society:
WP 1 - Roadmap for energy balancing from Norwegian hydropower
WP 2 - Demand for energy balancing and storage
WP 3 - Modelling and analyses to develop business models
WP 4 - Environmental impacts of new operational regimes in reservoirs
WP 5 - Social acceptance and regulatory framework

Project period: October 2013 to September 2017

Total budget: 25 million NOK
Financing: About 70 percent from the Research Council of Norway, and about 30 percent from industry and research partners from Norway and abroad.

References

1 ENTSO-E (2014), "Supporting document for the network code on electricity balancing", 6th August 2014.

2 European Commission (2014), "Communication from the Commission - Guidelines on State aid for environmental protection and energy 2014-2020", 2014/C 200/01.

3 See e.g. Rebours et al., IEEE Transactions on Power Systems, 22(1), February 2007. For information about Norwegian reserve markets, i.e. primary, secondary and tertiary reserves (RKOM for procurement, and RKM for activation) see e.g. http://www.statnett.no/Kraftsystemet/Markedsinformasjon/.

4 https://ec.europa.eu/energy/en/topics/wholesale-market/electricity-network-codes

5 Korpås et al. (2015), "Norwegian pumped hydro for providing peaking power in a low-carbon European power market - Cost comparison against OCGT and CCGT", EEM 2015. IEEE Press.

6 Maaz et al. (2016), "Value of Additional Norwegian Hydropower to the European Electricity System", EEM 2016. IEEE Press.

7 Wolfgang et al. (2015), "Scheduling when reservoirs are batteries for wind- and solar-power", Energy Procedia, Vol 87, pp. 173 – 180.

CEDREN
SINTEF Energy Research
Postal address: P. O. Box 4761 Sluppen, NO-7465 Trondheim
Office address: Sem Sælands vei 11, NO-7034 Trondheim
Telephone: +47 73 59 72 00
www.cedren.no

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Contact CEDREN/HydroBalance
Atle Harby, Centre Manager atle.harby@sintef.no
Michael Belsnes, HydroBalance Project Leader michael.belsnes@sintef.no
Ove Wolfgang, Modelling and analyses to develop business models Ove.Wolfgang@sintef.no
Website: http://www.cedren.no/Projects/HydroBalance