HydroCen
NORWEGIAN RESEARCH CENTRE
FOR HYDROPOWER TECHNOLOGY

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

HydroCen Report nr.1

T 3.1 Future Market Structures and Prices

Workshop summary

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HydroCen

The main objective of HydroCen (Norwegian Research Centre for Hydropower Technology) is to enable the Norwegian hydropower sector to meet complex challenges and exploit new opportunities through innovative technological solutions.

The research areas include:

- Hydropower structures
- Turbine and generators
- Market and services
- Environmental design

The Norwegian University of Science and Technology (NTNU) is the host institution and is the main research partner together with SINTEF Energy Research and the Norwegian Institute for Nature Research (NINA).

HydroCen has about 50 national and international partners from industry, R&D institutes and universities.

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The FME-centers can be established for a maximum period of eight years HydroCen was established in 2016.

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Abstract

Schäffer, LE, 2017. T 3.1 Future Market Structures and Prices. HydroCen Report 1 – Norwegian Research Centre for Hydropower Technology.

This report summarises the results of the HydroCen workshop in work package 3 Market and services with focus on the drivers of future market structures and prices. The results presented in this report are processed recapitulations from the group work discussions based on the notes of the group work leaders. The group work discussions revealed uncertainty among the participants regarding several aspects, such as:

- external conditions
  e.g. formal market access and requirements to participate in different markets. What impact will the regulatory changes in the EU have on Norwegian stakeholders?
- transmission cables
  e.g. how will international cables be regulated? Which products can be traded? Will there be limitations on ramping?
- products
  e.g. will energy continue to be the dominating product or will system services become a substantial source of income?
- competition
  e.g. what role will batteries and demand response play? How will the costs of synthetic system services develop?
- technology development
  e.g. how much can efficiency of flexible operation be improved? What new opportunities and competition can power electronics provide?

Even though it is difficult to predict the outcome of many of these factors we can point to some main findings which there seemed to be a general agreement on:

- A surplus of energy is expected from 2020 towards 2030 as a result of investments in new renewable generation capacity. Higher share of unregulated power production is expected to in-crease price volatility.
- Flexibility is an important strength of hydropower. The need for flexibility services in the European energy system is increasing. Currently hydropower appears to be the superior technological and cost-efficient solution to the flexibility challenge.
- Demand response will play an important role, but it is uncertain in what scale.
- The risk of investing in hydropower is high (both for new investments and reinvestments). The uncertainty regarding concessions and the revision of these are unfortunately contributing to increased risk of investments.
- Hydropower supply services for free which could have been compensated or traded in markets (e.g. flood control and inertia).
- Hydropower production should take advantage of the technology developments within automatization, smart systems, improved sensor technology and power electronics.
- The work towards an integrated power market in the EU is important for Norwegian stakeholders. More information is needed.

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Content

1 Introduction

This report summarises the results of the HydroCen workshop held the 12th-13th of June at Statkraft HQ in Oslo. The workshop was a part of work package 3 "Market and services" and is a delivery in task 3.1 "Future market structures and prices". The workshop was organised in collaboration with the KPN-project PRIBAS.

The purpose of the workshop was to improve the participants understanding of the value of Norwegian hydropower, the expected changes in value and the main drivers for change. This include, but is not limited to, the development of prices, services and market structures. The workshop consisted of one day with prepared presentations and one day with group work. Different scenarios for the development of the power market and important market drivers were presented and compared. The workshop contributed to useful discussions and networking between different stakeholders in the Nordic power system and the research community.

The first day consisted of presentations ranging from an overall level, discussing general trends, to model specific and more technical presentations. The presenters represented producers, system operators, energy market consultants, researchers and professors. The second day was divided into two sessions with group work, where relevant challenges were discussed based on two main topics. The role of Nordic hydropower in the European energy system was the first topic, discussed with focus on market assumptions, products and technology development. The second topic was regulatory changes and challenges, including discussions on subjects such as the integration of energy markets in the EU, challenges and opportunities with international cables and the ongoing revision of concessions of Norwegian hydropower production. The participants were divided into four groups in each session. After two sessions with group work all the participants had discussed both topics, either from a short-term perspective (now and five years ahead) or long-term perspective (20-30 years from now).

The results presented in this report are processed recapitulations from the group work discussions based on the notes of the group work leaders and does not therefore necessarily reflect the views of the authors. The topics presented are those which seemed to engage the most during the workshop. A selection of relevant reports is shortly summarised in chapter 2 before the results are presented. The results are given in chapter 3 following a similar structure as the discussion topics, where one section includes discussions from the "Role of Nordic hydropower"-topic and one section comprise discussions from the "Regula-tory changes and challenges"-topic. Finally, chapter 4 concludes the report with some remarks on what we take with us from the workshop and suggestions for further work.

2 Relevant reports

This section gives a short summary of a selection of relevant reports. The reports provide a broad selection of predictions and possible scenarios for the future. The SMUP report (Statnett, 2017) gives an evaluation of the future from a system operators point of view and describes Statnett's plans for development of the power grid the next years. Furthermore, Statnett's long-term market analysis (Bøhnsdalen et al., 2016) provide their predictions for the development of Nordic and European power prices towards 2040. The energy technology perspectives (IEA, 2017) investigate required changes in the energy system and technology developments to reach the two-degree target. Finally, the HydroBalance Roadmap (Charmasson et al., 2017) present the most important results from the HydroBalance research project; a coherent study of Norwegian hydropower as a flexibility provider to Europe. Furthermore, the roadmap includes recommendations on political actions needed to realise such a scenario.

2.1 Systemdrifts- og markedsutviklingsplan (SMUP)

Statnett's system operation and market development plan (Statnett, 2017) describes Statnett's best predictions and plans for the period 2017-2021. Important trends and developments that affect operation of the power system, plans for further developments of market design and needed tools for system operation are described. The report gives an overview of Statnett's mandate as the system operator of the Norwegian power system, and the assumptions and pre-requisites for a secure and efficient operation of the power system. Since Norway has a single-buyer solution for balancing services and system services, Statnett sets the premises for these markets. The report is finalised with a presentation of how to ensure secure and efficient operation: measures planned over the next years, identified development areas and concrete action plans. These measures are also necessary to increase the value creation from Norwegian power production. The need for cooperation and communication across borders and between different stakeholders is emphasised in the report.

Some of the major trends highlighted in the report are Europe's transition to a low-carbon system, improved international collaboration, the changing role of the demand side in the system and the changing production mix in the European system. To achieve the transition to a low-carbon system, high shares of renewable generation is implemented in the system, giving a less flexible system with increased need for balancing services and periods with excess generation. To improve system flexibility the EU is working towards more integration. A more integrated system makes balancing between regions possible, but also introduces increased operational challenges in many areas. Over time, increased integration is supposed to improve the system, making it more economic efficient and stable. Higher integration requires more centralised regulation, moving jurisdictions from the national TSOs to higher levels in the EU. Norwegian regulation depends on European regulation, as stated in the EEA-agreement (European Economic Area). Large efforts are put down by the national TSOs and inside the EU to succeed with a common, internal energy market and further ahead also a common balancing market. Uncertainty is tied to what role demand-side flexibility will play in the future power system, but a flexible demand-side is expected to play an important role for power system operation. Demand response has the potential to become a substantial source of flexibility, and the active consumer is expected to take part in the future balancing solution. Further, to manage and coordinate the response of demand and distributed power generation, the distribution system operator's (DSO) role is expected to change considerable. A picture is drawn of the DSOs as much more active in the future, with more responsibility for operation and investments within their regions.

In the Nordic region, both the production mix and power demand are changing over the coming years. Power demand will increase with electrification of industry, transportation and heating in the Nordic region. Still, there is an expected oversupply of 10 TWh in the Nordic region between 2020 and 2030. The largest changes in the Nordic production mix are caused by Sweden phasing out nuclear power and large investments in intermittent renewable production capacity. In addition, up to 50 % more transmission capacity out of the Nordic region is affecting the production mix. Hydropower will have limited capability to reallocate production in periods with low load and much available variable renewable energy (VRE) because the power mix largely will consist of non-controllable, non-flexible power production. Hence, both up and down regulation will be challenging. Still, increased transmission capacity will give larger potential for value creation from trade and is expected to have an overall positive economic effect.

The report points to several expected changes in the future power markets which can become potential business opportunities for hydropower producers. Statnett expect finer time resolution in the power markets and a need for securement of more reserves closer to the operational day. Furthermore, new solutions to ensure stability are required, and there will be stricter control of response time and available capacity. Automatization, increased reporting and improved communication are important factors.

2.2 Statnett's long term market analysis: Nordic region and Europe 2016-2040

Statnett's long-term market analysis (Bøhnsdalen et al., 2016) discusses the long-term development in Europe towards 2040 with special focus on the Nordic region. Main trends, uncertainties and expectations for the power market development are described. Furthermore, estimates of power prices are provided within an uncertainty range given by defined scenarios. The transition towards a low-carbon power system with large shares of renewable power generation in Europe is the main driver for change in the performed analyses. Important trends in the Nordic region are increasing demand, phase out of nuclear power generation and more unregulated power generation. Statnett expect the main part of existing grid development plans in Europe to be carried through, as higher share of unregulated power production will increase the power exchange between countries and regions. However, lasting internal bottlenecks in Germany are an important area of uncertainty.

The power price in the continental part of Europe is expected to increase up to 45-50 EUR/MWh towards 2025-2030 and then stabilise towards 2040. Increasing share of renewable and unregulated power production result in higher short-term price volatility after 2020. These tendencies affect the Nordic prices, but the price increase is expected to be lower because of oversupply and low prices in the summer. The short-term price volatility is expected to increase towards 2030-2040 in the Nordic region. Several factors affect the long-term development of the power price, such as fuel prices, CO2-prices, share of renewable generation capacity, capacity margins, technology development and demand response. In the base scenario, a moderate increase in gas- and CO2-prices towards 2025-2030, tighter capacity margins because of less thermal power production, increased demand as a result of electrification and considerable larger amounts of wind and PV power production are assumed. Uncertainty in these factors create a broad spectre of possible scenarios. To take this into consideration two scenarios are developed in addition to the base scenario: one for low power price (expectation of 30 EUR/MWh) and one for high power price (expectation of 60 EUR/MWh in Europe and 55 EUR/MWh in the Nordic region). The two scenarios are based on the same main assumption of a transition towards a low-carbon power system in Europe. The main difference is that the high-price scenario is based on a market driven development, where high and volatile prices give strong investment incentives. In the low-price scenario, the market price is not a sufficient driver for this change and other regulative measures such as subsidies are necessary to achieve the wanted emission reductions.

The three presented scenarios low power price, base and high power price, can be used as a base in future studies, as the change in price level, volatility and yearly trend are described thoroughly in the report. Furthermore, the underlying assumptions are presented and quantifications are provided. E.g. expected development of the coal, gas and oil prices, the share of renewable power generation, production mix and the CO2-price towards 2040 are given for all the scenarios. In addition, Statnett provide quantitative expectations of storage and demand response resources available for balancing. A potential of 160-215 GW down-regulation of demand and 225 -280 GW potential up-regulation of demand are assumed in the report.

2.3 Energy Technology Perspectives 2017

IEA's Energy Technology Perspectives 2017 (IEA, 2017) presents three possible pathways for transition of the power system towards 2060, comparing the pathway of existing measures and announced targets (RTS) with the pathway for the 2-degree scenario (2DS) and the pathway for moving beyond the 2-degree scenario (B2DS). The report points to the massive turnaround needed to meet these targets, transitioning from a power sector with increasing CO2-emissions towards a power sector with net-zero CO2-emissions in 2060 (2DS) or net-negative CO2-emissions by 2060 (B2DS). Bioenergy with CCS (BECCS) is an important part of the solution to achieve net-negative emissions (B2DS). Furthermore, end-use electrification, large-scale deployment of VRE and early retirement of coal-fired power plants are necessary. CCS retrofits allow the continued operation of some coal capacity. To ensure system stability, storage solutions, an active demand side and system services from gas plants and nuclear are needed. The report emphasises several required developments, such as further development of CCS and BECCS technology, innovations within battery technology and new business models to activate demand response. This requires reinforced policies to support further spur of low-carbon technologies into the electricity markets, development of transmission capacity, supportive and predictable regulatory conditions, a strong carbon price and sufficient price signals to lay the foundation for business models and trigger investment.

2.4 Roadmap for large-scale balancing from Norwegian hydropower

The roadmap (Charmasson et al., 2017) presents the most important findings in the HydroBalance research project and recommended actions towards 2050. The project investigates the role of Norway as a large-scale flexibility provider to Europe based on four scenarios towards 2050: "Small storage", "Big storage", "Niche storage" and "Nordic storage". The scenarios have different degree of integration (transmission capacity), expected volume of balancing and different types of balancing (different time-horizons). The need for balancing in Europe has been analysed closely, revealing that Norway has sufficient stored energy in the reservoirs to meet the balancing need, but insufficient production capacity to cover the peaks. The project has looked at different business models with trade in both day-ahead, intraday and balancing markets. The results show that access to balancing markets in Europe is important to maximise the benefits of hydropower and especially pumped storage. Furthermore, the ongoing work on integration of European power markets towards one common day-ahead market, one intraday market and harmonization of ancillary services are mentioned in the report. In addition, the project has developed a methodology for analysing environmental impacts of a scenario on specific reservoirs and considered aspects such as social acceptance in local communities.

The study assumes profitability of Norwegian hydropower to be dependent on the prices for flexibility in Europe and to what degree these prices penetrate to the Norwegian system. In addition, the profitability will depend on how prepared Norwegian hydropower producers are to utilise this opportunity. This comprise the investment level in extra capacity, investments in pumped storage and environmental constraints limiting operation. The main drivers of the flexibility prices are the share of renewable power generation, competing technologies in providing flexibility services (e.g. batteries) and existing flexible units (e.g. thermal generators). To what degree the European prices penetrate to the Norwegian system depends on the availability of transmission capacity, utilisation of interconnectors in different timeframes and formal access to European markets. To evaluate the profitability of hydropower, a new version of ProdRisk (Gjelsvik et al., 2010) which is able to analyse hydropower's supply to and income from several markets, including day-ahead, intraday and reserves, has been developed in the project. Simulated day-ahead prices considering procurement of reserves for several European countries were used. In addition, German prices for the intraday market, the market for activation of reserves and the market for procurement of reserves were used. The prices used in the analyses were provided by IAEW at the university of Achen and ECN (Energy research centre of the Netherlands). The Norwegian prices in the study were set equal the German prices because of the high transmission capacity assumed. Compared to historical Norwegian prices the simulated prices had a higher price level caused by higher gas- and CO2-prices and higher price variability. The study showed increased value by participating in several markets and of inter-market optimisation of the available reserves. Still, the result also shows that the day-ahead market and the average price level are the most important factors for the income from hydropower production. The benefit from investment in extra flexibility (pumped storage) depends on the price difference between low and high prices.

Overall, the project shows promising value potential for trade of large scale balancing services to Europe. The project also shows that pumped storage in Norway can be profitably used for long-term balancing between days, weeks, seasons and years. In other words, the results indicate that development of the Norwegian power system to become a large-scale flexibility provider is a profitable business model for the future. Still, it is important to keep in mind that the project has been a feasibility study of large-scale balancing supplied from Norwegian hydropower, an assumption that implies large or unlimited access to European markets and considerable investments in transmission and production facilities.

3 Workshop results

This section describes the main results from the workshop. The results are presented in the two following sections, "The role of Nordic hydropower in the European energy system" and "Regulatory changes and challenges". The most engaging topics from the two group work sessions have been selected and are discussed below.

3.1 The role of Nordic hydropower in the European energy system

It is important for Norwegian stakeholders to gain a strong position in the quickly changing power industry with new markets, regulations and competitors. Oversupply of energy results in low energy prices, hence a demand for new solutions and business models arises. Hydropower deliver energy when required – shifting load between weeks and seasons, and providing short-term flexibility and system services such as inertia. Still, profitable business models must be developed for hydropower producers to receive the market value of these products and services. This require grid codes and market regulation to be developed with the aim to ensure well-functioning markets and prices that reflect the real value of the products. Currently the variability and lack of predictability in potential new markets are barriers to new investments. Hydropower investments are evaluated over a long time-horizon; hence predictability on a regulatory level can contribute to reduce risk. In addition, reputation and stronger relations to active consumers are important to maintain a strong position in a dynamic market.

3.1.1 Marked structure and assumptions

It is the predominate expectation that the power price will stay low over a long period, as a result of excess power generation capacity, high shares of variable renewable energy (VRE) with low marginal costs and generally low global energy prices. It is not necessarily energy itself that gives value in the future, but the capability to provide energy at the right time and place. In the long term, a small increase in price is expected, caused by increasing global energy prices, CO2-prices and demand. Further, the power price is expected to become more volatile with increasing share of VRE in the European system. Higher price resolution in the power markets can help capture the price fluctuations better. Close to real time markets can reduce bidding uncertainty as better forecast are available. It is possible that increasing consumer flexibility combined with a higher level of integration, new markets for system services and increased transmission and storage capacity can have a flattening effect on the price in the long term. The use of capacity markets creates investment incentives, but reduce the price spikes and hence the value of hydropower.

Both total electricity demand and the demand variation are important factors for the development of power prices and need for reserves. Electrification is necessary to cut emissions and will in the long term result in increased electricity demand. On the other hand, the consumer-side of the power system is transforming from a static, non-flexible player to a flexible and active stakeholder in the power system. More distributed production, short-term storage and off-grid solutions are changing the traditional demand curve. Large-scale development of zero-emission buildings, distributed production and smart meters are expected to both reduce the total supply required from the grid and peak demand. Still, the overall impact on the demand-supply balance in form of the total amount of load that can be shifted is uncertain. Investments in distributed production are growing, even though they are not the most cost-efficient solutions. These developments are irrational from a socioeconomic point of view and it is difficult to predict the size of future investments. If distributed solutions and demand response are deployed large scale, there can be a shift in power from the producers to the consumers and from the TSO to the DSO. With more decentralised and local production and regulating power, a natural consequence is that the DSOs take over a larger part of the responsibility of power system operation and balancing. Furthermore, it is possible that new models will appear, e.g. solutions where the consumers are not connected to the central grid, but choose to be responsible for securing own reserves through storage solutions or agreements with local providers. However, there is not excessive belief in rapid development of such models, as they depend on rapid transition to a smart grid.

Consumers are becoming less dependent on the electricity grid because of more distributed solutions. It is possible to imagine a future where some neighbourhoods rarely use the central grid. At the same time, the grid cost will constitute a larger share of the overall cost of using energy, as large investments in the grid still are necessary. The grid costs are payed by the consumers per kWh energy received from the grid. If a smaller part of the consumers require energy from the grid, the grid-cost will increase per unit. This can lead to a vicious circle where those who can are driven away from using the grid. In other words, the more consumers that become independent of the grid or only use the grid rarely, the costlier it becomes for everyone else to maintain the grid. Some consumers, such as industry consumers, depend on a well-functioning grid and might be non-flexible in their consumption. Furthermore, the power producers depend on the grid to sell their products. For many of the actors in the power system, it is therefore crucial with a business model that supports maintenance and development of a strong, national grid and divides the associated cost. One alternative is a solution where consumers pay per unit power required (MW). This solution is one option considered by NVE (Andresen and Mook, 2015) 1. Applying different tariffs for different users of the grid can be necessary in such a solution. For example, power producers should not be charged per unit power (MW) because this could have unwanted effects on investments meant to increase the production flexibility.

Investments in hydropower production facilities are necessary to increase the value of Norwegian hydro power. Currently the uncertainty in potential new markets are barriers to new investments. Regulation could help reduce risk of investments. However, changing and unclear regulation are causing unpredictability regarding physical and formal market access in the future. This unpredictability becomes an obstacle to creation of new market opportunities. Furthermore, high risk is also associated with reinvestments in and maintenance of existing hydropower facilities. Hydropower producers are now considering to remove reservoirs, as the maintenance costs of dams are becoming higher than the added value. This has never been done before and create new challenges. As profit margins decline because of low energy prices, revision of current tax and tariff agreements could help to facilitate required reinvestments in hydropower facilities.

3.1.2 Products and services

The major part of hydropower producers' income has traditionally come from sales of energy, while reserve capacity and balancing services have contributed to a minor part. Increasing share of unpredictable and non-controllable power production result in increasing need for flexibility and system services. Furthermore, the system operators need improved tools to maintain stability and predictability. The system's need for new products and services can contribute to increased overall value for hydropower producers. Hydropower has the capability to deliver flexibility on short term as well as adjust to weekly, seasonal and yearly variations. However, there are pressing uncertainties concerning market access and available opportunities in the future Nordic and European power markets. For new business opportunities to open, well-functioning markets combined with physical and formal market access are necessary. Consequently, both satisfying grid capacity and well-functioning regulation are required. Furthermore, the power system must be able to handle quick changes in flow if the value potential in the markets is to be fully utilised. These requirements and obstacles have caused market players to question if short-term flexibility markets can become an important income source for Nordic hydropower after all. In addition, Nordic hydropower can only cover parts of the flexibility needed in Europe, meaning that complimentary solutions are necessary. Competition will therefore be strong, raising the question if hydropower will be the most cost-efficient solution in the long term. Still, hydropower currently appears to be the superior technological and

[1] https://www.energinorge.no/fagomrader/stromnett/nyheter/2017/effekttariffer-pa-horing-etter-sommer-ferien/ [Last accessed 21.11.17], https://www.tu.no/artikler/nve-vil-gjore-det-dyrere-a-bruke-mye-strom-pa-en-gang/410203 [Last accessed 21.11.17]

cost-efficient solution to the flexibility challenge. Hydropower already supply flexibility to the Nordic region (and partly to Europe) to adjust for weekly, seasonal and yearly variations.

Hydropower producers deliver several bi-products for free, such as system inertia and flood control. Inertia, which is critical for frequency control, is a system service hydropower naturally supply. Inertia is traditionally delivered by most power producing technologies and has historically been more than sufficient in the system. However, with increasing amounts of non-synchronous production there will probably be a shortage of inertia in the future European power system. This would create need for new ways to supply inertia, e.g. through a separate market. Natural producers of inertia such as hydropower would benefit from this, and investments in hydropower facilities can be done to increase supply of inertia when required. Flood control is another service hydropower naturally provide. Without regulated water systems, costs related to flood would have been much higher. Hydropower producers are not economically compensated for this service, but flood control is an important socioeconomic benefit from hydropower production.

Distributed power production (such as rooftop-PV) and more dynamic consumers (e.g. through smart meters) are changing the energy market and create interesting opportunities. Hydropower producers should try to take advantage of these new trends. One possibility could be to become a more general power and service provider by entering completely new markets and technologies. Hydropower producers have experience and knowledge of the system, hydrology and markets. This knowledge can be utilised to create business models combining technologies and experience in one package. Hydropower as a "package provider" holds an interesting potential and could bring hydropower producers closer to the consumers. Engaging in active consumers (e.g. through smart home apps) and emphasizing that hydropower is renewable can become important to improve the reputation of hydropower. Hydropower as a "package provider" is a quite new idea which require further development.

3.1.3 Technology developments

Automatization and smart systems are quickly improving technologies that are expected to increase efficiency in system operation and planning over the next years. Two areas where this can be especially useful are 1) to optimise operation and bidding through improved control of available capacity and 2) in smart failure search and handling. The introduction of new markets and products makes it more complex to achieve optimal bidding while honouring restrictions on production. At the same time production planners are facing stricter control requirements from the system operator to ensure that capacity is available according to bids. More automatization may be a part of the solution to this problem, continuously providing information about available capacity and bidding options given what is already placed and the current state of the system. Eventually, a large part of the operator tasks could be automatized. Furthermore, improved sensor technologies and smart systems can contribute to quicker identification of failures, recognition of critical system states and optimisation of maintenance scheduling. This is expected to reduce down-time and minimise loss from failure, maintenance and upgrades. In addition, improved information about operational parameters such as online estimation of turbine efficiency can be used actively in future operation.

Upgrades and technology improvements can help increase efficiency and flexibility of the hydro system. On the production side, new turbines with broader best point of operation and adaptions to more flexible operation should be developed. Further, turbines which can run on air, almost without use of water, or systems simulating this behaviour can be useful to provide system services such as inertia. A possible approach is to use generators that are connected to the grid through a frequency converter and work asynchronous to the grid frequency which allow operation at variable rotational speed. Combined with new developments in power electronics, such a solution can provide different products based on what is needed. Solutions that makes operation at variable operational speed possible is one of the main topics of work package 2 in HydroCen. It is expected that different types of synthetic system services can be supplied by use of power electronics in the future. While hydropower production is a mature business, power electronics is a quickly developing technology field which can provide new opportunities for hydropower producers also. On the other side, these types of technology developments can also provide new solutions that compete with the products hydropower can offer. Either way knowledge of the possibilities power electronics provide is useful, as it both can provide opportunities and be a potential threat.

More knowledge of how the income potential, maintenance costs and expected lifetime of components are affected by more flexible production and delivery of system services are necessary to evaluate the profitability of these types of investments. The effects of changed operation on maintenance cost and lifetime is one of the topics that will be further investigated in another task of this HydroCen workpackage (Task 3.2). In addition, changes in market design and operation of the system are needed to make better utilisation of the flexible production capacity possible. E.g. today, restrictions on cables that are meant to ensure stability of the overall system limit quick switching.

To better understand the potential value of new markets and products, as well as how this would change operation and impact the system, improved and new operational models are needed. Furthermore, better short-term weather predictions and inflow measurements are necessary to improve operational planning and bidding. Better forecasts would make overall balancing of the system easier.

Finally, sediment handling and secure tunnel constructions are important issues. Especially, investments in countries with different climate and geological conditions may lead to increased sediment handling issues. There is a large value potential in solving these issues.

3.2 Regulatory changes and challenges

Power markets are heavily regulated on all levels, from environmental constraints in a river to what type of products that can be sold on the national market and across borders. Regulation must be adapted and developed for new products, markets and business models to be implemented. The EU is currently implementing large changes in regulation and legislation that also will affect Norwegian stakeholders. Many of the actors in the Norwegian power system communicate uncertainties about the opportunities and challenges these changes will bring and how this will affect the Norwegian system.

3.2.1 Formal integration

Regulatory considerations and decisions are crucial for the development of and access to new markets. The regulatory development in the EU will set the stage for trade of power and power system services in Europe. The EU works towards an integrated European market for energy, and in the long term an integrated market for balancing services and possibly other system services. The new grid codes will describe the framework of the integrated European power market, hence what opportunities Norwegian power producers have in this market, what products they can sell and the products and services needed. There is disagreement on how well EU will succeed, but either way Norwegian stakeholders must accept and work with the regulatory changes the integration introduces. The changes can create opportunities in new markets and increase value in existing markets, e.g. reserve capacity is sold at a higher price in many European countries. There is a concern among Norwegian hydropower producers that Norwegian interests will not be considered in the development of new European grid codes, as Norway is a small country with a weak position in the EU.

Statnett represents Norwegian interests in the negotiations with the EU. Other stakeholders communicate lack of information and understanding for the impact of the new grid codes. Information, communication and collaboration between all stakeholders in the Norwegian power system will be crucial to ensure a strong position in the European energy system for Norwegian actors. This imply a responsibility to stay informed by reading up on available documentation. In addition, new arenas to share and discuss available information can be useful. The power producers request more direct information from Statnett concerning the new grid codes, and both information meetings and documentation of the consequences of the new grid codes would be appreciated.

A likely consequence of increased integration is that the regulatory mandate and operational responsibility – or parts of this – will be moved from the national TSOs and upwards in the system. It is unclear at this stage how the TSO's roles will change, but it is expected that responsibilities and authority must be moved upwards to a cooperation-organ between the TSOs, if an integrated European balancing market is to work. A well-functioning power system with the capability of early adaption has been an advantage for Norwegian stakeholders, but with regulatory power moving upwards in the system this first-mover advantage might be lost. Hence, integrated operation within the EU can become a disadvantage for Norwegian stakeholders. In the long run, it is reasonable to assume that the cheapest technological solution will have the competitive advantage also in cross-border markets.

3.2.2 Physical Integration

In addition to the regulatory framework, market access is restricted by physical limitations. Cables must be developed to make access to new markets possible, but construction and operation of cables are limited by the physical operation of the system. There are divided perceptions about whether extensive cable development is a good strategic decision for Norway or not. The Norwegian power price is expected to increase as a result of more transmission capacity to Europe. This is welcomed by the power producers, but not by energy intensive industry which receive much attention in the media. The power producers claim the media shows a biased picture, promising industry death to affect the government and ignoring the benefits of the cables. Furthermore, the recent authorization of merchant cables opens new opportunities for private investors to apply for cable concessions independent of the TSO. There are mixed feelings on allowing private investors to invest in transmission cables and several bureaucratic barriers still exists. One such barrier is that it is unclear to what degree the owner can decide which products to trade on the cable. Grid tariffs and how to divide the income from operating the cable between the owners, is another challenge international cables introduce. Considering investments in cables, it was commented in the group work that socioeconomic considerations in a Norwegian and a European perspective give different outcomes when analysing investments in transmission capacity. Currently most investments in transmission capacity are evaluated from a national perspective. However, with higher degree of market integration and closer international collaboration there might be increasing pressure on also conducting socioeconomic evaluations based on larger parts of the European system.

There are many unanswered questions regarding regulation and operation of transmission cables. Increased transmission capacity to Europe can provide both security of supply (i.e. less vulnerable to dry-years) and regulatory challenges such as increased need for system services. To fully take advantage of the cables, the option to trade other products than energy (i.e. system services) and faster ramping rates are necessary. At this time, it is uncertain to what degree the international cables will be open for trade of system services and which foreign markets the producers will be given formal access to. Furthermore, limitation on ramping is currently a necessity when the transmission capacity is increased because of the overall balancing challenge of the system. In the long run, limitations on ramping should be avoided to achieve maximum value.

3.2.3 Norwegian Perspective

As a result of a missing national strategy with clear action points Norwegian hydropower is losing out on valuable possibilities in Europe. Regulation should help reduce risk of investments in the Norwegian power system, not contribute to increased uncertainty. An example is the lack of action to meet the demand in Europe for balancing services. Instead other solutions are being developed in Europe to handle the challenges, and the idea of Norway as a green battery is slowly drifting away. To shift Norway to a flexibility provider, a clear national strategy and regulation that prioritise measures on all levels are necessary. This requires more focus on hydropower on a political level and a political commitment such as the engagement seen in Norwegian gas.

The lack of a comprehensive strategy becomes obvious in the revision of concessions for hydropower operation. Increased need for flexibility can be met with changed operation that can result in higher occurrences of start/stops and more ramping. Such operation must be in line with the given concessions, which among other factors are based on environmental considerations. Revisions of old concessions can allow for more operational flexibility, but can also limit the production flexibility. In the group work, producers reported the last to often be the case. In addition to allow flexible operation, regulation at other levels are important to ensure legal and physical availability to flexibility markets in Europe. Furthermore, it is important that producers utilise the given concessions and make the value of the existing operational flexibility visible to reflect the need for future flexibility in concessions. Existing flexibility is not always utilized if there are local disagreements. To avoid conflicts several companies have applied self-imposed restrictions on production when this has been possible without decreasing the value potential from production. This can change if the value of flexibility increase, giving a dilemma between maximizing profit and satisfying local expectations.

4 What can we learn from this?

4.1 Final remarks

The goal of the workshop was to increase the knowledge of drivers for the future value of Norwegian hydropower. There were several intense discussions during the group work and important questions were asked, such as how will the need of flexibility and system services develop? What role will demand response and distributed local production play? Will the EU succeed to integrate the national power markets to one common market? How will merchant cables be developed and regulated? And what will be the impact of the ongoing revision of concessions?

The discussions were dominated by a sense of uncertainty about the future. Lack of predictability is tied to aspects such as national and international regulation, technology development and development of markets and products. Creation of new markets can be necessary to provide the right investment incentives, and new business models will be important to ensure value of operation. It is uncertain which products that will be the most valuable and if there will be markets for other products than today. Provision of system services can be as valuable as energy in the future, as there is likely to be an oversupply of energy in periods. It seems to be the dominating opinion that the flexibility to supply energy and system services at the right time and place holds the key to continued value creation for hydropower. Furthermore, there is a general agreement that hydropower can solve parts of the flexibility challenge in Europe. Still, the role Nordic hydropower will play is uncertain. The results of the HydroBalance research project show very promising value potential for Norway as a large-scale flexibility provider. However, if Norway is to become a large-scale supplier of flexibility to Europe large investments in transmission and production capacity are required. To achieve this, a coherent Norwegian strategy with political commitment is necessary.

Furthermore, export of flexibility services is not the only possible option for increased value creation. To fully utilise the value potential of hydropower it is necessary to develop business models and enter markets where hydropower is valued for its qualities. One such model is trade of flexibility to Europe, while other alternatives are to specialise towards other markets and products such as inertia and other system services or to better utilise the energy internally in the Nordic region. To exploit the excess supply of energy towards 2020 and stabilise the power price, more energy intensive industry could be developed. An example of such an opportunity is to have the establishment of data centres in Norway. Political incentives are also needed to facilitate development of new industry.

Finally, it is even possible to continue on a "same as usual"-track, and only do absolute necessary maintenance on operational hydropower facilities. However, this path is not expected to increase the value creation from hydropower. There is a choice between if Norway should have a passive or offensive attitude towards the changing power system in Europe and what position we want to secure. Investments in new and existing facilities can increase the value potential of Norwegian hydropower. Still, high levels of risk are making it difficult to obtain profitable results on investment analyses and a green light for investment decisions. Hence, uncertainties regarding physical and formal market access, as well as variability in prices, puts a hold to ambitious investments. This points to a critical need for better information about external conditions and national measures to reduce risk. If the ambition is to increase the value creation from hydropower, our impression is that an offensive attitude is needed. This implies taking more risk and should therefore be backed up by national initiatives.

4.2 Further work

Further work on this area in HydroCen will be to follow the general development and to prioritise and concretise some scenarios for future price developments. These scenarios will include prices for simultaneous markets for capacity, energy and short-term balancing. Different possible developments for future markets should be considered because of the high level of uncertainty associated with the underlying drivers.

Identified areas where there is interest for further research are:

- Price developments in simultaneous markets for capacity, energy and short-term balancing with different degree of formal market integration in Europe (formal market access) and different degree of physical market access to Europe (international cables)
- A future market for and value of inertia
- The role demand response can play as a flexibility provider in the system
- Knowledge of the European integrated energy and balancing markets and requirements for participation
- Nordic market for ramping products; requires reduced ramping restrictions on cables

There is a wide selection of previous work to build on. Several scenario studies for future development of the European energy system over the next decades have been conducted, such as IEA's Energy Technology Perspectives 2017. More concrete Statnett's long-term plan provide three coherent scenarios for the development of the Nordic and European day-ahead price towards 2040. Quantification of the underlying assumptions are also provided in the report. HydroBalance provides simulated day-ahead prices for Europe, and intraday and balancing prices (up- and down regulation) in Germany for a scenario where Norway is a large-scale flexibility provider to Europe. In other areas, there are less available research to build on. There are to our knowledge not many studies looking at value of inertia and market models for provision of system inertia. Thiesen et al. (2016) touch on this topic and discuss the cost of supplying synthetic inertia through a separate market. Here a cost of 167.64 EUR/(kg*m2*year) for provision of synthetic inertia using a flywheel based storage system is calculated.

Furthermore, there is planned a close collaboration with the KPN-project PRIBAS. In this project, a multi-market model with simultaneous clearing will be developed. This work will be very useful for HydroCen WP3, but results from this project are not expected in a couple of years.

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