Flex4RES

Flexible Nordic Energy Systems

Framework Conditions for Flexibility in the Electricity Sector

in the Nordic and Baltic Countries

December 2016

DTU NMBU KTH RTU TUT Aalto University Stockholm School of Economics NIFU

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Flex4RES project summary

The Flex4RES project investigates how an intensified interaction between coupled energy markets, supported by coherent regulatory frameworks, can facilitate the integration of high shares of variable renewable energy (VRE), in turn ensuring stable, sustainable and cost-efficient Nordic energy systems.

Through a holistic system approach based on coupled energy markets, we identify potentials, costs and benefits of achieving flexibility in the Nordic electricity market created by the heat, gas and transport sectors as well as by electricity transmission and generation. Flex4RES develops and applies a multidisciplinary research strategy that combines technical analysis of flexibility needs and potentials, economic analysis of markets and regulatory frameworks, and energy system modelling that quantifies impacts.

Through the development of a coherent regulatory frameworks and market designs that facilitate market interactions, which are optimal for the Nordic conditions in an EU context, transition pathways to sustainable Nordic energy systems are identified. Flex4RES will comprehensively discuss and disseminate the recommended pathways and market designs for achieving a future Nordic sustainable energy solution with a variety of stakeholders from government, industry and civil society.

More information regarding the Flex4Res project can be found at

www.Flex4RES.org

or by contacting project manager Klaus Skytte at klsk@dtu.dk

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Flex4RES work package 2: Framework conditions, December 2016

Framework Conditions for Flexibility in the Electricity Sector

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Problem statement

- The technology mix in the Nordic/Baltic region is presently endowed with a large share of hydropower and flexible conventional technologies compared to the current level of variable energy resources (VRE). The Nordic power exchange Nord Pool is well-functioning and the grid infrastructure within and between the countries are well deployed. Therefore, flexibility is not a major issue in the Nordic and Baltic countries at present.
- VRE are however expected to play an increasing role in the years to come. At the same time, low power prices limit the future role of conventional flexible power plants and deployment restrictions limit the development of additional hydropower. Therefore, additional flexibility is required in the future.
- Most of the present regulatory framework conditions have not been designed to provide flexibility or to ease the integration of VRE. Some even work against providing flexibility services to the power market.
- Identification of regulatory flexibility barriers and drivers are needed in order to come up with policy recommendations for flexibility enabling regulatory frameworks.

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Key Findings

Barriers and drivers for flexibility exist in the market setup or in the regulatory framework conditions of the Nordic-Baltic power market.

Drivers and Barriers in the Market Design

- The Nordic/Baltic power market is presently well functioning. The main driver for the provision of flexibility in the Nordic-Baltic region is the Nord Pool market, its associated market rules and price signals.
- Nord Pool was designed to balance seasonal variations in hydropower, and hourly and seasonal variations in demand. This design is optimal for energy flexibility and for dispatchable supply. However, in a future with large shares of VRE, hour-to-hour power flexibility and shorter time spreads between the market closure and the actual delivery are also needed. This could call for a redesign of the power market, e.g. with gate-closure closer to time of delivery or more liquid integrated intraday markets, and broader access to cross-border transmission capacity.
- Flexible supply normally has a higher marginal cost than VRE supply. A high share of VRE lowers the price level on the power market and makes it less profitable to operate or invest in flexible supply capacity. The phasing out of existing flexible supply capacity and limited new investments in these, could threaten the adequacy and security of supply in hours with little VRE generation. A redesign of the power market would have to consider this issue as well. So far capacity markets have not been appealing to policy makers in the Nordic countries. However, other EU countries have introduced capacity

markets to solve the adequacy problem. An open research question is therefore, if a redesign of the Nordic power market could handle the capacity problem without introducing a capacity market.

- The framework conditions for electricity balancing are, overall, favourable for the provision of flexibility. However, although all conventional generation resources participating in the Nordic power exchange have common rules and price setting between countries, the handling of imbalances of VRE does not. Specifically, the degree of balancing responsibility is specific to each individual country and the determination of costs is not uniform. The possibility of netting imbalances could be a central element in the redesign of markets that are better suited for VRE integration.
- There are a considerable number of interconnectors within the Nordic and Baltic region, and with neighbouring countries. Interconnection capacity is implicitly auctioned together with day-ahead energy bids at Nord Pool. This is a major driver for using the transmission lines to handle imbalances and thus for flexibility.

Barriers in the Regulatory Framework Conditions

Direct Regulation

- Spatial planning and direct regulation by restrictions are limiting the technical potentials for flexibility. This is for example the case for new deployment or extension of existing hydropower in most Nordic countries, where water and river directives set deployment restrictions.
- The decision to decommission nuclear capacity in Sweden and the phase-out in Lithuania give room for dispatchable technologies to keep operating. This holds despite the fact that a large share of VRE will lower the price level and the number of hours with prices high enough to operate large dispatchable plants. In that way, the phase-out of nuclear power is helping more flexible supply to stay in the market. In Finland however, the addition of new nuclear power capacity will increase the inflexibility of the system and thus the need of other flexibility resources.
- The European energy legislation set binding targets to lower GHG (greenhouse gases) emissions. The target set by the 2020 climate and energy package of increasing the use of renewable energies to 20% of total energy production by 2020 was already or nearly reached in 2014 by all Nordic and Baltic countries. The 2050 Nordic roadmap indicates 90% of electricity generation will be based on renewable resources by 2050, with hydro covering 55% of it, VRE 30% and biomass 5%.
- The Nordic countries have set ambitious targets with respect to green energies accompanied by a ban to use fossil fuels for electricity generation. This decision was taken by the Nordic countries and will negatively impact the existence of several flexible generation technologies in the future.

Fiscal Regulation

- With a good institutional framework the very different technology mixes of the seven countries is an advantage rather than a disadvantage. The deregulation and liberalisation of the power market in the Nordics and Baltics have implied very little general regulation that limits the supply from existing generation. The regulations governing the electricity supply industry in the seven countries are national but should derive from EU-directives and will over time converge and become more and more harmonised.
- Initiatives aiming at enhancing the business case of thermal-based technologies are a supportive framework to prepare a transition toward the activation of new flexibility resources in the region. Such initiatives are either tax reductions or investment subsidies mostly granted to biomass energy which also impact its operational competitiveness.
- Biomass energy, which is notably used in district heating, receives tax exemptions. This implies more investment in biomass-based heat-only (HO) boilers rather than on CHP or power-to-heat (P2H) technologies. This decreases the coupling of the heat and electricity sectors instead of providing the desirable advancement of coupling.

RES Support Schemes

- It is an advantage for the system, if VRE is active in the market and reacts to the system needs for flexibility through market prices. Two things need to be present simultaneously;

  1) VRE should be exposed to the market signal. I.e. the support has to be linked to the market price.
  2) The VRE operator should have an explicit incentive to act flexibly.

  Market based support systems with regulatory incentives to act flexibly are introduced in some of the Nordic countries. For example, the feed-in premium (FIP) for wind power in Denmark, that is given for a certain amount of full-load hours instead of a fixed number of years. This gives the wind power operator the possibility to postpone the support in hours with negative power prices to future hours with positive prices. In other words, wind power operators have incentives to curtail their generation (act flexible) in hours with negative prices.
- However, most of the present support schemes are not market-based or are not supported by regulatory incentives to act flexibly. For example, feed-in tariffs (FIT) are often supplied without any connection to system needs reflected in the power price or with incentives to act flexible. Another example is the Norwegian and Swedish green certificate system, which is a market based system but there are no incentives that encourage flexible operation of renewable energy plants as they obtain their certificates from the amount of generated MWhs independently of the power price. That is, there are no regulatory incentives in the Norwegian/Swedish green certificate setup to act flexibly to negative power prices.

Demand-Side Regulation

- In most countries, smart meters are being rolled out and changes to the retail electricity market design are taking place, i.e. the conditions to further develop demand-side flexibility are given. The emergence and consolidation of business models for demand response will, nonetheless, ultimately depend on the market conditions.
- In general there are no regulatory barriers for demand response in Europe. The main barrier is that there is no business case for the consumers to act flexibly at present. Therefore, demand response is not very developed. Not even in large manufacturing industries where individual contracts and metering technologies have made it possible for a long time. For other groups of consumers demand response is very marginal.
- Prosumers are still a very marginal phenomenon in the Nordic-Baltic countries. The number of household installations like rooftop photovoltaics (PV) is, however, increasing. The regulatory frameworks differ between the countries and between technologies. Net metering, tax and grid tariff rules will in most cases imply no incentives for the prosumers to act flexibly with respect to the system needs for flexibility. However, it may imply lower loads in the distribution network, which in some cases is in benefit for the system.
- Pumped storage and other storage technologies are currently not important in the Nordics or Baltics.

List of Abbreviations

CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
DH	District Heating
DSO	Distribution System Operator
FP	Fiscal Policy
FIP	Feed-in Premium
FIT	Feed-in Tariff
FLH	Full Load Hour
GHG	Greenhouse Gas
HVDC	High Voltage Direct Current
NTC	Net Transfer Capacity
P2H	Power to heat
PSO	Public Obligation Charge
PTR	Physical Transfer Right
PV	Photovoltaic
RES	Renewable Energy Sources
RR	Regulatory Regime
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption frequency Index
SS	Support Scheme
TSO	Transmission System Operator
TTC	Total Transfer Capacity
VRE	Variable Renewable Energy

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1. Introduction

This report is one of the deliverables in Work Package 2 of the Flex4RES research project. The present work addresses the identification and analysis of existing framework conditions in the electricity sector, i.e. the characteristics of the regulatory enabling frameworks and market designs that act as drivers or barriers for the flexibility in the Nordic and Baltic countries.

Following a long tradition of cooperation among Nordic countries, their electricity markets are coupled and have recently been expanded to include the Baltics. Though this constitutes a driver for flexibility, the countries face a common challenge: adapting to the substantially higher variability imposed by an increased integration of VRE into the system. Thus, identifying what practices help or hinder flexibility in the region is a timely question to ask.

To answer the question posed, as a primary source of information, this report has relied on a survey specifically designed to identify the framework conditions. Respondents were Flex4RES project partners in the seven countries of the region, namely: Denmark, Estonia, Finland, Latvia, Lithuania, Norway, and Sweden. The respondents' expertise in the framework conditions of each country was complemented by a body of literature composed of policy reports, statistical information, regulations and laws, which constituted a secondary source of information.

The report is structured as follows. Section 2 describes the methodological approach employed to analyse the information contained in the surveys and in secondary sources. Moreover, this section clarifies conceptual issues regarding flexibility, such as the time frame of interest, the resources from where it can be obtained and the factors that enable it.

Section 3 contains a review of the framework conditions affecting the power system flexibility with a particular emphasis on studies that identify drivers and barriers. It explains in a succinct manner their relevance for the flexible operation of resources and the investment in such options. In other words, the section describes the transmission mechanism between any given framework condition and flexibility. For example, it explains how the taxation framework or the design of RES-E support policies affects flexibility.

Section 4 contains a comparative analysis of the barriers and drivers in the region and aims at identifying a set of best practices in regulatory and market design for flexibility.

Finally, the section 5 of the report summarizes the main conclusions and findings of the report.

The appendixes present the construction of the survey and contain a detailed description of the framework conditions for flexibility in each of the seven countries in the region. By way of graphical summaries, it is straightforward to identify the main drivers and barriers present in each country.

2. Methodology

This section presents the methodology used in Flex4RES to identify and analyse the framework conditions affecting existing flexibility resources in the Nordic and Baltic electricity sectors.

The section starts by defining the concepts used in Flex4RES for flexibility and flexibility potentials in the electricity sector. The second part of the chapter develops the concept of framework conditions that are necessary for a flexibility potential to be realisable. The third section presents the concepts of flexibility resources and flexibility enablers, and provides insights into the approach used to categorise the framework conditions that apply to them. Each new concept introduced is italicised. Finally, the fourth and last section, describes the data utilized in the report.

2.1. Definition of Flexibility

In Flex4RES, electricity supply or demand is considered flexible when it is possible to regulate the increase or the decrease of generation or consumption. That is, flexibility is defined as a measure to keep the balance between generation and consumption of electricity, since the variability in generation and in consumption is to be balanced in flexible supply and in flexible demand (Figure 1).

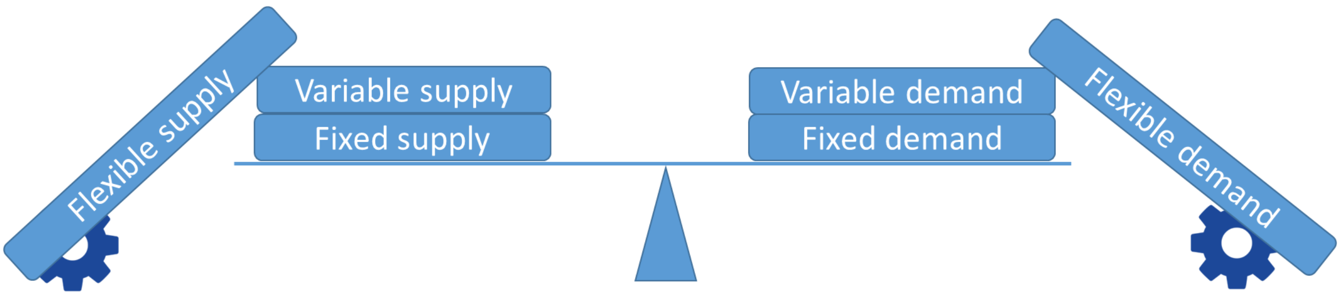

Figure 1: Flexible supply and demand balance the variability in generation and consumption of electricity

Flexibility can be obtained locally or it can originate from other regions through the transmission lines to the surrounding countries. Furthermore, the supply and demand of electricity can satisfy final electricity consumption directly, or can be coupled to the heat, gas or transport sectors, or even storage facilities.

Although flexibility is relevant from a level of seconds to an annual level, in Flex4RES the analyses are limited to flexibility on an hourly level.

2.2. Flexibility Resources

Flexibility can be activated by the supply or the demand-sides (Figure 1). Although not a resource in itself, flexibility originating through transmission lines is categorised in the third item of the following list:

1. Generation
2. Demand
3. Grid infrastructures

Adding the grid infrastructure to the analyses is relevant for several reasons. Institutionally, it allows integrating regulated actors (grid operators) to the analysis alongside the market-based flexibility providers. In consequence, we obtain a complete representation of the electricity supply chain and we can formulate a more complete set of policy recommendations. Additionally, power grids represent the physical link between up and downstream activities and between countries without which the issue of activating new flexibility options would lose consistency.

Grid infrastructures can be distinguished from supply and demand resources in the sense that they do not represent a direct flexibility resource but rather *enables* the provision of flexibility. Thereby, the transmission lines act as *flexibility enablers*.

As mentioned previously in the definition of flexibility, the supply and demand of electricity can satisfy final electricity consumption directly, or can be coupled to the heat, gas or transport sectors, or even storage facilities. The links to these coherent (adjoining) markets are important potentials, and the framework conditions in each of them affecting the flexibility they can actually supply to the electricity markets are crucial (Skytte et al. 2016). However, in Flex4RES, these topics are treated in separate reports such as the study on district heating (Sneum Møller et al., 2016).

2.3. Flexibility Potentials

Different studies report a large variety of flexibility potentials (Lund et al. 2015). The differences between the studies in the estimates arise not only from calculation differences or different approaches, but also from the methodology for defining potentials. Some of these estimated potentials are theoretical and hypothetical. In contrast, Flex4RES aims at estimating potentials that are realistic and realisable within the existing framework conditions, and within the time elapsing from the current situation until the long-term target year of 2050.

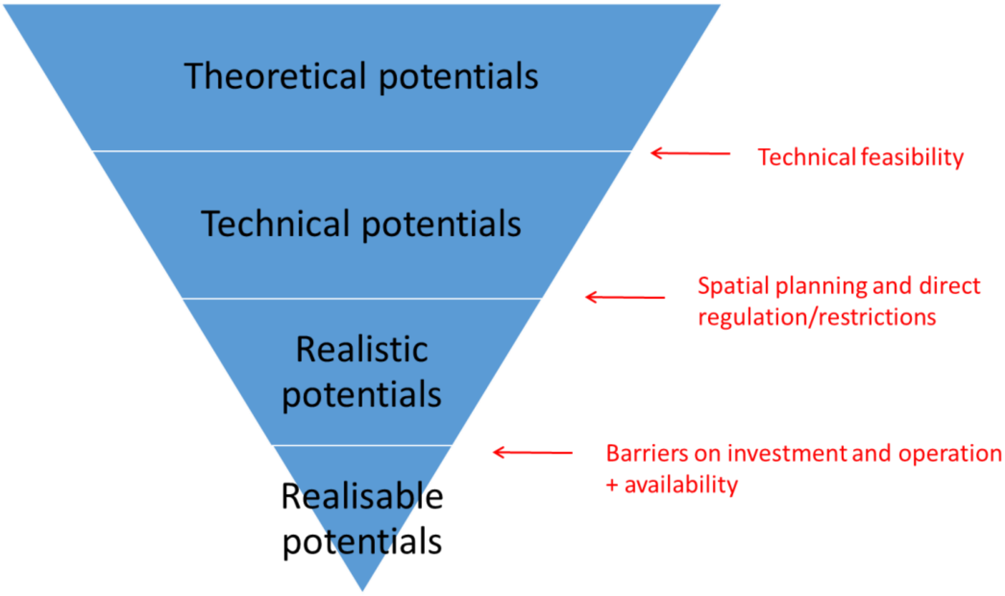

Figure 2: Methodology for definition of potentials.

The ***theoretical potential*** of an energy source refers to its total possible and physical energy flow. For example, the total energy content of solar radiation on any given area during one year. Technical feasibility restricts this potential to the ***technical potential***, by accounting for the availability of potential sites or primary fuel streams, e.g. of biomass. Large wind turbines, for example, cannot be installed in large urban areas, and all the wood residues from forestry are not available for electricity production.

The reduction from technical to ***realistic potentials*** takes into account that, although there might be enough space or resources technically available for a certain electricity production or consumption, it is not always desirable to occupy all the technical potential. Such restrictions are often captured by spatial planning restrictions, direct regulation and technical restrictions, e.g. water directives for hydropower plants.

The ***realisable potentials*** are derived from the realistic potentials and are always smaller than the latter because their estimation accounts for restrictions due to the presence of regulatory or market related barriers, e.g. market designs, regulatory and legal rules such as taxes, or limited production/deployment rates.

For realisable potentials, the only restriction left for the penetration of a certain flexibility technology is the cost price (investment and operation costs). If presently, the cost price (including subsidies, taxes and tariffs) is competitive, the technology will penetrate into the electricity market as an *utilised flexibility resource*.

Flex4RES focuses on realisable potentials. The present report surveys regulatory barriers that reduce the realistic to the realisable flexibility potentials. In a later work package Flex4RES uses the Balmorel model to determine which realisable potentials are utilised as flexibility resources. As mentioned above, this is determined on the basis of the cost price versus the power price. It is useful, therefore, to notice how barriers and drivers in the surrounding framework conditions influence how much of the realistic potentials that are realisable can actually be utilised as flexibility resources (Figure 3). In a later stage, the Flex4RES project will also look at potentials for future scenario years.

2.4. Framework Conditions, Barriers, and Drivers

Flexibility resources may be present in terms of a realistic potential but may be prevented by framework conditions to become realisable and to operate flexibly.

Framework conditions are sets of regulatory-based or market-based setups that influence the way in which agents invest in or operate technologies (Figure 3). Part of the framework conditions can act as *barriers* for investing in flexible technologies or for operating these technologies flexibly, i.e. they impede investment in flexibility resources or on its flexible operation. Other parts of the framework conditions can act as *drivers* for increasing the realisable flexibility potentials. Finally, there are framework conditions that do not affect flexibility.

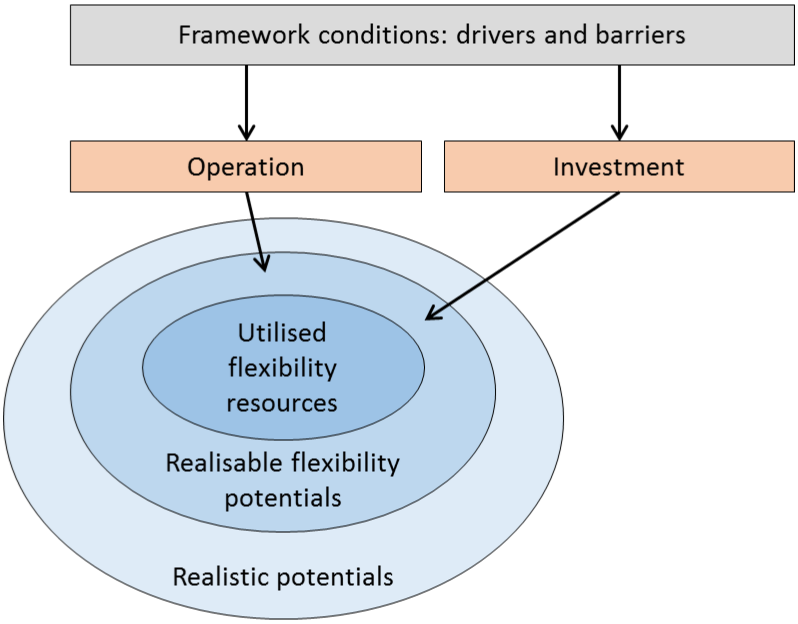

Figure 3: Influence from the framework conditions on realisable potential and utilised flexibility resources.

The identified barriers and drivers are categorised into two main groups of framework conditions: *market-based* and *regulatory-based* (Table 1). The market-based framework conditions include market design, which is a common terminology for the set of rules that govern the participation of market actors in the various markets. The regulation-based framework conditions are divided into four subcategories: (1) Direct regulation, (2) Fiscal policies, (3) Support schemes and (4) Regulatory Regimes. Direct regulation includes all political decisions that have a direct and restrictive impact on the actors, e.g. water directives have restricting effects on the construction of new hydropower plants. Fiscal policies are the indirect regulation of actors that influence the economy through taxation and spending, e.g. fuel and CO_2 taxations. Support schemes are the financial support that are specifically awarded to installations based on renewable energy sources, e.g. feed-in tariffs and premiums or investment grants. Regulatory regimes refer to the cost recovery frameworks that apply to grid operators.

Framework category	Framework subcategory	Explanation
Market-based	Market design	The set of rules that govern the participation of market actors in a given market place.
Regulatory-based	Direct regulation	Political decision with a direct, compelling and restrictive impact on the actors.
	Fiscal policies	Actions to influence the economy through the use of taxation and spending.
	Support schemes	Financial support schemes that specifically apply to renewable energies such as wind, biomass or solar PV.
	Regulatory regime	Incentive schemes and instruments that regulate the investments and operation of regulated power grid operators.

Table 1: Framework categories and subcategories

While there exists a significant amount of literature categorising barriers to desirable developments in the energy system, such as energy efficiency (Trianni et al. 2014; Leete et al. 2013), renewable energy (Painuly 2001; Wee et al. 2012; Ropenus & Skytte 2005) and smart grid deployment (Wee et al. 2012; Soshinskaya et al. 2014), there is to our knowledge no past studies aiming at categorising the barriers to flexibility. Thus the proposed categories in the literature cannot be directly used in this study, but need to be adapted to the specific characteristics of flexibility. Below we briefly explain our choice of categories based on previous methods for categorisation.

Generally, categories in past studies on barriers in the energy system intent to capture overall problems related to the different energy system issues. First, there are several categories related to technical viability (e.g. Technology (Painuly 2001), Technology risk (Leete et al. 2013), Lack of innovation (Luthra et al. 2014), Technology immaturity (Luthra et al. 2014)). Second, economic viability is analysed using categories related to market (e.g. Market structure (Golove & Eto 1996), Market failure (Painuly 2001), Market distortions (Painuly 2001), Market uncertainty (Luthra et al. 2014) and Market performance (Wee et al. 2012)), financial options (e.g. Financial (Trianni et al. 2014), Financing (Golove & Eto 1996), Capital constraints (Schleich & Gruber 2008), Limited capital available (Worrell & Price 1998), Investment time (Leete et al. 2013), Lack of financial resources (Olsthoorn et al. 2015)), and general economic categories (e.g. Economic (Trianni et al. 2014), Misplaced incentives (Golove & Eto 1996) and Cost and pricing (Beck & Martinot 2004)). Third, several approaches point at restrictions due to regulation and institutional framework as potential problems and have adopted categories to capture related barriers (Legal and regulatory [3], Regulation (Golove & Eto 1996; Crossley 1983), Regulatory environment (Leete et al. 2013), Institutional and Regulatory (Reddy & Painuly 2004), Consenting and licensing (Leete et al. 2013), Institutional mechanisms (Muench et al. 2014), Institutional (Painuly 2001)). Fourth, despite economic and technical viability the 'human factor' may impede optimal decision making, and barriers related to this problem can also be found in the literature (e.g. Social, cultural and behavioural (Painuly 2001), Behavioural (Reddy & Painuly 2004), Low public awareness (Luthra et al. 2014), Lack of information (Worrell & Price 1998; Crossley 1983), Customs and information (Golove & Eto 1996), Bounded rationality (Schleich & Gruber 2008), Lack of skilled personnel (Worrell & Price 1998), Lack of necessary technical skills and knowledge (Luthra et al. 2014)).

An important difference between barriers to flexibility and barriers to energy efficiency is the variety of actors affecting flexibility, including suppliers, consumers and grid operators. This difference is clear in (Cagno et al. 2013) who proposes a comprehensive taxonomy for categorising barriers to energy efficiency in the industry. He divides barriers into two main categories according to the origin of the barrier: internal and external with respect to the firm. This approach avoids the problems of overlapping categories and implicit interactions, however, it is designed for analysis of barriers to only one type of actor: the firm. When analysing an issue involving a variety of actors, this approach implies considering each type of actor separately, potentially leading to a disaggregation of the barriers rather than an aggregation of barriers into overall categories. The distinction between internal and external is therefore not feasible for categorizing barriers to flexibility.

An example of classification that encompasses several types of actors is the study on barriers to smart grid implementation, conducted by (Muench et al. 2014). Here policymakers, smart grid technology providers, grid operators and end users are considered. The applied barrier categories, which were chosen inductively, include (1) cost and benefit, (2) knowledge, and (3) institutional mechanisms. The approach is, however, prone to ambiguity, as the authors point out that despite the limited number of categories some barriers can be allocated to more than one.

We have selected two categories and subcategories (Table 1) for this study so they appropriately include several types of actors, while no overlap in categories exists. Furthermore, we assume that all actors are profit maximizers and we have therefore focused on barriers that affect either the economic viability of the actors' potential choices or restrict the set of choices. Other types of framework conditions, related to e.g. the technical viability of behavioral or cultural issues of different actors, are not included in this report.

2.5. Data Sources

This report has relied on a qualitative, open-question survey, specifically designed to obtain an overview of the current state of framework conditions for flexibility in the seven countries that are the subject of this study, namely Denmark, Estonia, Finland, Latvia, Lithuania, Norway and Sweden. The structure of the survey was organised taking into consideration the aspects already described in the earlier subsections. First, it was specifically aimed at identifying realisable potentials. Second, it takes the flexibility resource view above-mentioned and was purposefully organized according to the immediacy of the impact on flexibility. Starting from generation, followed by grid structure, demand and storage. Respondents to the survey were experts from the Flex4RES partner institutions. Their views were the primary source of information used in this report. Secondary sources of documental information, such as statistics from reliable sources, institutional policy reports and academic papers, were also relevant for the analysis (for more details on the construction of the survey, see appendix 7).

3. Framework Conditions

Based on the survey data regarding the set of relevant flexibility resources, we have identified a number of market-based and regulatory-based framework conditions that affect the investment in or the flexible operation of the respective resources and are either present or absent in the surveyed countries. This chapter introduces the identified framework conditions and provides a theoretical and empirical ground to the analysis.

The first subsection explains market-related framework conditions applicable to the different resources. The second and third subsections refer to the framework conditions that apply, respectively, to the supply and demand flexibility resources. The fourth and final subsection presents the framework conditions that apply to the grid infrastructures.

The concise explanations of this section are one of the contributions of this report because, so far, most existing works have not been explicit in relation to the kind of regulation and market arrangements that create VRE-friendly flexibility.

VRE modify the physical constraints of power systems and require that an adapted set of framework conditions is introduced (Dourlens-quaranta et al. 2016). As stated by Holttinen et al. (2006), most studies have investigated the impacts of wind generation on power systems in terms of physical constraints or costs. Other studies have shown that important flexibility potentials exist to accommodate intermittencies (Holttinen 2013; Batlle et al. 2012; Pickard & Meinecke 2011), whether they are provided by generators, consumers or enabled by the market and grid operators and interconnections.

Ela et al. (2014) make a comprehensive review of the impacts of VRE on electricity markets. Their study acknowledges the need to adapt traditional market designs and emphasizes the missing link between short-term price signals to operate the system in a flexible way, and long-term signals to ensure that sufficient flexible capacity is deployed. The IEA (2014), provides an extensive techno-economic study on the integration of VRE encompassing the flexibility resources mentioned before. It also attests that market designs need to translate the new technical operating paradigm into appropriate price signals but do not specify how to do this. Other studies that are discussed later in this section focus on one specific flexibility resource and also provide insights on the necessary evolution of markets and regulatory designs.

3.1. Market Design Features

Electricity generation is traditionally the core activity of power industries (Mäntysaari 2015). Generators constitute the main flexibility providers and the most suited resource to adjust to supply and load variations as well as to provide balancing services. The market design of the wholesale market is an important framework condition for both flexible and VRE generators.

In general, VRE increase the uncertainties between the predicted and the actual supply of electricity in the system (Skytte 2000). Borggrefe & Karsten (2011) observed in Germany that wind forecast uncertainty and related imbalances decrease from 15% to 4% in the last

24 hours before generation. Dourlens-quaranta et al. (2016) identify two main challenges relative to market designs in a highly variable supply context: i) increase market coupling to access diversified mix and; ii) allowing near real-time trade. Incentivising imbalance settlement arrangements to minimize forecast errors would complete the framework.

When it comes to identifying market-based supportive framework conditions to efficiently operate this resource, a first step arises from the harmonization of participation rules.

3.1.1. Common Energy Markets

This framework condition refers to the existence of common marketplaces for electricity trade, where buyers and sellers participate. Participants plan in advance demand and supply schedules and bid into day-ahead and intraday markets.

Having a large market through market coupling and strong interconnections is commonly considered a precondition for VRE integration (EWEA 2015; Weber 2010; Holttinen et al. 2009; Skytte 1999; IEA 2014; Borggrefe & Karsten 2011; Skytte 1996). Holttinen et al., (2006) show that the level of accuracy in wind generation prediction is positively correlated with large market places. Market coupling, provided sufficient interconnection capacities exist, reduce the overall cost of dispactching. In that sense, the European Directives for an Internal Energy Market are considered an institutional facilitator to market integration. Considering that, the extension of the Nord Pool market to the Baltic countries represents a supportive step toward a higher degree of coordination in the physical markets, which facilitates flexibility. The increase of market actors is also beneficial to competition and the transmission of price signals. Both the supply and the demand-side should be active in the market.

Investment: Increases the accuracy of price signals over which investors can base their investment decisions.

Operation: Improves the degree of coordination and expands the available generation technologies and resources, resulting in a least-cost operation of the system with a higher degree of reliability.

3.1.2. Common Intraday Markets

This framework condition refers to the existence of a common marketplace for intraday electricity trade, where buyers and sellers can adjust their bids from the day-ahead market.

An increase of the size of the intraday market and of the number of auctions during the day of delivery increases the liquidity in these market which is considered a proxy of how flexible the markets are (Weber 2010) and is preconized to support VRE development (TradeWind 2009; Borggrefe & Karsten 2011).

Investment: Increases the accuracy of price signals over which investors can base their investment decisions.

Operation: Improves the degree of coordination and expands the available generation technologies and resources, resulting in a least-cost operation of the system with a higher degree of reliability.

3.1.3. Balancing Responsibility in the Imbalances Settlement

Market participants who face balancing responsibility are incentivised to provide the transmission system operators (TSOs) with accurate forecasts of generation which lower imbalances. With the rapid growth of VRE, the question of who should be held responsible for balancing costs has emerged resulting in a progressive extension of balancing responsibility to wind operators in the European countries (EWEA 2015) with expected positive outcomes for flexibility (REserviceS 2014).

Investment: This framework condition has no impact on investment.

Operation: Gives an incentive to lower the forecast errors and improves the dispatching.

3.1.4. Cross-Border Capacity Allocation

The use of interconnections plays an important role in the handling of supply variability (Moura & de Almeida, 2010; Passey et al., 2011). Here again, harmonized framework conditions between interconnected countries and an alignment between wholesale markets and capacity allocation mechanism is key to flexibility (Brunekreeft et al., 2005; TradeWind, 2009).

The capacity allocation mechanism whether through implicit or explicit auction estimates the value attributed to interconnectors. Sharing a common framework in the allocation of limited interconnection capacities is a first good practice for the operators to use a same exchange routine and improve coordination (European Commission 2015). In what concerns flexibility, the adoption of implicit auctioning that couple the physical allocation of capacities to the transactions completed on the electricity marketplace is a second good practice. It ensures that the allocation of both transmission capacity and power is coordinated.

Investment: Increases the overall efficiency of electricity markets with positive impact on investment choices.

Operation: Increases the overall efficiency of electricity markets with positive impact on system operation.

3.2. Framework Conditions for the Generators

A well-functioning, competitive market is expected to transmit the right signals for market actors to operate or invest appropriately. However, policy makers may also intervene to fulfil broader objectives as it is the case for instance with the development of renewable energies. Three categories of framework conditions that apply to the supply-side are considered; i) The fiscal policies and subsidies granted to conventional flexible plants ; ii) The direct regulations enacted by the authorities and iii) The support schemes attributed to renewable energies.

3.2.1. Fiscal Policies

Fiscal incentives and subsidies for conventional, flexible plants

Such measures improve the business case of suppliers participating in energy-only markets. They limit the uncertainty related to the profitability of the installation along its life cycle and positively impact the existence of flexible technologies.

Investment: Limits the uncertainty related to the profitability of the eligible installation along its life cycle and positively impacts future installed capacities.

Operation: Output-based measures improve the business cases of the eligible installation and subsequent competitiveness whether capacity-based measures only impact investment.

3.2.2. Direct Regulation

Restrictions affecting fossil fuelled, nuclear or hydropower plants

There exist a number of direct regulations, such as direct prohibitions or physical restrictions that prevent the deployment, expansion or operation of certain flexible resources. The binding CO_2 emissions target decided by the European Union provides an example of an institutional setting that could translate into the political decision of forbidding the commissioning of new plants or the operation of existing plants fuelled with polluting resources. Because of safety-related and environmental concerns, or a strong opposition from civil society, the authorities can also decide to ban the use of nuclear energy or the construction of large dams.

Investment: Limits or hinder future development of concerned technologies.

Operation: Limits the operation of concerned technologies.

3.2.3. Support Schemes

It is an advantage for the system if VRE are active in the market and react to the system needs for flexibility through market prices. To reach that aim, two things need to be present simultaneously;

- The RES producer’s revenue depends on the market price;
- There has to be an explicit incentive to act flexibly to system conditions.

Market-based support

Market-based support schemes refer to the financial measures granted to RES generation and that follow market price variations. Dourlens-Quaranta et al. (2016) recall that in most cases in Europe, the financial support to renewable generation was initially granted in form of FIT, that is, decoupled from market signals. Yet, policy makers have a growing interest in introducing market-based streams of revenues for renewable energy sources (RES) operators. The two main support schemes to do so are through FIP or the exchange of tradable green certificates (Miller et al. 2015; Papaefthymiou & Dragoon 2016; Jensen & Skytte 2002; Jensen & Skytte 2003; Skytte 2006).

In themselves, the support schemes indirectly support flexibility in improving the business case of energies technically suited to be used in flexible installations such as biomass (Dotzauer et al. 2015; Batlle et al. 2012).

Investment: Market-based support schemes keep transmitting an incentive to invest into the eligible resource, with a potential positive impact if it used in technically flexible units such as biomass in CHP.

Operation: As it does not cut the link between the market and the producer, it is a precondition for supported technologies to act flexible.

No support during negative price periods

With additional explicit incentives, RES operators face a direct incentive to adjust their outputs according to market conditions without inducing a financial risk that would impact investments decisions. For instance when the bonus is no longer paid during negative prices, a compensation by a slightly higher premium is generally granted (Dourlens-quaranta et al. 2016).

Stopping the payment of the bonus during negative price periods brings a direct signal to RES operators to stop feeding in. It is also aligned with the European Commission's guidelines that impose measures are adopted to ensure that generators have no incentive to generate electricity during these periods (European Commission 2011).

Among other additional incentives, flexibility bonuses are considered important drivers for biomass plants to shift the power fed in according to market needs (Szarka et al. 2013).

Alternatively, a FIP awarded for a certain number of full-load hours (FLH) incentivises the wind power operator to postpone the support in hours with negative power prices to future hours with positive prices. In other words, wind power operators have incentives to curtail their generation in hours with negative prices in order to maximize their profit during a later period when market conditions are more suitable without harming their economic viability.

Investment: Under the assumption that the number of incident with negative prices during the support period is rather small, this rule has no direct impact on investment.

Operation: Increases the responsiveness of eligible actors to market conditions.

3.3. Framework Conditions for the Consumers

The demand-side is considered a major flexibility resource, able to provide load adjustments to better match market conditions and system needs (IEA 2014; Strbac 2008; Greening 2010; Healy & MacGill 2012). One of the benefits of having an active demand-side is to increase the dispatching flexibility in order to better respond to unforeseen output variations and to lower failure probability. By activating the demand-side, we refer essentially to load curtailment (or shedding), and load shifting.

The largest consumers are traditionally associated with system flexibility and have the main flexibility potentials. Retail consumers also represent significant flexibility potentials, provided that electric energy is used for thermal (heating or cooling) purposes, or in the future with the development of electrical cars. However, the lack of technical basis to effectively bill the consumers according to the cost they incur to the system; and ii) profitability associated with load adjustments are often lacking.

3.3.1. Fiscal Policies

VRE-friendly taxes or tariffs

The bill paid by final consumers is made of a variable and a fixed part. The variable part refers to the cost related to the energy that was consumed and depends on market prices. It also refers to the taxes and part of the grid tariff that are paid in accordance with the energy consumed. The fixed part reflects the additional subscription cost of transmission and distribution.

Fiscal measures aiming at reducing the fixed component of the final bill or at increasing the link between the non-market variable part of the bill to market price variations (that reflect VRE generation) would increases the profitability of acting flexibly.

Investment: In itself, the measure has no direct effect on investments.

Operation: Represents a prerequisite to benefits from load adjustments according to market conditions.

3.3.2. Direct Regulation

Roll-out of smart meters

Smart meters allow monitoring the energy consumed in real-time. Chao (2010) or Eurelectric (2015) show that the deployment of smart meters is a first step for retail consumers to respond to market conditions. It allows developing advanced billing solutions and provides the technical basis to develop contracts designed to value flexible consumption patterns. The European Directive 2012/32/EC states that 80% of consumers should be equipped with smart meters by 2020 where roll-out is assessed positively which is a positive institutional framework. Consequently, the decision to deploy smart meters represents a supportive framework condition.

Investment: In itself, the measure has no effect on investments into a flexible resource.

Operation: The presence of smart meter coupled with an adequate incentive to adjust the load to market conditions would send appropriate signals for acting flexibly.

Use of net metering

Net metering allows separating the energy produced by a prosumers' on-site generation units (mostly solar PV) from the energy they consume over certain periods of time.

Consumers are taxed according to their net consumption from the grid which in itself strengthens the incentive to auto consumer their own variable generation and limits subsequent need for flexibility on a larger scale.

Investment: Provides the technical basis to develop flexibility-friendly pricing that may encourage storage investments.

Operation: Provides the technical basis to develop flexibility-friendly pricing that may encourage an active use of the generation unit.

3.4. Grid Infrastructures

Ensuring that enough interconnection capacity is available allows capturing the benefits of international integration through the access of a broader portfolio of flexibility resources. Eventually, it contributes to reducing the uncertainties linked to intermittency (Finon & Menanteau 2004) and involves the investments made to adapt or reinforce the grid infrastructures to variable in-feeds, both domestically and cross border.

The TSOs already play a key role in ensuring the geographical connection of VRE and the daily dispatching. The regulatory frameworks that apply to them are consequently generally supportive to VRE integration. Contrarily to TSOs, distribution system operators (DSOs) are considered as passive actors. However, this status may change in the future along with the increase of electricity produced by prosumers and the development of smart grids. Studies indicate that flexibility gains can emerge from a more active operation of distribution grids with positive effects on VRE development (Clastres 2011). An advanced operation of the grid is also expected to substitute to more capital intensive investments, for instance in grid reinforcement and should reduce the overall infrastructure cost. However, the regulatory regimes are often not adapted for driving the DSOs toward innovative investments and operation (De Castro & Dutra 2013; Bauknecht 2011).

Similarly to TSOs, DSOs can enable flexibility in ensuring sufficient grid capacities are available or through a more active operation of their grid.

3.4.1. Regulatory Regime

Capital cost recovery instruments

A cost + regulatory regime periodically renegotiates the revenue the operator is allowed to receive based on its total costs plus a rate of return that ensures a suitable remuneration for the invested capital. It allows a complete pass-through of investment costs to final consumers and ensures the operator to get a profit from it. Accordingly, it eliminates the risk associated with new investments and incentivizes the operator to invest. Contrarily, the operators subject to an incentive-based regime such as a price or revenue cap, face an investment risk since they are not guaranteed to pass through their entire costs if they do not improve their cost efficiency.

Investment: A cost + regulatory regime supports investments in new infrastructures, although with a risk of overspendings, whereas an incentive-based regime creates a revenue risk and potentially negatively impacts investment decisions.

Operation: This framework condition has no direct impact on operation.

Flexibility-friendly performance targets

A flexibility-oriented operation of the power grid can be triggered by the regulatory framework that applies to them through performance indicators by coupling the provision of flexibility services to the operator's earnings through a reward/penalty mechanism. For instance, a financial incentive to outages reduction may conduct regulated operators to upgrade their assets or to improve their routine operation and thus their resilience in a power system receiving more and more variable outputs.

Investment: Incentivises investments into advanced solutions that will provide the technical basis to operate more flexibly.

Operation: Incentivises an active operation of the power grid.

3.4.2. Direct Regulation

European funding

The European Union implemented several programs to participate in the funding of critical infrastructure aimed at the completion of the Internal Electricity Market.

Investment: Reduces upfront costs, alleviates the risk borne by operators and facilitates the completion of national or transnational grid projects. Thus it supports flexibility.

Operation: This framework condition has no direct impact on operation.

4. Drivers and Barriers

This chapter starts with an introduction to the Nord Pool power exchange since it represents the common market basis on which flexibility resources are traded. Both the fundamentals of Elspot and Elbas related to flexibility are discussed as well as the national-based balancing settlement mechanisms. Then in a second step, we present a comparative analysis of the countries. The comparison is built on the results of the electricity survey that was filled out by project partners in each of the Nordic and Baltic countries.

4.1. The Nordic Power Market Nord Pool

The Nordic countries have a long tradition for cooperation in different areas and one example of this is their common wholesale electricity market Nord Pool. The expansion of the market to include the Baltic countries adds to this driver for flexibility, because a more diverse set of resources can be utilized to keep the balance between demand and supply.

Nord Pool originally started as a Norwegian power exchange for coordination of electricity generation from hydropower areas with varying precipitation levels. Therefore, the markets at Nord Pool were originally designed to balance seasonal variations in hydropower, and hourly and seasonal variations in demand. Two markets were pivotal from the beginning; the day-ahead market, *Elspot*, and the balancing market/real time market, *Regulating Power*.

Elspot was primarily introduced as an enabler for the electricity generators to make production plans for the following day. However, the physical characteristics of electricity require balance between supply and demand in the hour of dispatch. Therefore, an additional balancing market, the Regulating Power market, was introduced in order to ensure that.

Sweden, which also has a large share of flexible hydropower in their production mix, joined Nord Pool in 1996, and it became the first binational power exchange with a common spot market in the world. Simultaneously, Finland made its own power exchange, EL-EX.

The operation of EL-EX was basically similar to the Nord Pool day-ahead market. However, EL-EX also developed the so-called Elbas market (Electricity Balance Adjustment Service), an intraday market with the purpose to allow participants on the day-ahead market to *adjust* their positions (physical market) up to short before the generation hour. Svenska Kräftnett went into collaboration with Fingrid, which implied that the Elbas market became a binational market between Sweden and Finland - in parallel with Nord Pool and EL-EX.

Finland joined Nord Pool in 1998 and Elbas became a separate market for balance adjustment in Finland and Sweden in 1999 at Nord Pool. Denmark joined Nord Pool in 2000. Eastern Denmark joined the Elbas market four years later in 2004. In 2005 Nord Pool Spot opened the Kontek bidding area in Germany, and the year after Nord Pool Spot launched Elbas in Germany. Western Denmark followed by joining the Elbas market in 2007. In 2009 Norway finally joined the Elbas intraday market. Simultaneously, Nord Pool implemented a negative price floor in Elspot. Today Elbas also covers the Baltics.

The original design of Nord Pool with only a day-ahead and a balancing market was optimal for energy flexibility and for dispatchable supply like flexible hydropower. However, in a system with a large share of variable energy resources (VRE), power flexibility between hours and shorter time spreads between the market closure and the actual delivery are also needed. The intraday market Elbas was designed to support the spot market for less flexible generation technologies which had difficulties to predict their generation 12-36 hours ahead - as was required at the day-ahead market Elspot. Therefore, even though the Elspot market have the largest daily trading volume, the Elbas market has an important role in allowing for adjustments in the bids. It is part of EU-policy to develop a common intraday market in the north-western region.

Figure 4 provides an overview of the three markets Elspot, Elbas and the regulating power. Besides these three markets with physical delivery, there also exists a financial market for futures and forwards which is organised by Nasdaq OMX Commodities. The financial market will not be analysed further in this report.

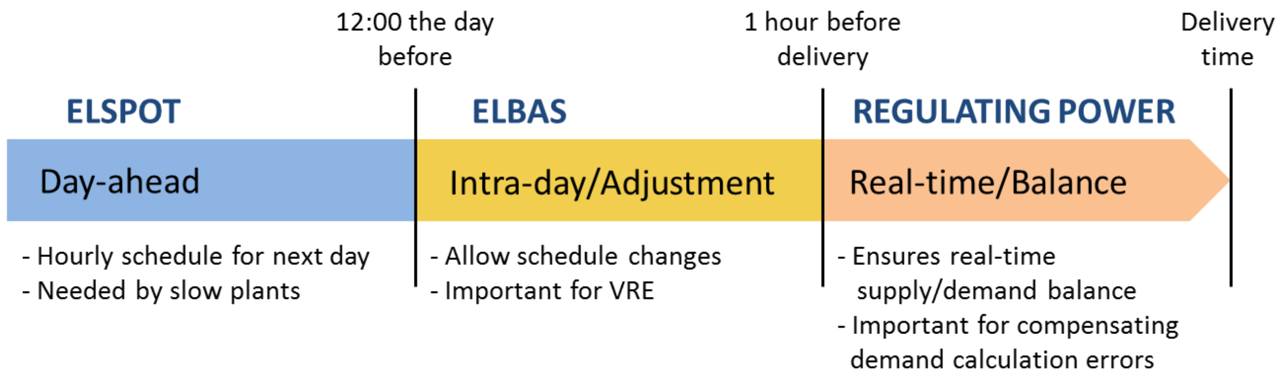

Figure 4: Market structure at the Nordic power market with the three physical markets: Elspot, Elbas and Regulating Power.

The three markets for physical trade at Nord Pool have different price mechanisms. The prices on Elspot are determined as the uniform marginal price. The intraday market, Elbas, has a price setting based on pay-as-bid, i.e. the actors' bids are settled at the price of the individual bids. The prices at the regulating power market are like the Elspot cleared at a fixed clearing time as marginal prices for the following hour (Table 2).

Markets	Purpose	Trade	Price
Elspot	Make production plans a day-ahead	Fixed clearing hour at 12am the day before trade	Uniform price
Elbas	Adjustments of bids	Continuous trade over the day	Pay-as-bid
Regulating power	Balance of bids and actual trade	Fixed clearing 15 minutes before real time trade	Uniform price

Table 2: Set-up of the physical markets at Nord Pool.

The main observations are that Nord Pool has adapted to the present mix of technologies and that the Nordic power market is well functioning at the present. The main driver for the provision of flexibility in the Nordic-Baltic region is the Nord Pool market, its associated market rules and price signals.

4.2. Balance Settlement

The regulating power market is not traded at Nord Pool, but through the Nordic Operational Information System (NOIS) operated nationally by the TSO that contracts with balancing responsible actors (BR) for up- or downward regulation. The Nordic countries have a set of agreements on the common operation of the regulating power market, and the TSOs can contract with BR on a Nordic scale, even if they have a national regulating power framework (Table 2). Thereby, the way imbalances are settled still differ between the Nordic and Baltic countries. However, there is a common initiative to create a Nordic Imbalance Settlement mechanism that underpins the development of a common Nordic retail electricity market (eSett). The solution, which will be operational in 2017, includes Norway, Sweden and Finland.

Nevertheless, some market arrangements still lack common rules. Firstly, the future settlement of imbalances will not apply to Denmark and the Baltic countries and there currently exists different treatments with respect to who faces balances responsibility, notably from VRE operators.

4.1. Grid Regulation

Regional coordination for the future development of interconnections faces challenges. In particular, these are related to the absence of a common Nordic view in the licensing and financing process of projects. This may translate into future impediments for interconnection developments. Presently, interconnection capacity among Nordic countries is well developed and has exceeded the EU 10% interconnection target. The implicit auctioning of capacity in the existing energy marketplaces is a driver for flexibility. However, the Nordic TSOs still report congestion situations on the interconnection lines half of the hours of the year which limits the provision of flexibility.

The regulations of the electricity supply industry in the seven countries are national. Despite the fact that there is a common understanding in relation to the relevance of cooperation, national regulatory frameworks differ significantly. For instance, none of the countries take an explicit Nordic perspective when evaluating grid development projects in general and cross-border interconnections in particular. In all countries, a higher level entity than the TSO itself (i.e. ministries, regulators) must license transmission infrastructure according to specific criteria. This translates into politically-driven decisions. In Denmark and Norway for instance, the authorities require a positive national socio-economic benefit to develop transmission lines. Finland requires that any given project helps to develop the market while ensuring reciprocity. The European objective and related Directives to complete the Internal Energy Market should, however, strengthen a higher degree of convergence between the countries.

Besides the regulatory perspective, there is also a coordination challenge present. Following the introduction of the ENTSO-E in 2008 and the dismantling of Nordel, i.e. the association where Nordic TSOs convened since 1963 to discuss issues of common interest, the pressure to implement transmission development plans seems to have weakened due to the absence of political and stakeholder push (Makkonen et al. 2015). Nordel was commissioned by the Nordic Council of Ministers to publish the Nordic Grid Master plans, which were based on socio-economic benefits for the Nordic area, but without producing the desired results. More specifically, the existing Cross Border Cost Allocation (CBCA) tool, derived from EU regulation no. 347/2013, introduces interconnection risk (Nordic TSOs 2016). This is because projects of common interest may have to be developed at the expense of states that benefit of an interconnection, even if some of the states do not obtain a positive impact from it. The Nordic TSOs advocate for a more holistic view, in which mutually beneficial regional cooperation is emphasised.

4.1. Data Hubs

All Nordic countries have initiatives to develop centralised IT-systems to create a supplier-centric market design. The only country that has so far gone live with this solution is Denmark (DataHub) but Norway (elHub) will introduce it in 2017, while Sweden (serviceHub) and Finland (DataHub) in 2020. This will be an important step in the development of a common Nordic retail electricity market which, in turn, will have a positive impact on demand-side flexibility. The existence of a common Nordic Balance Settlement will lower the barriers to entry to new retailers. The larger deployment of smart meters will further facilitate the development of energy services and new business models for demand-side flexibility.

4.2. Comparative Analysis

The comparative analysis of the framework conditions in the Nordic and Baltic countries in this chapter presents emphasizes the main framework conditions that act as a driver or a barrier and stresses out good practices. The detail of findings for each country is presented in the appendix in chapter 8.

For comparability purposes, the main findings are summarized in tables. They provide a representation of which framework conditions are present or contrarily inexistent for each resource or for the grid infrastructure and in each country. The framework conditions are presented in such a way that they represent a supportive ground for flexibility. Each table refers to a flexibility source. Table 3 provides the legend of the colour code being used. Their presence or absence if marked by a colour such as:

	Yes	No	Not relevant	Not available
Presence of the framework condition			n/r	n/a

Table 3: Legend summary table

To ease the reading and facilitate the interpretation, the framework conditions are formulated in such a way that their presence always corresponds to a driver for flexibility. A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. Accordingly, the more a country column is blue, the more supportive its framework conditions are to flexibility. On the contrary, a large concentration of pink cells indicates that many barriers are identified. A blank cell noted n/r means the related framework condition does not apply and is not relevant (for instance Denmark is not endowed with large hydropower plants due to topographic reasons, so the framework conditions that stand for this resource are not relevant). A blank cell noted n/a means the data in not available.

4.2.1. General Overview

At present, non-dispatchable VRE technologies are still marginal for the region in total. Additionally, the Nordic region is endowed with a diversified power mix and strong interconnection capacities, particularly between the Nordic countries that gives access to large hydropower resources, the majority of which is with reservoirs. Missing links do exist, such as between Estonia and Latvia but here there are extension plans to improve the situation. The Baltic countries were before an integrated part of the Soviet power system but are now both physically and with respect to market organization included in the Nordic system. At last, Nord Pool that includes day-ahead, intraday and balancing markets is a major enabler for increased coordination and reliability in the region. The Nord Pool price areas also contribute to handle bottlenecks. All these settings ensure a high degree of flexibility on the regional scale given current technology mixes. Finally, the TSOs have developed adequate routines for handling intra hour imbalances. As they have the overall responsibility for balancing the system they are provided with strong incentives for keeping and improving flexibility.

In the future, however, this situation is expected to change and the need for flexible services will increase.

- Non-dispatchable generation coming from VRE is increasing, notably coming from onshore and offshore wind power.
- Current technology mixes are expected to evolve dramatically to reflect the increase of wind energy and the progressive reduction of fossil-fuelled generation units. This will negatively impact the availability of dispatchable generation resources and back-up capacities for VRE in most countries unless fossil fuels are substituted by biomass.
- Water directives decrease the availability of additional hydropower resources in the future and further limit the availability of flexible capacities.
- The addition of new nuclear power capacity in Finland will increase the inflexibility of the system.
- The substitution of the present nuclear plant in Lithuania and the phasing out of shale oil capacities in Estonia are other unknowns for the future.

The final picture we obtain is one in which unexploited flexibility resources need to be activated to keep guaranteeing a high degree of reliability and sustainability of Nordic-Baltic power systems at least cost.

4.2.2. Framework Conditions for Power Markets

The electricity market designs in the Nordic and Baltic countries are generally supportive to flexibility. All seven countries participate in Nord Pool where common day-ahead and intraday market rules apply and common products are traded. While not all marketplaces are equally liquid, the existence of such common market arrangements guarantees harmonized daily dispatch and adjustment settings the day of delivery.

The broad participation of countries increases liquidity and competition and ensures more accurate price signals. Provided congestions are minimized, it permits to get the benefits of different electricity mixes with positive impacts on regional flexibility.

	DK	EE	FI	LA	LT	NO	SW
Common day-ahead market							
Common intraday							
Common regulating power							
Common cross-border allocation							

Table 4: Common market-based framework conditions in the Nordics and Baltics.

Other obstacles to the lack of flexibility-friendly investment or operation are identified that fall under political, institutional or regulatory reasons, against which leverages can be used.

4.2.3. Framework Conditions for the Supply-Side

Conventional flexible plants

Because of their flexibility potentials, large hydropower plants and centralised thermal-based capacities including CHP are today the main answers to VRE fluctuations.

Flexible hydropower plants can be compared to storage capacities able to accommodate large variations of outputs. However, in the countries where this resource exists, it faces important barriers to be operated flexibly. Norway, Finland Latvia and Sweden enacted environmental directives derived from EU water Directives that limit the turbining of water and prevent them from using the resources optimally with respect to flexibility. More stringent legislations were also drafted that make it difficult to invest into new hydropower capacities. As a consequence no new hydropower plants are planned in the region, only some extension projects, like in Latvia or Norway, are underway to add up generation capacities to existing hydro facilities.

Gas technology is also technically well suited for providing flexibility. However, the role played by gas and other fossil based plants in general is very likely to be challenged due to reasons such as environmental targets. Particularly, Denmark set ambitious roadmaps to phase out fossil energies by 2050 where it is expected that more than 70% of its electricity production will be based on VRE (IEA 2016). Also, a substantial share of fossil-based plants, particularly oil and coal-based are ageing and should be phased-out in the next decade. The Baltic countries provide a particularly good illustration: no new investments in conventional plants are planned to counterbalance future large phasing outs.

Both hydropower restrictions and fossil decommissions are based on political decisions or directly translate the end of the installations' lifecycle. Several policy-based leverages such as subsidies or taxes reductions granted to keep operating these technologies are however identified. Sweden and Finland grant subsidies to hydropower producers. Lithuania introduced a tax exemption for the electricity produced in CHP plants using natural gas and oil products. Such measures directed to fossil-based units remain however rare as they go against environmental objectives.

More generally, tax exemptions or subsidies directed to thermal energy address to biomass like in Denmark or Finland, with the heat bonus. This represents an important driver because biomass can substitute for other fossil fuels such as coal or gas, notably in CHP that offer substantial flexibility features when accompanied with a water tank (Skytte et al. 2006). Sneum et al., (2016) concluded that current market prices are not favourable to CHP and we observe empirically a general decrease of their load factor with a takeover of heat-only boilers that are unsuited to provide flexibility. The measures that apply to biomass consequently represent a supportive signal for maintaining flexible technologies in the future.

Renewable energies

When it comes to RES, wind energy is the resource that showed the greatest increase over the last decade thanks to incentivizing support schemes. Biomass energy is also central since most of the Nordic and Baltic countries are endowed with biomass resources and because of its flexibility features when used in CHP. The support schemes attributed to these energies impact investment decisions and to some extent the provision of flexibility. A common observation is, however, that although the investment impact of the different mechanisms is positive, new flexibility needs call for an evolution of the mechanisms to trigger more suited generation behaviours from RES operators.

Three main support mechanisms are used in the Nordic-Baltic region; a green certificate system is in place in Sweden and Norway; a FIP is mostly present in Denmark, Estonia and Finland; and a FIT is dominant in the Baltic countries, with the exception of Latvia where the FIT is on hold until 2020. Some countries also have implemented support funds in order to reduce the risk related to upfront costs in investing into renewables. This is the case in Estonia with wind energy or in Lithuania for all green energies with the exception of geothermal.

The presence of market-based support schemes is a first step to increase flexibility, however the schemes still lack of complementary framework conditions to effectively push the operators to be flexible. The green certificate mechanism and most of the FIP give only limited regulatory incentives to act flexibly to negative power prices.

The Danish, and to some extent the Finnish FIP, do not allow RES operators to receive the premium during negative price hours which is considered an important driver to flexibility. Estonia is currently reviewing its FIP to introduce a similar measure. Denmark and Estonia also uses a Full-Load Hour mechanism to limit the FIP payments during negative prices. The FLH mechanism consists in linking the support policy to a fixed number of hours of operation during the lifetime of a project, rather than to a number of years. Thus, the VRE producer can choose to curtail output and still receive support payment in a different hour (when price is positive). In both cases, market prices apply to wind operators when the threshold of generation is reached. At last, only three countries namely Denmark, Estonia and Finland, recognize wind operators as balancing responsible, even though it is through the intermediary of the TSO.

		Framework conditions	DK	EE	FI	LA	LT	NO	SW
FP	Conventional plants	Presence of tax reduction / subsidy						n/a	n/a
DR	Fossil	Absence of restrictions							
	Hydro	Absence of restrictions	n/r	n/r		n/a	n/a		
	Nuclear	Presence of restrictions	n/r	n/r	n/a	n/r		n/r	
SS	RES	Market-based support							
		No support during negative price periods							

Table 5: Framework conditions that apply to the supply-side flexibility.
FP = Fiscal Policy; DR = Direct Regulation; SS = Support Scheme .

4.2.4. Framework Conditions for the Demand-Side

Industrial consumers

All Baltic countries, Denmark and Sweden, reported that tax reductions were granted to electro-intensive or industry consumers. This measure is identified as a driver since it increases the relative profit opportunity related to load adjustment.

Retail consumers

The first key barrier identified for small consumers is the large use of flat or seasonal tariffs that disconnect them from the market. The obligation emitted by the European Directive for all suppliers to offer time-of-use tariff and to install smart meters is seen as an institutional driver to trigger flexibility.

Indeed, the transmission of accurate signals relies on the technical possibility to introduce time-related prices in the final billing through smart metering. The decision to roll-out smart meters is considered a driver to demand activation. Today, only Lithuania has not emitted a clear decision regarding the deployment of smart meters which constitutes a barrier to retail demand response. However, the share of retail consumers facing market prices and be possibly price responsive and flexible remains low.

In spite of this supportive institutional framework, very few consumers decided to switch to a more time dependent pricing scheme, including in Sweden who was pioneer in deploying smart meters. Due to market prices, final consumers lack of financial incentives to engage in these contracts and to respond to market signals. Only Norway took substantial actions to limit the extent to which seasonal tariffs are offered with more than half of retail consumers having contracts linked to the Elspot prices. The survey also showed that the impact of time-based pricing highly depends on the way it is practically implemented. For instance, in Latvia, the price spread between peak and off-peak periods was not high enough to create load shifting. Some supportive initiatives to include more retail consumers to participating in demand response programs stand out. This is the case for instance in Denmark where a possible extension of the hourly settlement to smaller consumers is discussed.

At last, Denmark, Finland and Latvia use a net metering system that allow them to bill the prosumers according to whether they use their own generation or consume from the grid. Electricity charges are paid in accordance with the latter consumption which incentivises them to absorb the variable energy that is produced on site.

		Framework conditions	DK	EE	FI	LA	LT	NO	SW
FP	Industrial	Fiscal measures & subsidies			n/a			n/a	
DR	Consumers	Roll-out of smart meters							
DR	Prosumers	Net metering		n/a			n/a	n/a	n/a

Table 6: Framework conditions that apply to the demand-side flexibility.
FP = Fiscal Policy; DR = Direct Regulation.

4.2.5. Framework Conditions for Grid Infrastructure

The grid infrastructure is currently one of the major enabler to flexibility. Transmission interconnectors encompass national boundaries and connect the supply and the demand-side. Their role is expected to further increase in the future along with the penetration of VRE in the region between the Nordic countries first but also with the rest of continental Europe and the United Kingdom. Interconnectors are both a means for Nordic exports, smoothing wind power, and give continental Europe access to balancing power from Nordic hydropower. In what follows, is firstly discussed the impacts of the regulatory frameworks on capital investments, then the incentives for operator to adopt and flexibility-friendly operation activities and at last, the rules that apply to the handling of bottlenecks is commented.

The general observation is that of the identified barriers no major barrier interacts with the construction of new lines or the reinforcement of existing grid capacities. First of all, the European objectives to complete the Internal Energy Market bring a supportive institutional ground to upgrade and extend the grid infrastructures in order to consolidate the interconnections. Then, the integration of VRE is clearly stated as a main driver to capital expenditures. Such investments are facilitated by a cost + regulatory regime and a complete pass-through of related costs in the tariffs in Latvia, Lithuania and Norway. Only Finland and Sweden use an incentive-based regime to regulate investment costs to both the TSO and the DSOs. At last Denmark and Estonia only use an incentive-based regulatory regime that applies to the DSOs' capital expenditures. This setting, complemented by stringent performance target in Estonia drove the DSOs' investment choices to advanced flexible solutions instead of traditional capital intensive choices in remote areas. Incentives for investing into R&D activities that are consistent with flexibility-oriented activities are also observed in Finland and Lithuania.

However, although the regulatory frameworks do not represent a barrier to flexibility, the flexibility issue is addressed through traditional capital expenditures and lack of incentives to directly inflect a more active operation of the grids, particularly from DSOs. The only noticeable exception being in Estonia and restricted to isolated areas. In that context, stringent cost reduction incentives coupled with fine-tuned performance objectives succeeded in creating a substitution effect between capital spending and operation-related spending and actually drove the DSOs to develop advanced and integrated solutions to deal with supply and load variations.

		Framework conditions	DK	EE	FI	LA	LT	NO	SW
RR	TSO	Elimination of investment risks							
RR		Flexibility-friendly performance targets							
DR		European funding							
RR	DSO	Elimination of investment risks							
RR		Flexibility-friendly performance targets							

Table 7: Summary of the framework conditions that apply to the grid infrastructure.
RR = Regulatory Regime; DR = Direct Regulation.

5. Conclusion

With an eye on the future, one of the most likely developments in the Nordic and Baltic region will be the substantial penetration of VRE in the technology mix. This poses the challenge of managing greater levels of uncertainty and variability in the operation of power systems. To address this challenge, flexibility – defined in Flex4RES as a measure aimed at keeping the balance between generation and consumption – must be activated. A diverse mix of resources in both the demand and supply-sides and the role of enablers, such as grid infrastructures, are crucial to keep the necessary balance between supply and demand (IEA 2014; Martinot 2016).

Electricity markets throughout the world were initially designed with a paradigm in which dispatchable resources followed demand requirements. In particular, the Nordic electricity market was designed to balance hydropower resources, which follow a seasonal pattern, with demand. While flexibility isn't a new concept, as contingencies have always existed, the need for it becomes considerably more pressing with the deployment of VRE. This requires rethinking the existing regulatory and market rules with which Nordic and Baltic power systems work. In this regard, the present report has aimed at systematically survey and analysing the framework conditions that currently act as drivers or barriers for flexibility in the region.

We have found that the Nordic power market, which functions well in the present, is the main driver for flexibility in the region. The settlement of energy at different time horizons together with transmission capacity in a single step (implicit auction) under a common set of rules is an important driver for flexibility. Furthermore, interconnection capacity is well-developed throughout the region and a number of projects to keep up with future exchange requirements exist. But because the energy market was not originally designed to handle large shares of VRE, a redesign of certain rules may be called for. For example, establishing gate closure closer to real time, creating rules that increase the liquidity of intraday markets, and broader access to cross-border transmission capacity, are among the topics to be considered.

An element of present concern for flexibility is the merit order effect that VRE supply has on electricity markets. As a result of the typically higher cost of flexible supply, as compared to VRE, flexible plants are less profitable to operate and to invest in. In hours with little VRE generation, security of supply and resource adequacy could be challenged. Thus, an important open question for policy design is if the existing Nordic power market can actually handle this problem without introducing a capacity market.

Regarding regulatory framework conditions, flexibility is not an explicit goal of the existing policy setup and both drivers and barriers exist. For example, the tax reductions and subsidies for conventional flexible plants and biomass used in CHP constitute a driver to maintain and improve the economic viability of these technologies. Such policies are important to prepare the transition toward the activation of new flexibility resources in the region.

In contrast to the subsidies and tax reductions applied to some thermal power plants, there are other direct regulations that limit the technical potentials for flexibility. Hydropower is a case in point. Water and river directive restrictions limit both the deployment and flexible operation of large hydropower plants in most Nordic countries.

Similarly, the role of nuclear power in the region will also have an impact on flexibility. On one side, Sweden has a “nuclear parenthesis” policy, which allows for new facilities to be established or replaced, while increasingly pressing economic conditions for nuclear producers exist, which ultimately translates into uncertainty. Similarly, Lithuania is phasing out nuclear power. However, these developments give room for dispatchable technologies to keep operating, despite the fact that larger shares of VRE tend to depress the price level and the number of hours with prices high enough to operate large dispatchable plants. In contrast to Sweden and Lithuania, Finland plans to add new nuclear facilities, increasing thus the inflexibility of the system and the need of other flexibility resources.

An important potential for flexibility in the region is the coupling of electricity markets with the markets for heat, gas and transportation. However, there is a dissimilar degree of development of such markets throughout the region, and the existing regulatory frameworks are also different and not typically designed to offer flexibility to the electricity system.

Another important potential source of flexibility is VRE producers themselves. This will become particularly evident when even higher shares of VRE materialize in the system. Consequently, it is advantageous if VRE is active in the market and reacts to the system needs for flexibility through market prices. More specifically, RES support schemes should be explicitly linked to market prices and there must in addition be an explicit regulatory incentive for VRE producers to act flexibly. For example, the Danish feed-in premium design in which a certain number of full-load hours, not a fixed number of years, is used to estimate the duration of the subsidy. However, most of the present support schemes are not market based or lack the regulatory incentives to act flexibly.

In relation to demand-side flexibility, regulatory barriers for demand response are mostly absent; as smart meters are being rolled out in most countries and changes are being introduced in retail electricity markets. This paves the way for further developing demand-side flexibility. However, it will be the retail market conditions that ultimately determine what business models will emerge and consolidate. Presently, however, business cases for consumers to be flexible are not clearly present. In that respect, a redesign of the electricity tariffs with an introduction of dynamic tariffs may become a solution to strengthen without distorting the price signal transmitted by the wholesale market and eventually improve the business case for load adjustments. Similarly, prosumers remain a very marginal phenomenon in the Nordic-Baltic region, in spite of the increase in household installations like rooftop photovoltaics. Storage technologies are also very marginal in the region.

Overall, the Nordic-Baltic region has a considerably flexible power system but important challenges lie ahead. Particularly, the ones stemming from the greater reliance on VRE. Consequently, it is of fundamental importance to address the market and regulatory changes that need to be introduced in a timely manner.

6. **References**

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7. APPENDIX 1: Construction of the Survey

In order to collect information regarding country specific drivers and barriers to flexibility in the electricity sector, a qualitative survey questionnaire was distributed to Flex4RES partners in the Nordic and Baltic countries.

The survey first aims at giving a broad representation of the electricity systems in each of the seven Nordic-Baltic countries and provides data of the electricity mix, system organisation, market and unbundling. The survey was designed in order to treat the different actors that are present on the electricity chain.

Then it collects more specific information about:

- The different generation technologies, dispatchable (baseload and pick load) and non dispatchable.
- The grid infrastructures, domestic high (transmission) and low voltage (distribution) grid as well as interconnectors.
- The demand-side, that consists of industrial, businesses and households. Due to the level of detail provided, we aggregated the data relative to businesses and households into a same retail category. For practical reasons, prosumers’ category is filled out in the demand-side.
- And storage related to pumping station and electric vehicles.

The survey was also designed in order to give a photography of current situation as well as to identify future path with respect to the above-mentioned topics. In that respect, we obtain information about current and future situation which is aligned with our objective of depicting short-term operational impact of framework conditions and long-term investment impacts.

8. APPENDIX 2: Country Profiles

This appendix compiles the main outcomes of the surveys completed by the project partners. Each country profile is organised according to a common frame. First is a short description of the electricity mix, then the framework conditions are presented for the supply-side, the demand-side and then for the grid infrastructures. For each of them, we present the market and regulatory barriers and drivers in current situation and point out relevant future aspects of framework conditions impacting flexibility. Due to the different national energy policies or resources, all framework conditions are not present in each country. All technical terms are defined and briefly explained in chapter 3 and the main results are summarized in a table for each country profile.

8.1. Denmark

Toward a flexibility-oriented policy to comply with future energy strategy

Guaranteeing the system reliability is on the top of Danish energy agenda and implementing a “stable framework with flexibility” is clearly stated as part of the key elements of Danish energy policy (Danish Energy Agency, 2016). However, future technical potentials are constrained by the decision to progressively phase-out fossil-fuelled generation capacities. The central role played by grid infrastructures in the management of intermittencies is expected to increase, supported by coherent regulatory frameworks. Other positive regulatory measures such as the support schemes granted to biomass energy and the time-related mechanisms coupled to renewables FIP represent supportive framework conditions for maintaining flexible capacities and subsequent operation.

Category	Relevant technology/actor	Framework condition	Impact
Supply-side			
FP	Conventional plants	Presence of tax reduction / subsidy	
DR	Fossil	Absence of restrictions	
	Hydro	Absence of restrictions	n/r
	Nuclear	Presence of restrictions	n/r
SS	RES	Market-based support	
		Support during negative price periods	
Demand-side			
FP	Industrial	Fiscal measures & subsidies	
DR	Consumers	Roll-out of smart meters	
DR	Prosumers	Net metering	
Grid infrastructures			
RR	TSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	
DR		European funding	
RR	DSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	

Table 8: Main drivers and barriers for flexibility in Denmark.
A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. n/r means the related framework condition does not apply and is not relevant.

8.1.1. Supply-Side

Current Aspects

The generation portfolio in Denmark is characterised by the high penetration of wind. Both onshore and offshore wind turbines contributed to cover more than 42% of electricity demand in 2015 (13 TWh) with an increase of output of respectively 17% and 19% as compared to previous year. Centralised thermal-based power plants have dramatically decreased their output. In 2014, they covered slightly less than 40% of total demand that is a 20% decrease as compared to previous year. Among the fossil plants, coal is the dominant source of generation. It represents 50% of conventional installed capacities. Natural gas and oil-fired power plants account for 24% and 11% respectively. 14% of installed dispatchable capacity (1,370 MW) is based on biofuels and waste. Almost all thermal plants in Denmark are CHP plants and all together covered 11% of total demand in 2014 with a decreasing trend for the last past years.

The most important flexibility resource provided by the Danish supply-side comes from its gas capacities and, to a lesser extent, coal power plants. However future existence of these flexible power plants is jeopardized by the authorities' decision to eliminate the use of fossil fuels in the energy mix. Additionally, current low market prices due to the large share of VRE and the access to low cost electricity from the Nordic countries have contributed to decrease the load factors of domestic flexible power plants. The business case for these technologies is consequently unsatisfactory to incentivise investments.

Biomass energy is also technically suited to be flexible. It is mainly used in centralised plants, mostly CHP, and can, to some extent, be used as a substitute for natural gas. Biomass participation to the market is dependent on market prices. Similarly to other flexible thermal plants, biomass faces a competitiveness issue as compared to coal capacities which translates into lower production.

However, several regulatory-based initiatives are aimed at improving the business case of biomass and act to some extent as drivers to invest into the technology. First, biomass is exempted from taxation which makes it more attractive for market actors to invest in it. Second, the electricity generated by biomass energy receives a 34 EUR/MWh FIP that applies to the first 10 years operation. Consequently, biomass plants receive market signals.

With respect to variable energies, several support schemes have succeeded in Denmark with real success in terms of wind energy development. The support schemes bring different sets of signals with respect to flexibility.

Wind generation receives FIP that is coupled to a yearly full-load hour (FLH) of 22,000 hours (OECD/IEA 2012) after which, wind operators receive the spot price. In 2014, the threshold was reduced to 6,600 hours for the biggest turbines (of 5.6G MWh/m^2 rotor area). At last, a 3 EUR/MWh allowance for unbalances payments due to deviation from the forecasted wind production is granted and the TSO is recognized as the Balance Responsible for wind operators. FIT only remains active for small scale biomass or solar PV technologies, mainly decentralised and marginal in the power mix. The legal status for decentralised generation in Denmark is that a net metering system is in place in order for prosumers to receive financial support for the energy they do not use. However, the measure shows important limitations since the level of the support scheme is perceived too low and eventually incentivises over auto-consumption from consumers.

The funding of RES support schemes is made through the Public Service Obligation (PSO) that corresponds to a per unit fee added on the electricity bill paid by all final consumers. Only prosumers are exempted from paying the PSO on auto-consumed generation.

Future Aspects

The goal of the Danish government is to reach independence from fossil fuels by 2050. Danish Energy Strategy 2050 sets long-term goal of energy policies is 100% renewable energy in Denmark by 2050. Interim goals to a fossil-free economy entail 100% renewable energy-based power and heating sectors by 2035 and full phase-out of coal and heating oil by 2030. By 2030, wind and biomass and waste will become respectively the largest and second-largest electricity generation source. The electricity generated from coal and natural gas is expected to fall by 50% by 2030.

This political decision will eventually deprive Denmark from the most flexible and reliable domestic flexibility resource. However, a positive outcome of this decision is that it can positively impact the development of biomass as an alternative. The main drivers for biomass energy to develop were previously discussed and refer to market conditions and subsidies.

8.1.2. Demand-Side

Current Aspects

The demand-side can participate in all markets on equal terms with generation. Any market actor that sees potential profit in providing load adjustment meets no restriction to provide it (which may involve the need to aggregate decentralised loads). Accordingly, no major market-based barriers are identified in the provision of demand flexibility.

As of today, the most important flexibility resource is provided by industrial consumers. Industrials are also granted tax exemptions on energy and CO_2 and are compelled by flexibility contracts. More than 50,000 Danish industries are part of this programme which represents nearly half of the electricity consumed yearly in Denmark. Despite no regulatory obstacles exist to operate flexibly these actors, the flexibility effectively provided remains low due to low spot prices.

Smaller consumers are not specifically targeted to act flexible due to low load adjustment potentials. This picture may change with the development of heat pumps or electric vehicles but barriers exist that need to be addressed if retail flexibility is to be activated.

First, the large use of flat or seasonal tariffs due to low profitability potential of time-dependent pricing removes any price signal sent from the market. Second, the relatively marginal part of the energy cost in the final bill limits the potential gains to load adjustment. The share of the energy component in the final price paid by an average household is around 5%[1]. Grid tariff accounts for about 25%, electricity charges including PSO is half of total price and VAT the remaining 20%. Accordingly, the potential profitability of load adjustment is marginal.

We also identify good practices to flexibility arising from different sources. First, the obligation from European directive to suppliers to develop time-of-use tariffs is a positive basis to activate the demand-side, provided that market conditions are supportive. Second, the survey shows Danish authorities actively raise awareness among consumers to increase energy efficiency. Large enterprises must carry out energy audits and since October 2015, consumers must receive a simplified bill in order to create awareness to energy efficiency.

Future Aspects

The future phase-out of the PSO system in 2017 should enlarge the relative economic benefits of load adjustment. However, for real reaching substantial load variations, electricity use would have to increase.

Danish authorities have also mandated of full deployment of smart meters by 2020 that should provide the technical basis to develop time-based pricing. In addition, Danish authorities decided to expand the hourly settlement currently in place for larger consumers to retail consumers (fleksafregning). This initiative, considered as “phase 2” of Danish

[1] Based on the electricity prices provided on Elpris platform.

demand-side activation is aligned with more time responsiveness but again, its impact will highly depend on market conditions.

At last, the survey showed that rather than flexible operation there is a potential for process heat fuel shift (to electricity in times of low prices). The total potential is estimated to be around 50.000 TJ per year. Fuel shift options for existing electricity consumption for process heat is estimated to be around 1000 TJ.

8.1.3. Grid infrastructures

Current Aspects

The TSO is traditionally responsible for system upgrades and reliability. In the Danish system that must integrate large amounts of fluctuating energies, the TSO has a direct interest in flexibility provision through grid capacity adequacy. The regulatory regime authorises the TSO to pass entirely its costs in the tariff and no cost reduction is expected along the regulatory period (CEER 2016). Thus, capital investments are not constrained.

The DSOs are much more restricted to capital expenditures. They face a revenue cap regulatory regime that applies to total expenditures. The incentive scheme on total expenditures is identified as a barrier since it increases the investment risk related to grid reinforcements. At last, since 2008, DSOs are bounded to quality objectives. They are financially incentivised to lower the duration and frequency of outages. Provided the financial mechanism is incentivising enough, it can have a positive effect on flexibility in the sense that the operators should have sufficient capacity to operate efficiently its grid with potentially large variations in VRE generation.

Denmark has strong interconnectors with Norway, Sweden and Germany. Total physical export capacity amounts to 5.6 GW and import capacity amounts 4.6 GW, while system peak load is about 6.3 GW.

In particular, the interconnection line with Norway is important for ensuring the integration of the 50% wind power target in 2020. Hydropower plants act as a storage capacity and are necessary to both smooth large domestic wind generation when national demand is low and to provide balancing services. The provision of flexibility through interconnections responds to two parameters; that effective capacity exists and that the allocation of capacity does not constraint flexibility. The survey shows that no regulatory barriers exists that hinder the development of interconnection capacities and the operational rules used for capacity allocation ensure all available capacity is used.

The physical expansion of interconnections is the main determinant for flexibility. The regulatory instruments that apply to cross-borders line investments constitute the relevant element to look at. Since no cost efficiency requirement is applied to this category of costs (CEER 2016), we identify no barriers to flexibility through capacity expansion.

Since Denmark is located at the interface between the Nordic region and Germany, it responds to Nord Pool rules with Nordic countries and to the Central Western European market rules with Germany to allocate cross border capacities.

With respect to interconnection operation, the Nord Pool rules are the same for all Nordic countries that provides positive coordination outputs with respect to flexibility. Despite large interconnection capacity congestion is common, for example, between western Denmark and Norway 61% of the time, and between western Denmark and Sweden, 44% of the time. Generally, bottlenecks are handled by Nord Pool system where flows and prices are determined through implicit auction. The implicit auctions are considered a major achievement for handling imbalances. There is no capacity margin associated with Danish cross border capacities, however, the only exception is between Sweden and Eastern Denmark where a 50 MW Transfer Reliability Margin (TRM[2]) is in place. Otherwise, Danish Net Transfer Capacity[3] (NTC) is equal to Total Transfer Capacity (TTC) (Entso-e 2015). There is no specific interconnection capacity reserved for balancing purposes, meaning that all available capacity is included in the spot market. Residual capacity that is not used in the day-ahead market is given to the intraday market in accordance with the use-it-or-sell-it clause.

Unlike the transmission between other Nord Pool areas, transmission capacity between Denmark and Germany can be reserved through Physical Transmission Rights (PTRs), issued monthly and yearly and coupled to a use-it-or-sell-it clause as well. The rationale of PTRs in this context is to improve hedging possibilities for market participants. Evaluation of the scheme shows that the capacity is used for financial purposes only. Since the use-it-or-sell-it clause is implemented, physical capacities are sold back to the TSO and are thereby available on the spot market where the PTR holder receives the price-spread as compensation (DERA 2015). Therefore this difference is not expected to affect flexibility in the physical system.

Denmark is also offering special regulating power to Germany, meaning that in times of overproduction in Germany, down-regulation can be supplied by Danish plants (e.g. by electric boilers turning on or even wind mills turning off). The compensation for downregulation is higher compared to the regulating power marked (special regulation uses pay-as-bid instead of pay-as-clear), making it a very attractive market to participate in. The high compensation is the result of grid congestion in Germany and the German wind mills not being allowed to offer regulating power services.

Future Aspects

The Danish regulator is currently discussing future regulatory framework to cover DSOs expenses. No official decision was made public so far, but it is expected it supports investments related to more advanced solution to better activate distribution operators.

Additionally, the regulatory agency together with Energinet has developed the Danish “smart grid concept” that aims at establishing a fully functional market for trading flexibility

[2] TRM is a security margin that copes with uncertainties on the computed TTC values arising from: a) Unintended deviations of physical flows during operations due to physical functioning of load-frequency regulation, b) Emergency exchanges between TSOs to cope with unexpected unbalanced situations in real time, c) Inaccuracies, e.g. in data collection and measurements.

[3] NTC is the maximum exchange program between two areas compatible with security standards applicable in both areas and taking into account the technical uncertainties on future network conditions.

products. The report gives the TSO as well as the market players a framework for unused flexibility valorisation. More specifically, it supports future adaptation of technical regulation (frequency stability etc.) in order to support a greater contribution of flexibility resources. Due to the time frame, this is out of the scope of the present study, but it provides an insight on policy orientation toward a more flexible demand. The final aim of the SG concept is for these resources to eventually compete equally with traditional resources.

Several future interconnection projects are underway; between Denmark (DK1) and The Netherlands (COBRA-link); Germany and the UK (Entso-e 2015). Others are being evaluated; between Denmark and Sweden, Germany and the Netherlands. The latter is part of the Baltics-Continental Europe project that will synchronize Baltic countries with European system (Entso-e 2015).

Interconnectors are encouraged by policy makers and the European Union which provides a supportive basis.

8.2. Estonia

Large existing flexibility potentials remaining inactive.

Estonia offers large flexibility resources but lacks instruments to effectively activate them. In the future, existing flexible generation capacities will be reduced in response to the phasing out of aging thermal-based units and growing environmental concerns. It is unclear how Estonia will replace aging facilities. In 2016, the status is that no large new power plants are planned that strengthens the need to enable new flexibility resources. To what concerns the demand-side, inexistent incentives for consumers to act flexible and time-disconnected regulatory schemes applied to VRE are the main barriers to overcome to trigger flexibility.

The role played by interconnections and transmission grids in the provision of flexibility services can be defined as traditional since it only relies on capacity expansion and reinforcement to allocate energy variation. Distribution grid operators located in remote areas are incentivised to provide flexibility through and active operation of the grid.

Supply-side			
FP	Conventional plants	Presence of tax reduction / subsidy	
DR	Fossil	Absence of restrictions	
	Hydro	Absence of restrictions	n/r
	Nuclear	Presence of restrictions	n/r
SS	RES	Market-based support	
		Support during negative price periods	
Demand-side			
FP	Industrial	Fiscal measures & subsidies	
DR	Consumers	Roll-out of smart meters	
DR	Prosumers	Net metering	
Grid infrastructures			
RR	TSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	
DR		European funding	
RR	DSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	

Table 9: Main drives and barriers for flexibility in Estonia.
A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. n/r means the related framework condition does not apply and is not relevant.

8.2.1. Supply-Side

Current Aspects

The Estonian generation mix is essentially based on fossil fuels. Total installed capacity is 2,200 MW[4] among which two thirds are oil shale condensing power plants that covers more than 80% of final demand. Natural gas and biomass energy (mostly used for CHP) represent together 12% of installed capacities and cover 6% and 4% of the demand respectively. Hydroelectricity is marginal and mostly run-of-river with no impact on flexibility. At last, wind energy showed a sharp increase due to the introduction of feed-in premium support scheme. Wind capacity accounts for 13% of total installed capacity and covers 5% of the demand. The future development of wind energy is, however, unclear due to the current regulatory framework.

Due to the technical features of the Estonian mix, the supply-side can provide flexibility services. However, no direct incentive to act flexible was identified and market-based actors see no profit opportunities in current price signals to invest into new reactive technologies.

Estonia uses several instruments to develop renewable energies. First of all, wind energy and biomass are eligible to investment funds to lower upfront costs. Then, all renewable sources receive a FIP. 53.7 EUR/MWh is granted to biomass plants only when operating in cogeneration mode. FIP of 32 €/MWh is offered to electricity production from cogeneration plants operating in a high-efficiency mode which use municipal waste, peat of retort gas as fuel. All cogeneration power plants below 10 MW operating in high-efficient production mode are also eligible for the same FIP. It should be acknowledged that Estonia restricts from the eligibility of FIP the energy produced from biomass in conventional thermal power stations. Only the energy generated by high-efficiency CHP plants fuelled by biomass can be offered the support scheme.

In the case of wind energy, wind output is also offered a premium of 53.7 EUR/MWh subject to an annual production volume cap of 600 GWh. Accordingly, only the first 600 GWh of wind energy generated in the calendar year is eligible for support. The mechanism provides the incentive to reach the cap as fast as possible and in itself is not meant to serve flexibility purposes. Only, after this generation threshold is reached (around December), wind operators only receive the spot price. At last, wind operators are considered balancing responsible (Pöyry 2016).

Future Aspects

The barrier to future flexibility directly comes from future capacity adequacy issues due to too weak investment signals perceived by market actors. The Estonian's installed capacities are expected to decrease severely in the next decade. Large capacities of oil shale-fired plants will proximately be phased-out due to both aging reasons and more stringent environmental considerations. It is expected that installed capacity will drop from current

[4] This figure was estimated by the authors based on the documentation provided by the Estonian TSO (Elering 2016). It sums up dispatchable available capacity, and an estimation of available wind and TSO-operated emergency capacities.

2,200 MW to 1,250 MW in 2024. Meanwhile, yearly peak demand is expected to increase to reach 1,616 MW in 2024 (Elering 2016). No additional capacity investments are expected to be commissioned.

Consequently, the flexibility margin traditionally provided by conventional plants will decrease. In that respect, the New Electricity Market Law currently under discussion shows positive signals should emerge from the future modifications of incentives applied to VRE. The Feed-in Premium should no longer be paid for renewable electricity generated in hours with negative electricity market prices. Complementing the FIP with a floor price is a direct incentive for the operator to avoid generating when market conditions are not favourable and reinforces the link between time and generation. If implemented, this measure should be a major driver to the flexibility provided by wind operators in Estonia. Also, the Law on Renewable Energy is currently reviewing the adoption of an auction mechanism for new wind projects, thus maintaining the link between the payment mechanism and the market.

8.2.2. Demand-side

Estonian consumption shows a slight increase driven by the services sector. Household demand remains stable and the industry consumption shows a slight decrease. Total consumption was 7,440 GWh in 2015 and annual peak demand was 1,553 MW. The number of industries connected to the high voltage grid is very limited in Baltic countries. Thus, their participation to wholesale market is marginal.

Currently, the only signal to act flexible is sent to the biggest, electro-intensive, industries (i.e: whose electricity cost corresponds to 50% or more of total production cost). Their electricity tax is removed which could potentially act as a driver to flexibility since their relative benefit from load adjustments would increase. As of now the effect is limited due to the marginal part electricity excise plays in the final price of electricity (4,47 €/MWh). However, the low spot prices in Estonia reduce any profit opportunities. They face no regulatory barriers to participate in the intraday market, however, no specific financial incentives are provided for them to offer load modulation services. They consequently directly compete with generators and anticipate no profit to act flexible.

At last, the potential for retail consumers to provide flexibility services is significant because of the use of individual electricity heaters and residential heat pumps. One positive decision from Estonian authorities was to mandate a full deployment of smart meters. However, currently no clear flexibility-oriented incentives exist. The two main barriers we identify come from the large use of flat tariffs and the high share of taxes and grid tariffs compared to the energy component in the final bill. The role played by retail consumers remains very marginal.

Future Aspects

Some initiatives can be mentioned that may have a positive impact on the provision of decentralised demand-side flexibility in the future. First, the roll-out of smart meters, expected to be completed by 2017, will provide the technical basis to valorise flexibility. Second, the obligation for suppliers to offer of time-of-use tariffs is a first step to trigger more rational peak vs. off peak consumption behaviours. A third supportive signal comes from the interest in smart grid-related technologies observed through DSM and smart metering trials. However, so far these pilots only refer to first step R&D initiatives and do not have the maturity to activate retail flexibility potentials.

8.2.3. Grid Infrastructures

Current Aspects

We identify two drivers for system infrastructures to provide flexibility services. The first one comes from a supportive regulatory framework to expand and reinforce transmission capacities. The second one comes from the large costs faced by the DSOs to supply consumers in remote area coupled with cost reduction and quality objectives set by the regulator.

In the first case, the TSO, Elering, must comply with traditional reliability and grid development objectives. We do not identify specific regulatory instrument that act as a barrier to the completion of this objective. Elering's capital expenditures are entirely passed through in the tariff which removes the investment risk and allows for a fair revenue out of the investment.

It should be acknowledged that the Estonian regulatory framework applies a deep charging scheme to wind connection, i.e. the wind operators are the ones who support the potential grid construction or reinforcement costs. This scheme transmits a very strong signal to wind operators both in terms of capacity investment and location, and brings insights on the future needs for flexibility. Given that best locations in terms of wind capacity-related connection have been utilized, it is likely wind energy has plateaued. This measure brings negative signals to future VRE investment as well.

The regulatory regime that applies to DSOs is characterised by strong incentives to reduce capital expenditures and improve the quality of service (Ots & Mere 2016). For the DSOs who operate in remote areas, this framework conducted them to choose advanced solutions involving a more active operation of the local grid together with storage or demand-side management instead of grid reinforcements. This setting is a major driver for grid-related flexibility in such remote geographical areas. No direct regulatory incentives were implemented.

With respect to interconnections, Estonia is interconnected with Finland and Latvia[5] and is a net power importer. The capacity is allocated through an implicit auction mechanism. The Net Transfer Capacity (NTC) is used for hourly capacity allocation between Estonia and Finland. The entire cross border capacity is given to Elspot for day-ahead trading and any unused interconnection capacity is offered to Elbas through a use-it-or-sell-it clause. Interconnections are used for balancing purposes only if a margin subsists from the day-ahead usage of interconnection capacities. Empirically however, it is observed bottlenecks on interconnectors during day time and no capacity is used for balancing purposes. The

[5] Interconnection lines also exist between Estonia and Russia but they serve no commercial purposes. They consequently remain out of the scope of the present report

interconnection with Russia does not allow commercial flow and its impact on flexibility is null.

The interconnection to Russia could be considered as a barrier for flexibility in the short term. As a part of the IPS/UPS synchronous system, the frequency in the grids of the Baltic countries is maintained by Russia. Estonia is required to maintain its balance with Russia within 30 MWh/h (30 MWh/h for Latvia as well and 50 MWh/h for Lithuania) and the final imbalance is paid for according to a tariff decided by Russia. The future might bring about a drastic increase in the need of flexibility in this area, because the Baltic countries are looking into decoupling from the Russian AC grid, and would be then only connected through DC links. The exact future of the Baltic grid remains unknown as of this time, but after decoupling, outsourcing the balancing services to Russia will not be an option any longer.

Future Aspects

No evolution of the current regulatory framework was identified for the future regulatory periods.

Estonia status report on interconnection shows that cross-border capacity expansion project with Latvia is underway to anticipate future capacity inadequacy needs and to comply with the European interconnection capacity objective. As such, the European framework to complete the Internal Electricity Market is a driver to interconnection and indirectly to flexibility.

Additionally, European financial participation into the funding of the interconnection line is a main driver to its construction. It is anticipated that the expansion of cross-border capacities between the two countries will provide Estonia with access to hydropower storage capacities in Latvia, and further away in Sweden through the future Kurzeme Ring completion. No additional interconnections are currently planned.

8.3. Finland

A key link between the Nordic and the Baltic countries.

The geographical location of Finland, with proximity to the Baltic states, together with the fact that it is at one end of two existing HVDC interconnections between Finland and Estonia (Estlink1 and Estlink2) make of this country a key link to increase integration between the Nordic and Baltic electricity markets. Technology-wise, Finnish generation is dominated by CHP, which constitutes a vigorous contribution to flexibility. Operated without substantial government support, the main driver for the flexible operation of CHP is given by market conditions. Overall, the main challenge observed stems from the fact that the role of CHP may be outweighed by the future greater reliance of Finland on nuclear power. This, together with the fact that wind power is increasing considerably will potentially boost the flexibility requirements of flexibility originating from Finland. On the demand-side, apart from load size, there is no regulatory restriction for the participation of end-consumers in power markets. On the contrary, an important driver for flexibility is that smart meters have been almost completely rolled out and that a precise set of regulations, which will pave the way for different models of demand-side flexibility, are in place. For example, hourly metering, local access by consumers to data from the smart meter's interface and direct load control capabilities are all mandatory requirements in the Finnish regulation.

Supply-side			
FP	Conventional plants	Presence of tax reduction / subsidy	
DR	Fossil	Absence of restrictions	
	Hydro	Absence of restrictions	
	Nuclear	Presence of restrictions	n/a
SS	RES	Market-based support	
		Support during negative price periods	
Demand-side			
FP	Industrial	Fiscal measures & subsidies	n/a
DR	Consumers	Roll-out of smart meters	
DR	Prosumers	Net metering	
Grid infrastructures			
RR	TSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	
DR		European funding	
RR	DSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	

Table 10: Main drivers and barriers for flexibility in Finland.
A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. A blank cell noted n/a means the data in not available.

8.3.1. Supply-Side

Current Aspects

The two main sources of supply-side flexibility in Finland are CHP and hydropower plants. With a total installed nominal capacity of 16,749 MW at the beginning of 2015, CHP power plants accounted for 7,380 (44.1%), of which industrial CHP added to 18% and DH CHP to 26.8%. Hydropower installed capacity was 3,153 MW (18.8%) and nuclear 2,752 MW (16.4%). The remaining capacity is composed of: condensing power with 1,593 MW (9.5%), gas turbines and engines with 1,161 MW (6.9%), wind power with 630 MW (3.8%) and small scale production (by plants with 1 MVA and less) with 80 MW (0.5%).

By source of generation, of the 82.5 TWh electricity consumed in 2015, nuclear power accounted for the largest share (27.1%), followed by CHP (25%), hydro (20.2%), net imports (19.8%), condensing power (5.3%) and wind (2.8%). Excluding net imports, CHP produced 31.1% of domestic electricity generated, a share that was only exceeded by nuclear (33.3%). This is in accordance with the IEA (2013) which observed that, on average, CHP has accounted for more than one third of total electricity production in Finland, well above the EU average of 10%.

In 2015, under peak load conditions (12,500 MW), 44.8% of generation capacity came from CHP plants. Respectively, DH CHP and Industrial CHP accounted for 26.8% and 18% of the total. Similarly, nuclear power accounted for 22.2%, hydro for 20.2%, and condensing power for 12.8%.

The significant role of CHP in the Finnish electricity sector has been the joint result of a successful incorporation of this technology into both DH and industrial applications, without particularly strong governmental incentives and overall exposure to market conditions. Without mandatory electricity procurement by grid or distribution companies, the only incentive present is through tax subsidies. For example, fuels used in CHP plants received a 50% reduction on their carbon tax (IEA 2013a; Eurelectric 2012). The main drivers for the use of this technology have been and remain to be Finland's demand for heat by industry (particularly forestry and paper) and district heating applications. In an environment characterized by low electricity prices, competing technologies (e.g. P2H) and heat only sources may be more profitable than CHP.

Regarding hydropower, the second largest installed source of generation in Finland, existing regulations regarding technical aspects such as flow rates and basin heights may limit the flexible operation of existing power plants. Aside from direct governmental subsidies for research and development, to which hydropower is eligible, and property tax subsidies levied by municipalities, there are no incentive schemes for hydropower in place. In consequence, market conditions largely determine the flexible operation of hydropower.

Moreover, despite the fact that wind power output remains a negligible part of total electricity output, it is growing rapidly, which is in line with Finland's goal of a 38% share of renewables in its final consumption by the end of 2020. In fact, relative to 2014, installed wind power capacity grew by 59% in 2015 and output from this source increased by 110.8%.

The Finnish RES main support policy is a premium tariff scheme applicable to electricity produced from wind, biogas and biomass (note that although the scheme is indeed a premium tariff, in Finnish energy circles it is referred to as a Feed-in Tariff). According to this scheme, producers are paid an amount equal to the target price (currently set at EUR 83.5 per MWh) *minus* the average Elspot price of the past three months, for a period of 12 years. However, if the average market price of the past three months is below 30 EUR/MWh, the premium is not variable anymore and is fixed to the target price minus 30 EUR/MWh, i.e. 53.5 EUR/MWh. In addition, RES producers are not granted priority access and face full balancing responsibility. Furthermore, heat producers from new CHP plants running on biogas or wood fuels are eligible for a “heat bonus” of, respectively, 50 EUR/MWh and 20 EUR/MWh. Timber chip power plants are also part of the scheme but the payment depends on the price of the emission allowance and the peat tax.

A positive aspect of the policy, which facilitates flexibility, is the exposure of RES to market conditions, albeit to an average market price of the past three months. Despite the fact that the premium is variable in nature (sliding premium), the design exposes RES operators to market signals. However, the mechanism in itself does not incentivise curtailment during negative hours.

Future aspects

With a medium to long term perspective, the development of main relevance for supply-side flexibility is the construction of the Olkiluoto 3 (by TVO) and Hanhikivi 1 (by Fennovoima) nuclear power plants, which are to begin production in 2018 and 2024, respectively. According to the survey, this has the potential of increasing nuclear power plants’ share of output to 40% or more. Another issue of relevance relates to the limited potential for further developing hydropower capacity, given environmental restrictions. Both developments are important because they will likely reduce the overall flexibility of the power system.

In addition, another source of potential impact for flexibility is the re-design of the current RES support scheme, as the existing feed-in tariff system will be discontinued. According to the new energy and climate strategy (approved in November 2016 by the Finnish Government), the new support scheme will be technology-neutral and based on competitive tendering, thus ensuring cost effectiveness and exposure to market conditions. Details are unknown yet but will unfold in 2017. Some of the concrete design options are currently under discussion, and implementation is expected by 2018 (Krogerus 2016). From a flexibility perspective, it is interesting to note that the suggested policy design would take the producer’s flexibility as one of the relevant elements to consider.

8.3.2. Demand-Side

Current aspects

Total electricity consumption was 82.5 TWh in 2015, with the industrial sector accounting for 47% of the total, which is above the corresponding average for OECD countries (32% in 2010). Specifically, the forest industry accounted for 24%, the metal industry for 10%, the chemical industry for 8% and other industries for the remaining 5%. Households and agriculture added up to 27%, services and public consumption had a share of 23% and losses were 3%.

Aside from load size requirements, there is no regulatory restriction for the participation of end-consumers in power markets. In fact, the Finnish TSO and the survey identify as strengths for demand-side flexibility the long tradition of industrial scale consumers in the provision of reserves.

The Finnish TSO reports that at the industrial scale, loads have for a long time participated as reserves and, apart from minimum load limitations which range between 0.1 MW (e.g. for FCR-N) and 10 MW (e.g. for FRR-M), there are no restrictions on the participation of demand-side resources. More specifically, in line with the timeframe of interest for Flex4RES, Fingrid provides a rough estimate that during each hour of 2016 up to 200 MW (in the Elbas) and 600 MW (in the Elspot) of average capacity have been sourced from Finnish demand response.

In contrast to large-scale suppliers of demand-side flexibility, the development of business models for demand-side flexibility, particularly at the small-scale level, remains insufficient. According to NordREG (2015), 8% of Finnish customers have contracts that are linked to day-ahead prices and 54% of customers have variable price contracts.

95% of final consumers already use a smart-meter (NordREG 2015; NordREG 2016). However, it is worth noting that regulation-wise the required roll-out is complete, because the Finnish decree on the matter obliged DSOs to bring 80% of all metering sites within the scope of hourly measurement by 2013. And by the end of 2014, 89% of installed smart meters were used for balance settlement (NordREG 2015; THEMA 2015). Regarding functionality, Finnish requirements are precise and open the possibility for the development of demand response. First, installed smart-meters must be (technically) able to measure consumption every 15 minutes although hourly metering is mandatory. Furthermore, it is a requirement that remote load control is enabled, and data are collected on a daily basis, while providing the consumer direct access to data via the smart meter's interface, as opposed to the DSO only.

Thus, third party access by energy service providers, aggregators, technology providers is facilitated. As in the other Nordic countries, the participation of third parties in marketplaces implies balancing responsibility and suppliers are not obliged to offer hourly prices to their customers. Similarly, direct load control by the DSO, who could design its tariffs to compensate load interruptions is also an open possibility.

In relation to micro-production, Finland has - among Nordics - the highest threshold in relation to what is considered to be output from distributed sources for consumer use. The fact that existing smart meters in Finland are required to deliver hourly metering and are able to measure power both *from* and *to* the grid imply that existing devices are able to support micro-production, without having the requirement to further upgrade existing technology. In addition, as long as the site remains a net consumer, normal connection fees for consumption apply. Furthermore, there are tax exemptions in relation to the electricity sold to the grid.

Future aspects

On the demand-side, the main developments of future relevance are on the focus placed by Finnish regulators and policy makers to further develop the retail market. Its participation in eSett, a common framework for imbalance settlement together with Sweden and Norway, and the development of a centralised IT solution (DataHub) paves the way for a common Nordic retail electricity market, while facilitating the development of demand response.

8.3.3. Grid infrastructures

The Finnish model of regulation is ex-ante revenue cap for operators of the transmission and distribution networks. Accordingly, the regulator defines a reasonable revenue cap but does not introduce specific guidelines in the tariff design. While this framework provides certainty for the revenue side, cost uncertainty is not entirely removed, thus potentially disincentivising grid expansion. However, innovation and quality of service are explicitly incentivised.

Because the regulator does not have direct say on the tariff structure, Fingrid applies a seasonal consumption fee, which increases in the daytime during winter weekdays. Other fees, i.e. for input, output and capacity are neither time nor location-dependent. At the distribution level, there is no time dependency of tariffs. Except for the smallest scale consumer group (2000 kWh/year), tariffs have decreased for all groups. However, the fixed part of it has increased across all customer groups between 2010 and 2015.

In summary, the grid tariff structure does not explicitly account for flexibility. The structure of grid tariffs does not hinder flexibility but it does not enable it either, as there is not a specific mandate for flexibility in their structure. At the transmission level, like its Nordic counterparts, Finland has a point-of-connection approach but price signals are not locational and only account for seasonal changes. At the distribution level, there isn't a clear mandate for flexibility. However, it is worth noting that among the Nordics, Finland has – on average – the highest share of electricity prices on the final consumer's electricity bill and DSO tariffs account for less than 30%.

Regarding interconnections, the Finnish system is interconnected with Sweden, Norway, Estonia and Russia and serves as an essential link between the Baltic States and the European electricity market. According to ENTSO-E (2014) and EC (2015), it has 30% of interconnections as a share of it installed capacity, well above the EU's 10% interconnection target.

Cross-border transmission management differs from country to country but a set of common rules to the Finnish interconnections with other Nordics apply (Fingrid n.d.).

But it is Finland's participation in the well-established Nord Pool market arrangements what drives the flexible operation of interconnections, favouring the Nordic power balance while accounting for potential transmission bottlenecks.

8.4. Latvia

High policy and regulatory uncertainties that impede flexibility initiatives.
The actual provision of flexibility services is left to current market prices and largely depends on the level of water in Latvian hydropower plant reservoirs. On the medium to long-term, severe capacity inadequacy is likely to occur in Latvia. The main drivers we identify with the development of interconnections are linked to the European IEM plan. The first driver is the obligation to comply with the 10% interconnection capacity. The second major driver is the direct financial support provided by the European Energy Program Connecting Europe Facility programme.

Supply-side			
FP	Conventional plants	Presence of tax reduction / subsidy	
DR	Fossil	Absence of restrictions	
	Hydro	Absence of restrictions	n/a
	Nuclear	Presence of restrictions	n/a
SS	RES	Market-based support	
		Support during negative price periods	
Demand-side			
FP	Industrial	Fiscal measures & subsidies	
DR	Consumers	Roll-out of smart meters	
DR	Prosumers	Net metering	
Grid infrastructures			
RR	TSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	
DR		European funding	
RR	DSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	

Table 11: Main drivers and barriers for flexibility in Latvia.
A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. A blank cell noted n/a means the data in not available.

8.4.1. Supply-Side

Current Aspects

Latvian power mix is largely based on hydroelectricity capacity with three hydropower stations that represent 55% of Latvian capacities and gas-fired plants (36%). 5% is renewable energies (wind and biomass) and the remaining 4% consists of mixed fossil fuels technologies. Nearly half of the energy generated in 2015 came from thermal-based power plants and 34% from hydroelectricity but this rapport can be inverted in accordance with the level of available water in the hydro plants. Biomass participation is also significant. It covered 14% of the demand in 2015 and wind energy remains marginal (3%). Total installed capacity is 2,900 MW of which 30% to 70% is recognized as “reliable available capacity” throughout the year (Entso-e n.d.).

The Latvian mix is technically adapted to provide flexibility. As revealed in the survey, no specific incentives are designed to support the provision of flexibility by generators. The Nord Pool spot and intraday market prices (Latvia entered the Nord Pool markets in 2013) are the principle signals received by dispatchable actors.

Particularly, gas-fired plants are mostly dispatched for load following during peak events and are used as reserve capacities. Hydroelectricity provides modularity services but also involves generation uncertainties due to yearly hydrometric variation. It is estimated total generation from hydro resource can vary between 1,800 and 4,600 GWh per year (Rasmussen 2003). This feature increases the need for guaranteeing available capacities as much as it involves important revenue risk for potential investors. A side effect derived from the level of water in the reservoirs is that it can limit the generation of electricity via cogeneration systems (Enefit 2014) and represents an exogenous barrier for the provision of flexibility. Accordingly, Latvia must highly rely on importations to ensure its balancing throughout the year. In 2013, 20% of Latvian energy was imported.

Some regulatory initiatives send supportive signals for flexibility-oriented investments but are not completed by specific measures to operate the resource flexibly. A tax exemption is granted to electricity produced in CHP plants using natural gas and oil products. Market actors receive an investment signal aligned with investments in flexible generation units. However, the tax exemption needs to be supplemented by additional measures to effectively activate the flexibility resource.

Contradictory mechanisms are in place to support RES penetration that bring controversial signals and reflects the authorities' first objective to control the increase of electricity prices[6]. Feed-in-tariffs were implemented to promote renewable energies and CHP. However, concerns about corruption and a lack of transparency in the attribution of the support (EurObserv'ER 2015) led to its suspension for new entrants and to the implementation in 2014 of a new tax paid by existing VRE and CHP operators in order to limit their revenue.

Future Aspects

On the medium to long-term, severe capacity inadequacy is likely to occur in Latvia. Market conditions do not bring sufficient incentives for capacity replacement. This situation could potentially support the development of more flexible solutions, particularly to cope with peak load. However, no incentives are currently discussed.

In 2015, the Latvian TSO issued a forecast on future generation capacities development until 2025 (AST, 2015). The report shows up to 1,000 MW capacity investments is expected, coming solely from small-scale decentralised units (<40MW). Wind and gas-based units should account for half of future developments each, of which gas-fired cogeneration should represent 15%. There are also investments planned for the modernization and reconstruction of existing large hydropower stations, but no investments are planned for the construction of new capacities.

[6] Latvia's electricity prices increased significantly with the introduction of FIT (by 36.5% for domestic and 43% for industrial use).

The future of RES in Latvia is highly uncertain. The estimated potential of wind power can reach 1.5 TWh onshore only, but currently only around 95 MWh are generated annually. The authorities are awaiting the outcome of a State Aid case (SA. 37970) on FIT before proceeding with designing a new support framework. This implies that investments in many new projects are currently on hold.

8.4.2. Demand-Side

End-use electricity demand in Latvia is increasing faster than in most European countries with a large share consumption coming from non-household sectors. Final electricity consumption raised by 35% between 2000 and 2010 due to a growing use of electrical appliances (Ecologic Institute 2014). Final consumption (with losses) was 7.2 GWh in 2014 that is 4.2% more than previous year. Maximum peak load in 2014 was 1,316 MW and shows a decrease trend since the 2009 crisis but is expected to grow steadily again (Latvian Minister of Economy, 2015).

The number of industries connected to high voltage grid is very limited in Baltic countries and their participation to wholesale market is null or marginal. Similarly to the rules that apply to the supply-side, no direct incentives to act flexible exist for manufacturers although Latvia is considered as one of the most energy-intensive country in Europe (OECD, 2015).

However, one driver emerges from the recently adopted Regulation n. 395. This measure allows since 2016 manufacturers to reduce their participation to the Mandatory Procurement scheme[7] and acts as a tax reduction on the electricity bill (Cabinet of Minister 2015). Along the proceeding, the tax reduction was extended from the largest industrials (> 10GWh/year) to smaller manufacturers of 0.5 GWh/year. This measure potentially provides a basis to benefit from load adjustments if demand response programs are developed.

There are no studies conducted in Latvia that estimate the flexibility potentials in residential sector. However, it is acknowledged to be marginal since the main resource for individual heating is fuelwood. Latvia also uses district heating for households and businesses. Accordingly, the rules that apply to CHP are relevant here.

At last, prosumers are originally granted a FIT and the Latvian Electricity Tax Law implemented a tax exemption for autonomous generators of less than 2MW. Latvia also uses net metering system to measure the output of prosumers. By Electricity Market Law, prosumers are excluded from the price of electricity in the case the amount of supplied electricity to the grid is equal with the amount of electricity consumed from the grid, but all the remaining taxes are payed as for regular electricity consumer. The fact that the grid charge still applies to self-consumed energy pushed in some cases decentralise operators to install on-site accumulation systems and acts as an indirect flexibility driver.

[7] The Mandatory procurement component compensates additional expenses of the public seller (JSC Sadales tīkls) caused by purchasing electricity produced by cogeneration power plants by using renewable resources.

Future Aspects

Latvia decided to roll-out smart meters, but except from the obligation from the European Directive to offer time-of-use tariff to end consumers, no measure is being developed to trigger flexibility in using this device. Additionally, the survey revealed the time of use tariff doesn't incentivise load shedding due to too low price spread between base and peak periods (Bariss et al., 2014).

8.4.3. Grid Infrastructures

Current Aspects

The main driver for transmission and distribution system flexibility is derived from their obligation to ensure efficient supply continuity and quality of service. The TSO and the DSOs are bounded by a financial penalty of 10% from net turnover of the previous year if they do not ensure sufficient planning construction and connection of new installations (Electricity Market Law). This measure consequently acts as a direct driver for the operators to invest into grid capacity.

The security of supply is further strengthened by the European single electricity market integration. Accordingly, Latvian transmission grid is undergoing important investments to anticipate future interconnections with neighbouring countries in reinforcing and/or expanding national high voltage lines to cope with future interconnection developments.

Grid operators also perceive two additional supportive incentives. Firstly, they receive a financial incentive to comply with SAIDI[8] reduction objectives. The compliance with more stringent performance objectives are perceived as favourable to a more flexible operation of the grid. Second, smart meters should be fully deployed by 2023 and should provide the technical basis to develop demand response programs. However, no clear initiatives are dedicated at operating actively the distribution grids and the lack of R&D incentives is identified as barrier.

With respect to cross-border interconnections, Latvia is interconnected with Estonia, Lithuania and Russia and new or reinforced interconnections capacities are expected along with the integration to the European system. The main drivers we identify with the development of interconnections are linked to the European IEM plan. The first driver is the obligation to comply with the 10% interconnection capacity compared to installed generation capacity (European Commission 2016). The second major driver is the direct financial support provided by the European Energy Program Connecting Europe Facility programme.

In 2013, a first common basis to operate cross-border lines was brought by the agreement on Common Calculation of Capacity Allocation signed between the Baltic countries. Capacity is allocated through implicit auction.

[8] System Average Interruption Duration Index.

Congestion constraints together with internal generation cost determine the market conditions to invest into cross-border interconnection lines. Since Latvian generation costs vary with hydropower resource, the low availability of hydropower plants acts as an exogenous driver to strengthen interconnections.

The money accumulated from the income of balancing costs, by the decision of the Public Utility Commission is used for the co-financing of the 3rd interconnection between Latvia and Estonia and for the upgrading of existing transmission networks.

Future Aspects

One project is currently underway in Latvia. The 3d Interconnection line between Latvia and Estonia that is identified as key flexibility enabler and a precondition for off-shore wind development in the region.

8.5. Lithuania

Interconnections at the core of the power strategy.
Currently no direct incentives are identified for the supply or demand-side to act flexible and market prices are distorted by Russian exports. It is expected that distancing from Russia's export would restore electricity prices and provide more suitable incentives to future technology mix. Regulatory frameworks that apply to transmission and distribution operators are coherent with the provision of VRE-oriented flexibility. At last, interconnectors are perceived as the present and future key enabler to flexibility in Lithuania.

Supply-side			
FP	Conventional plants	Presence of tax reduction / subsidy	
DR	Fossil	Absence of restrictions	
	Hydro	Absence of restrictions	n/a
	Nuclear	Presence of restrictions	
SS	RES	Market-based support	
		Support during negative price periods	
Demand-side			
FP	Industrial	Fiscal measures & subsidies	
DR	Consumers	Roll-out of smart meters	
DR	Prosumers	Net metering	n/a
Grid infrastructures			
RR	TSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	
DR		European funding	
RR	DSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	

Table 12: Main drivers and barriers for flexibility in Lithuania.
A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. A blank cell noted n/a means the data in not available.

8.5.1. Supply-Side

Current Aspects

In 2013, total installed capacity in Lithuania was 4,300 MW (of which 3,400MW available capacity) (Litgrid 2015). The power system is 90% based on gas-powered plants capacities of which reactive gas turbines and combined cycle account for 20%. Since the phasing out of its nuclear power plant in 2009, Lithuania substituted base load generation by an increase of gas generation, RES and a massive increase of imported energy from neighbouring countries, notably from Russia. This is an important feature in the Lithuanian power market. Since Russian electricity prices are subsidized, they distort domestic market prices with critical impact on future investment signals. Imports presently cover in average 2/3 of yearly Lithuanian demand. The trading balance between Lithuania and neighbouring countries translates high generation costs in Lithuania rather than a capacity adequacy issue.

The Lithuanian power mix is technically suited to provide flexibility and since 2013, the country participates in the Nord Pool spot and intraday markets. However, the generation mix is too costly to be fully operated and shoulder and peak generators face severe missing money issues. The rejection by civil society to build a new nuclear power plant hindered significant base load capacities from being phased-in, which leaves more generation opportunities to flexible power plants.

In addition, part of the Lithuanian PSO that is financed by all electricity consumers and paid to the electricity suppliers is allocated to the funding of thermal reserve capacities. The PSO consists here of a supportive framework condition to maintain the profitability of these flexible units (NCC 2016).
The penetration of RES energies has progressed since Lithuania implemented dedicated support schemes. In 2015, RES energies covered 11% of final demand (Entso-e 2016). The PSO budg*et al*located to reserve capacities in 2016 was 20%. However it should be acknowledged uncertainties come with reserves funding that may interfere with the incentive. The Lithuanian regulator shows important discontinuities regarding this funding. Over the 2010-2016 timeframe period, the PSO only participated in the reserves financing in 2013 and 2016 and represented 1.6% and 16% of total PSO budget respectively.

The penetration of RES energies has progressed since Lithuania implemented dedicated support schemes, also funded through the PSO. In 2015, RES energies covered 11% of final demand (Entso-e 2016).

FIT is the dominant scheme used to support the development of all RES in Lithuania including biomass and wind energy. It is set by the authorities for less than 10kW units and granted through tenders above this threshold. RES producers may also apply for grants to lower upfront costs from the Lithuanian Environmental Investment Fund (LEIF) and the Fund for the Special Programme for Climate Change Mitigation, but cannot cumulate the both FIT and access to the funds which brings a potential negative signal to RES investors. then, RES operators are exempted from excise tax (RES Legal 2016).

One particular feature in the Lithuanian support scheme is that the FIT is only granted for the first 50% of the energy generated yearly by the less than 10kW units and until a given volume cap is reached for larger units. This measure shall apply at least until 2020 meaning that only a limited amount of electricity produced with a particular technology will be supported through the feed-in tariff scheme.

At last, the FIT received by less than 10kW units may change every quarter and is only granted for half of the production generated on a yearly basis. The rest is considered as auto consumption. A net metering system comes with the measure to monitor the level of generation. The quarterly tariff reset, together with the net metering obligation, may potentially provide a seasonal incentive to invest into biomass units and provide flexibility services provided that the FIT is correlated to quarterly average market prices variations. However, we observe empirically that the FIT progressively decreases (NCC 2016). As designed, the support measure translates a cost reduction objective of the subsidy and to a large extent, does not support the provision of flexibility. At last, these operators are exempted to pay the Public Service Obligation charge for auto-consumed electricity.

At last, the survey shows the complexity of incentive schemes and numerous regulatory changes in the last past years. This created high institutional uncertainties to RES investors. Accordingly, future developments of RES in Lithuania may be delayed.

Future Aspects

Very marginal future power capacities are expected to be commissioned by 2024. Most of expected new connections are mainly wind and biomass units and some development scenarios mention capacity extension to existing hydro pumping station. 40% to 50% of current thermal-based capacities are expected to be decommissioned on the same time period. According to Lithuanian TSO, Litgrid status report, Lithuania should account for 2,700 to 3,250 MW total available capacities in 2024[9]. Future demand should reach 13 TWh in 2024 according to baseline scenario and peak load should be 2,200 MW (Litgrid 2015).

These figures tend to show that Lithuania will not be facing a capacity adequacy issue but is likely to keep being confronted with missing money issues, potentially impacting negatively the existence of flexible technologies. Future synchronization with the European system together with the harmonization of balancing settlement currently under preparation should move away Lithuania from Russian imports and restore market prices.

8.5.2. Demand-Side

Current Aspects

Final demand and losses was 10.5 TWh in 2013 and maximum peak load was 1,810 MW. The demand increases steadily. Both households and the service sector account for 30% of total energy consumed and the industry accounts for the remaining.

[9] This figure is based on the authors' estimation. It corresponds to Litgrid forecast in 2024 minus the expected capacity of Visaginas nuclear power plant (Litgrid 2015). New nuclear power plant project receives negative opinion from civil society and was dismissed.

The number of industries connected to high voltage grids is very limited in Lithuania and the rest of Baltic countries and their participation to wholesale market is null or marginal. Important efficiency gains potentials are however identified for manufacturers but no direct drivers for demand-side flexibility are identified. The only supportive signals for industrial consumers come from a tax exemption and the large share of the energy cost in their final bill. Both are considered supportive as they would improve the potential profitability for them to provide flexibility services if appropriate incentives to act flexible are implemented.

At last, households and businesses keep facing flat tariffs and have recently seen the fixed part of their electricity bill increasing due to grid costs and the PSO charge. However, since the PSO contributes to fund the balancing of VRE in Lithuania it is considered a driver to VRE-related flexibility.

Future Aspects

No major flexibility-oriented initiatives were identified. Lithuania is currently undergoing smart meters pilot projects that should be used as a basis to perform the cost-benefit analysis and decide on large-scale deployment.

8.5.3. Grid Infrastructures

Current Aspects

Power infrastructures are currently playing a key role in Lithuania with respect to flexibility. We observe a boom of investments for the last years and recent changes in the regulatory framework that introduced a price-cap on OPEX in 2013 (NCC 2015). Accordingly, both transmission and distribution operators receive an incentive to lower their operational costs but are not constrained regarding capital expenditures and balancing costs that are passed through in the tariffs.

Investments on the transmission grid increased by 67% between 2013 and 2014 (NCC 2015). Until 2025, further investments are expected that will be allocated in three main categories: System Reliability; ICT and Strategic Power System (Litgrid 2015). The projects necessary for the “system’s reliability” refer to grid expansion, reconstruction and reinforcement. They have the double role of ensuring adapted national infrastructures to cope with future interconnections and domestic load increases. The “ICT projects” category refers to transmission system upgrading and involves automation technologies. The “Strategic Power System” category refers to interconnection projects.

The direct pass through in the tariffs of these costs is identified as a regulatory driver since it supports investments that will provide a robust basis to flexibility services. It should be noted however that based on cost repartition data, we note that the ICT project share remains marginal. It solely accounts for 1.4% of total Litgrid expenditures along the next 10 years against nearly 25% for classical grid reinforcement (Litgrid 2015). The focus on grid capacity addition is aligned with the development of VRE since one of the main factors hindering their development currently identified is the lack of transmission capacities. In that respect, the regulatory decision to grant priority access to VRE act as an indirect driver to improve transmission and distribution capacity availability

Several performance targets with a financial penalty/reward mechanism. Three indicators[10] reflect the system outages and are identified as drivers to flexibility (NCC 2015). However, since implementation in 2009, the TSO's performance has improved the first couple of years but seems to have reached a plateau since then. This situation may translate unsuitable financial incentive schemes or a technical inability to further improve the quality of service in current transmission infrastructure state.

The survey shows the development of interconnections receives strong institutional support from both national policy makers and E.U. legislation that both act as a supportive institutional framework. Direct access to the Scandinavian market is provided by the interconnection between Lithuania and Sweden. The link to the Central and Western Europe is given by the interconnection between Poland and Lithuania.

Even though Lithuania is very dependent from third countries imports, the survey shows imports are decreasing from them while imports from Finland are slightly increasing. Currently, the main limit to imports from Nordic countries in Lithuania is due to the bottlenecks on the Latvian-Estonian interconnection.

The funding of interconnections project by the European Commission to integrate Lithuania to the European market represents a major supportive framework condition alongside the regulatory framework. With respect to the handling of bottlenecks, an explicit auctions mechanism is in place and Lithuania uses a reliability margin with the use of interconnector capacity that is aligned with the provision of flexibility services.

Future Aspects

The regulatory instruments and mechanisms reviewed in previous section should remain active during the current and next 5 years regulatory period (until the end of 2014). No other future drivers or barriers were identified.

Two interconnection projects are of key importance to fully integrate Lithuania to Eastern power markets. The cross-border electricity transmission line NordBalt that connects Lithuania and Sweden and the LitPol Link between Lithuania and Poland. The latter project clearly states VRE integration as a key objective of the interconnection line. It consequently has a key role to play in future flexibility of the Baltic area.

The Baltic Corridor project will enable new interconnection between Estonia and Latvia and Latvia and Lithuania by 2030. These interconnections are also considered a precondition to the future integration of off-shore wind parks in the Baltic Sea (up to 1,200 MW).

and NordBald projects both receive important funding (up to half the final cost) from the European CEF fund. European funding is identified as part of the most central driver to Baltic integration and flexibility. The income received by TSOs for imbalances are used to

[10] The END reflects the actual quantity of the electricity not delivered due to interruptions in transmission network. The AIT shows the average duration of interruptions in transmission network. The SAIDI sets targets to improve the system average interruption of duration index. The SAIFI is also applied but due to its <1 hour activation timeframe, it remains out of the present study.

expand trans-border capacities. As a consequence, the regulatory rule that applies to balancing expenses (see previous section) is well suited.

At last, the trans-national capacity allocation through explicit auction is being reviewed by the Lithuanian regulator (NCC 2015) . This brings uncertainties and possible harmonization losses with neighbouring rules that could act as barrier to flexibility provision in the future if implemented.

8.6. Norway

The hydropower house of the region.

By several measures, Norway is a world-leading country in hydroelectricity. With vast resources at its disposal, the main driver for its flexible operation is in its participation within the Nordic electricity market through well-developed interconnections. Norway's ability to supply flexibility largely depends on seasonal aspects. In dry years, Norway tends to be a net importer whereas in wet years it is a net exporter, but the volume of trade with neighbouring countries is always significant and highly correlated to short-term system conditions. However, the survey and the secondary sources of information reveal that it lacks a sufficiently diversified supply-side, in which natural gas-fired power plants could play a more relevant role. In accordance with its commitment to develop Carbon Capture and Storage (CCS), the Norwegian government bans the construction of any new natural gas fired power plants unless a CCS solution is in place, effectively limiting the potential for other sources of supply-side flexibility other than hydropower.

On the demand-side, given the fact that Norway has such a high level of consumption per capita which stands at the top of all IEA member countries, there is an important potential for flexibility. Based on the primary and secondary information surveyed, there are no regulatory barriers present that prevent the activation of a more active demand-side. However, the role of demand-side is not sufficiently developed so far.

Supply-side			
FP	Conventional plants	Presence of tax reduction / subsidy	n/a
DR	Fossil	Absence of restrictions	
	Hydro	Absence of restrictions	
	Nuclear	Presence of restrictions	n/a
SS	RES	Market-based support	
		Support during negative price periods	
Demand-side			
FP	Industrial	Fiscal measures & subsidies	n/a
DR	Consumers	Roll-out of smart meters	
DR	Prosumers	Net metering	n/a
Grid infrastructures			
RR	TSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	
DR		European funding	
RR	DSO	Elimination of investment risks	
RR		Flexibility-friendly performance targets	

Table 13: Main drives and barriers for flexibility in Norway.
A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. A blank cell noted n/a means the data in not available.

8.6.1. Supply-Side

Current aspects

The Norwegian technology mix is, essentially, composed of hydropower. Not only is this the main source of supply-side flexibility in the country, but it also constitutes an essential element of the flexibility it can provide to the whole Nordic and Baltic region through the existing interconnections.

In 2014, peak load was 33,697 MW, and hydro accounted for 31,240 MW (92.7%) of the total, followed by thermal with 1,597 MW (4.7%), and wind with 859 MW (2.5%). Total electricity production was 142 TWh in 2014, of which 95.9% (136.2 TWh) was hydro, 2.5% was thermal (3.6 TWh) and 1.6% (2.2 TWh) was wind.

The main driver for the flexible operation of hydropower is through market conditions, and the availability of flexibility from Norway's hydro resources mostly depends on seasonal factors. In rainy years, Norway is a net exporter, as has been the case between 2011 and 2014. During dry years, Norway becomes a net importer of electricity, as it was the case in 2004, 2006 and 2010. With a shorter term perspective, Norway tends to import during the night and on weekends, while it exports during daytime on (IEA 2011).

Aside from hydropower, other sources of flexibility in the Norwegian electricity system are essentially absent, despite the substantial availability of natural gas, which would favour the development of technologies such as CHP and CCGT. Currently, there are three natural-gas fired power plants in Norway, two of which operate way below full capacity and one is kept as cold reserve, but is expected to be permanently shut down.

The use of fossil fuels in the Norwegian electricity system appears as a controversial topic and a ban against the construction of new gas-fired power plants exists, unless CCS is utilized. The Norwegian government has a strong commitment to developing CCS technology and indeed, the IEA 2011claims that Norway is home to two of the five largest CCS projects in the world, i.e. Sleipner and Snøhvit. In accordance with this, the Norwegian government bans the construction of any new natural gas fired power plants unless a CCS solution is in place. The IEA 2011 points out that while it is reasonable to limit the role of carbon-unabated technologies in the system, the policy is costly because CCS still is not a sufficiently mature technology, but also because the seasonal patterns of electricity of Norwegian trade with its neighbours imply higher emissions elsewhere, e.g. from coal-fired power plants in neighbouring countries. Furthermore, with a flexibility perspective, the existence of such a policy impedes diversification and adversely affects security of supply.

Since 2012, Norway operates an electricity certificate system jointly with Sweden, which offers support to wind, solar geothermal, biogas, biomass and hydro. It was established with the goal of jointly increasing RES-E output by 28.4 TWh per year until 2020. The initial agreement was for Norway to finance 13.2 TWh/year, and for Sweden to finance 15.2 TWh/year.

Wind power plays a minor but increasing role in the Norwegian power system, lagging behind Denmark and Sweden. Compared to 2010, when there were 14 power stations and a rated output of 425 MW, at the end of 2014 there were 25 power stations and up to 859 MW were supplied from windmills.

Finally, it is worth mentioning that DH is a small but growing business model in Norway which could increase flexibility, provided that market conditions make of it a profitable option. Compared to 2008, the DH network has doubled in size. In 2015, approximately 10% (0.8 TWh) of heat was sourced from electric boilers and large heat pumps. As a share of gross production, 6.6 % (0.44 TWh) was delivered for the production of electricity. For further details on DH in Norway, the interested reader is referred to (Sneum Møller et al., (2016).

Future aspects

In a recent energy policy whitepaper (Norwegian Government 2016), the Norwegian government has announced that it expects to abandon the certificate market by the start of 2021, by not issuing new targets beyond that date. One of the reasons behind the decision is the decline in electricity prices which, according to the Norwegian government, has jeopardized the value of existing renewable production, i.e hydro. Despite the fact that it remains unclear what kind of support policy, if any, will substitute the certificate system, the government has reinforced the relevance of wind power in Norway's energy strategy.

Moreover, the whitepaper signals more government support for innovation and less focus on mature technologies. This rather imprecise policy focus can mean a myriad of possibilities which may or may not increase power system flexibility in the future. On a positive side, however, the government explicitly mentions flexibility as a desirable characteristic of the power system and expressed its interest in increasing the predictability of supplies for the hydropower industry, while accounting for environmental restrictions

8.6.2. Demand-Side

Current aspects

According to the IEA (2015), in 2013 Norway had the largest electricity consumption per capita among its members with 23,324 kWh. Such a figure sends the clear message that demand is one of the most important resources to enable flexibility in Norway.

Putting electricity consumption in the context of overall energy consumption allows depicting an even clearer picture of how relevant electricity is in Norway's energy demand. In 2015, final energy consumption (excluding raw materials) in all sectors of the economy added to 213 TWh. Industrial consumption of energy was 67 TWh, transport-related consumption was 57 TWh, while the group conformed by "other sectors" (which includes the service industries, households, agriculture and fishing) accounted for 89 TWh. In the industrial sector of the economy, more than two-thirds of the total energy consumption was electricity, while in the "other sectors" more than 70% of consumption was electric. In the transport sector, although fossil fuels remain dominant, the fleet of electric vehicles increased sharply standing at 69,000 privately-owned units at the end of 2015.

Statistics Norway estimates total consumption of electricity standing at 117,057 GWh in 2014, of which 3,418 GWh, i.e. 3%, is considered flexible. According to Statistics Norway's definition, flexible consumption refers to power that can be stopped in the event of limited net capacity.

According to the aforementioned figures, the main source of demand-side flexibility is in the power intensive manufacturing sector, which added to 981 GWh (29%) of total flexible consumption. Specifically, the chemical industry and the paper industry accounted for the largest shares. The second largest group with flexible consumption was "construction and other services", which added to 806 GWh. The third largest source of flexible consumption is in the sector named as "various supply and remediation activities" which accounted for 713 GWh (21%). Unsurprisingly, this statistical category contains "steam and air conditioning supply" as the single largest category for flexible consumption. In order of relevance, the remaining sources of flexible consumption in 2014 were manufacturing with 593 GWh (17%), private households and agriculture with 306 GWh (9%) and transportation and storage which added to 19 GWh (1%).

Regarding smart meter roll-out, as of February 2016, 5% of Norwegian customers had these devices (NordREG 2016). According to the existing Norwegian regulation, there is a deadline for full smart-meter roll-out at early 2019. Moreover, the regulation is specific regarding technical requirements, which includes 15-minute measurements (although actual measurement happens hourly) with daily collection frequency, the possibility for direct load control, and local access directly from the meter by the consumer. Third party access to data is also allowed for, provided that authorization from the consumer is given. The existence of such specific regulations constitutes an important driver for demand-side flexibility.

In addition, 56% of customers have contracts linked to the Elspot price, i.e. a monthly average price plus an add-on in NOK/kWh or NOK/month. 39% of customers have other variable price contracts in which the price is not directly linked to the Elspot price, i.e. the price changes every week, every second week, etc.

In addition, the Norwegian regulator has since 2010 simplified the processes related to end-use customers that generate electricity for their own consumption, i.e. prosumers who sell surplus electricity to the network during certain hours pay a simplified input tariff (NVE 2016). Surplus electricity generated at a customer's site can be purchased by the network company and the consumer pays a simplified input tariff. However, it is not mandatory for the network company to do this. In addition, there is net metering: consumption is deducted from the local micro-generation that is locally consumed.

8.6.3. Grid Infrastructures

Current aspects

As in the rest of the Nordic countries, Norway applies a point-of-connection approach. The usage component of the tariff depends on a locational charge for marginal losses to all users of the system. To reflect changing system conditions, loss factors are recalculated on a weekly basis and are differentiated according to two periods: weekdays and night/weekends, thus accounting for the time variations (Entso-E 2016). The fixed component of tariff covers customer-specific and network costs not covered by the energy use component.

One additional difference in relation to other Nordic countries is that the regulator does have somewhat more influence on the structure of grid tariffs at the distribution level. However, the implications for flexibility are not entirely clear. In particular, consumers with hourly measurement may be offered tariffs that depend on the following elements: a fixed charge, an energy component and a capacity component. The first of these must cover specific costs associated to the customer as well as a share of fixed grid costs. The second must cover marginal losses but can also be used to cover other kind of costs. Finally, the capacity component of the tariff must cover the customer's use of power over a pre-defined period.

Among the Nordics, Norway has the lowest fixed part of the DSO tariff. On average, the variable component is also the lowest among countries in the Nordic region (NordREG 2015).

Regarding interconnections, Norway has an export capacity of 6215 MW and an import capacity of 6531 MW, essentially accounting for 20% of its installed capacity. Norway is linked to Sweden, Denmark, Finland, Russia and the Netherlands and co-ordination exists regarding the rules governing the allocation of interconnection capacities. Norway's position is very important because of its role as a "storage" provider for neighbouring countries.

Future aspects

A remarkable regulatory development facing the future is the fact that the Norwegian government has clearly expressed in its recent energy policy whitepaper its intention to allow entities other than the state-owned TSO to own and operate interconnectors (Norwegian Government 2016). This is a fundamental departure from the European default model of regulated interconnector investments in which the merchant investment model for interconnections is allowed for.

8.7. Sweden

A country with an increasingly diversified generation mix and a pioneer in smart metering which, nonetheless, faces uncertainty from the future role of nuclear.

With 26% of interconnections as a share of its installed capacity (as of 2014), and the largest power system in the Nordic and Baltic region, Sweden represents – simultaneously – an important source for present-day flexibility as well as a potential key consumer of it in the not so distant future.

As a share of total installed capacity in 2015, the most important technology was hydro, immediately followed by nuclear. Driven by a substantial effort to diversify, mostly through the electricity certificate system in operation since 2003, wind power represents the third largest installed source of generation, followed by CHP. However, the share of nuclear power on output has declined over the years. Despite the existing “nuclear parenthesis” policy, which allows for further developments of nuclear power in Sweden, its future remains uncertain. Stringent taxation conditions and stricter safety requirements have created tougher conditions for producers to operate and invest.

On the other hand, we observe that the main driver for flexibility in Sweden comes from its potential on demand-side management. Not only is it the first country in the region to have a full roll-out of smart meters, but it has taken the development of Smart Grid solutions to the highest political level.

		Supply-side	
FP	Conventional plants	Presence of tax reduction / subsidy	n/a
DR	Fossil	Absence of restrictions	
DR	Hydro	Absence of restrictions	
DR	Nuclear	Presence of restrictions	
SS	RES	Market-based support	
SS	RES	Support during negative price periods	
		Demand-side	
FP	Industrial	Fiscal measures & subsidies	
DR	Consumers	Roll-out of smart meters	
DR	Prosumers	Net metering	n/a
		Grid infrastructures	
RR	TSO	Elimination of investment risks	
RR	TSO	Flexibility-friendly performance targets	
DR	TSO	European funding	
RR	DSO	Elimination of investment risks	
RR	DSO	Flexibility-friendly performance targets	

Table 14: Main drivers and barriers for flexibility in Sweden.
A blue cell indicates that a supportive framework condition for the relative flexibility resource is present. A pink cell indicates that the framework condition is not met, e.g. a barrier to flexibility is observed. A blank cell noted n/a means the data in not available.

8.7.1. Supply-Side

Current aspects

With an installed capacity of 39,313 MW and a peak hourly demand of 23,390 MW in 2015, Sweden has the largest power system among Nordics. The largest part of this is hydropower with 41.2%, followed by nuclear with 23.1%, wind power with 15.3%, CHP with 9%, and solar power with 0.3%. The remaining 11.2% is composed by condensing power, back pressure power and gas turbines.

Domestic output of electric energy was 151.2 TWh in 2014. Output from hydro and nuclear accounted for the largest shares of this amount with, respectively, 42.,4% and 41.1% of the total. Notably, wind power accounted for 7.6% and renewable-based thermal power plants, i.e. DH CHP, industrial CHP and condensing power, added up to 7%. Other thermal output (fossil and other fuels) and solar accounted for 1.8% and 0.1%, respectively.

The main source of supply-side flexibility in Sweden is hydropower, and the key driver for its flexible operation is through market conditions, over which seasonal aspects have a strong influence. When winter peak demand coincides with low hydro reservoirs and low nuclear plant availability, Sweden tends to be a net importer, as in 2010 when it imported 14.9 TWh through its interconnections. Conversely, when peak demand coincides with low nuclear power plant availability and a high reservoir level, it tends to be a net exporter (IEA 2013b). More generally, the interaction of output from hydro and nuclear with peak demand determine, to a great extent, both Sweden's flexibility requirements and the possibilities that its power system has to offer it in the form of exports via interconnections.

Another potential source of supply-side flexibility in Sweden are CHP power plants, which accounted for 9.8% of total electricity output in 2014. However, statistical information shows that its share in total output has steadily declined over the past few years. In particular, in 2010, CHP accounted for 13% of total electricity output in Sweden, 3.2 percentage points above the 2014 share. This downward trend is observed despite the fact that incentives in the form of tax reductions and exemptions exist for CHP in Sweden. In particular, heat-only production has been taxed whereas electricity output has not. A possible explanation for the reduced role of CHP in electricity output is in recent market conditions characterized by low prices, which may be explained by ageing facilities that were not eligible for green certificates anymore.

An important energy policy goal for Sweden has been to diversify its sources of electricity generation, and reduce its reliance on nuclear and hydro, while increasing the share of renewables. In line with the goal of achieving 50% of renewable energy in gross final consumption by 2020, Sweden introduced in 2003 a certificate system to promote renewables, except large-scale hydro. As of 2014, the overall share of renewables in Sweden was 53%, including large-scale hydro. In heating, cooling and industry, it added to 68%; in electricity it was 63% and in transport it was 19%.

Since January 2012, the Swedish certificate system was expanded to include Norway in a bi-national effort that expands the size of the marketplace. The goal of the framework is to increase renewable output by 26.4 TWh per year in both countries between 2012 and 2020. Although the system has proven effective and has a number of benefits, including its technology-neutral approach in which electricity produced with biofuels (including peat in Swedish CHP plants), geothermal, solar, small-scale hydro, wind and wave power are equally supported, the policy does not explicitly account for flexibility requirements.

According to the system, entitled power producers receive one electricity certificate per MWh produced over a maximum of 15 years. The price of the certificate, which is determined by supply and demand, defines the premium that producers obtain (in addition to the power market price) when these sell certificates in the certificate market. Demand for certificates arises because power suppliers and certain customers are obliged to acquire them in proportion to their electricity sales or usage. While the system explicitly supports flexible technologies, it does not account for current system’s needs. However, renewable producers face full balancing responsibility which is favourable for flexibility.

In particular, wind power is acquiring a growing role in the Swedish power system, which increases flexibility requirements. In 2015, it accounted for the largest share (71.7%) of renewable energy generated in the certificate system, and installed capacity has nearly tripled between 2010 and 2015. Thus, with substantially higher shares of wind power in the system, the existing design of the certificate market incentivises output, potentially leading to oversupply. In summary, the current design of the certificate system constitutes a barrier for flexibility.

Future aspects

The main uncertainties and potential barriers for flexibility in the Swedish generation side lie in the future and are mostly related to the role of nuclear and hydro in the decades to come. A set of somewhat conflicting policies blur the vision of a flexible Swedish generation side, unless clear pathways are designed. With these set of goals, it is unclear how flexible the technology mix will turn out to be.

On the one hand, according to the most recent political agreement of June 2016, Sweden shall not have net greenhouse gas emissions by 2045. Furthermore, Sweden has a target of achieving 100% renewable electricity production by 2040, which does not imply a ban on nuclear power. At the same time, the government shows concern for the capacity adequacy of its power system and opens the possibility of reviewing regulations and market design.

Following the nuclear phase-out policy from 1980, which aimed at ending nuclear power in Sweden by 2010, the Swedish political agreement reinforces the “nuclear parenthesis”. According to this policy, the construction of new reactors is allowed for in existing sites, but is limited to 10 new reactors in total. In addition, by the end of their economic life, the replacement of the existing reactors may be authorized.

Decisions to decommission four older reactors by 2020 have already been taken. Specifically, Vattenfall/E.ON-owned Ringhals 1 and 2 are to be decommissioned by 2019 and 2020, respectively. Likewise, Fortum/E.ON-owned Oskarshamn 1 will be decommissioned by 2019. The Oskarshamn 2 was planned to be decommissioned by 2020 but, claiming economic unviability, majority owner E.ON announced on October 2015 that the reactor would not be restarted.

One source of burden for nuclear operators is the presence of a special nuclear capacity tax since the early 2000s. It amounts to 12,468 SEK (approximately 1,300 EUR) per MW over a calendar month. After an intended increase of the duty by the current Swedish government in 2014 to 14,770 SEK (approximately 1500 EUR) producers appealed the decision and, finally, the European Court of Justice ruled to leave the tax unchanged. The Swedish government has, however, decided to gradually abolish the tax commencing on 2017. On the other hand, it has reinforced nuclear safety requirements, which increase operational and investment costs, and has emphasized its stance on a no subsidy policy for nuclear producers.

Regarding hydropower, an explicit recognition of its importance for flexibility purposes was stated in the energy policy agreement. In consequence, the government has decided to gradually reduce the property tax applicable to hydropower sites from the current 2.8% to the 0.5% applied to most other electricity production sites, starting on 2017. It has also clarified that the expansion of hydropower should primarily take place through the increased output of existing plants with modern environmental permits. It also opens the possibility for new developments provided that modern environmental permitting is implemented. It reinforces, however, the protection of the northern Swedish natural rivers.

In relation to the support for renewables, the certificate scheme will be expanded by 18 TWh of new electricity certificates by 2030, but this new level will not be increased before 2020. Technical adjustments of the system may be implemented but no specific focus on flexibility is expected. Finally, a simplified regulation for small-scale production will be introduced, the details of which will be known after an enquiry of the existing regulatory and taxation framework.

With a long-term perspective, it is worth noting that the Swedish government and the IEA expect Sweden to be a net exporter, even under (winter) peak conditions. According to their view, with an effective use of hydropower and bioenergy, power output could be increased. Furthermore, the government advocates for the strengthening of district heating and a reduced use of P2H.

8.7.2. Demand-Side

In 2014, total electricity use in Sweden was 134.3 TWh. The largest consumer group is the industrial sector which accounted for 49.5 TWh (36.9%), and is composed of an important number of electricity-intensive industries in the manufacturing, mining and quarrying economic activities. The service sector comes in second with 39.8 TWh (29.7%), closely followed by residential consumers which added up to 32.6 TWh (24.3%). The agricultural sector is the smallest electricity consumer with 2.9 TWh (2.2%). Losses amounted to 9.3 TWh (6.9%).

With the third highest electricity consumption per capita among IEA member countries, Swedish demand-side represents an important potential to enable flexibility.

Current aspects

Among the Nordics, Sweden is the country that first completed a full roll-out of smart meters, which places this country in a favourable position to increase demand-side flexibility. Already in 2009, all Swedish consumers had these devices. Sites with high consumption (i.e. with a smart meter of fuse size above 63A) are obliged by law to have hourly metering and daily reporting of consumption. In contrast, smaller-scale consumers (with a fuse size below 63A) have hourly reading and daily reporting as a choice but the default for this kind of customers is monthly reading and reporting.

In relation to the participation of loads in any of the Swedish electricity markets, besides specific technical requirements for activation and load size, there is no discrimination. In the reserve markets, minimum bid sizes vary between 0.1 MW (e.g. for FCR-N, FCR-D) and 10 MW (e.g. mFRR) but activation times are below the timeframe studied in Flex4RES. With a timeframe of 60 minutes or more, Elbas and Elspot have minimum bid sizes of 0.1 MW and no restrictions for the participation of loads exist.

The Swedish TSO procures since 2003 strategic power reserves for winter peak load periods (16 November - 15 March each year). The reserve system, which will be phased out in 2020, currently amounts to 1000 MW and from 2017 it will be capped at 750 MW, provided that no special conditions require an amount above this limit. It is a legal requirement that 25% of the capacity originates from demand response.

An important trend in the Swedish retail market is that an increasing share of consumers is choosing variable price contracts, i.e. contracts linked to the spot price and other variable price contracts like time-of-use. However, most consumers keep facing monthly prices contract unsuited to be flexible.

Despite the presence of many opportunities and “bright spots” in Sweden’s demand-side, the fact that it was an early starter in Smart Grid development has left some challenges open in terms of regulation and technical requirements. The technical capabilities of smart meters as well as the regulatory requirements for these lack details that are already present in some of its Nordic neighbours, who rolled them out later. For example, apart from specific requirements by the Swedish TSO on DSOs to enable remote control at large consumption sites, i.e. sites with consumption with capacity greater than 5 MW, not all smart meters have technical capabilities for direct load control. In addition, there is no current regulation in relation to local access by consumers to metered data directly from the smart meter interface. Regulatory recommendations which account for these aspects are, nonetheless, being proposed by the Swedish Energy Markets inspectorate in relation to the functionality requirements of smart meters at the time of replacement.

Regarding third party access by energy service companies, technology suppliers or aggregators to smart meter data is not restricted, as long as access is authorized by the consumer. Also, as in the other Nordic countries, any agent that acts on behalf of small consumers must bear balancing responsibility, but no restrictions exist in relation to any service that assists consumers to increase its price responsiveness.

In Sweden, an installation is considered micro-production if it generates at most 63A, has a capacity of at most 43.5 kW injected to the grid, and remains a net consumer over a year.

Because separate metering of consumption and output is not required for existing smart meters in Sweden, new meters may be required, which may constitute a barrier to increase micro-production. In relation to grid access, Swedish micro-producers are exempt from grid connection charges. Likewise, in relation to sales, Swedish micro-producers can offer the electricity produced to any retailer.

Future aspects

The most recent Swedish energy policy agreement establishes a priority in relation to increasing demand-side flexibility. In particular, it suggests removing barriers for business and residential consumers to act flexibly and increase energy efficiency. Similarly, the government calls for an inquiry to identify regulatory and tax legislation that hinder micro-production to propose a simplified framework.

8.7.3. Grid Infrastructure

In a similar way to Norway and Finland, the Swedish regulatory model is ex ante revenue cap but has closer similarity to the Finnish model. Controllable costs are the target of efficiency improvements, and include quality of supply as part of the regulation. However, once the revenue cap is defined, there are no specific regulations on the structure of tariffs, meaning that no flexibility-specific mandate exists in the regulation. As in the remaining Nordic countries, it is the government that licenses building new network components.

At the transmission level, Sweden applies point-of-connection tariffs, which have a power component and an energy component. The first of these, based on the installed capacity, is aimed at recovering operation, management and expansion costs and depends on the latitude at which production or output are located. For infeeds, charges are higher in the northernmost location, whereas for consumption the converse applies, i.e. charges are highest in the southernmost part of the country. The second component, which targets recovery of costs associated to transmission losses, depends on the four different Swedish price zones and loss factors. Consequently, grid tariffs vary according to location but there is no time-dependency in the tariff structure.

Regarding distribution network tariffs, the regulation principle is the same as for the transmission network, but the structure of the tariff is ultimately decided by the distribution company. The Swedish Energy Markets Inspectorate (SEI) has identified that some distribution companies have introduced power-based tariffs for domestic customers, which consist of a small fixed rate charge associated to the meter's fuse rating. In addition to the variable charge, a time-related energy charge is paid. Overall, the inspectorate identifies that smaller scale customers have less tariff choices relative to higher scale ones: whereas the latter are usually offered flat rates, the remaining have the choice of being charged a time-dependent tariff.

Taking a Swedish electrically-heated home that consumes 20,000 kWh/year as an example, the SEI finds that the largest share of the final electricity bill is taxation (46%) with equal shares (27%) for electricity prices and network charges. Similarly, NordREG (2015) finds that, on average, the annual distribution tariff charge in Sweden is the highest among Nordics, and that it has the highest fixed component among countries in the region.

In relation to interconnections, according to ENTSO-E (2014) and EC (2015), Sweden has 26% of interconnections as a share of installed production capacity, well above the EU target of 10%. It is interconnected with Norway, Finland, the two Danish Nord Pool zones, the Baltic States, Poland and Germany. As with the other Nordic countries, a common set of rules for the apply (ENTSO-E, 2015).

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