Distributed electricity production and self-consumption in the Nordics

A REPORT TO THE NORDIC COUNCIL OF MINISTERS (2019)

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Abbreviations

BAPV	Building Applied Photovoltaic systems: solar PV cell systems that are generally installed on top of roofs
BIPV	Building Integrated Photovoltaic systems are solar cells integrated into the building envelope elements, such as construction materials as roof tiles and ceramic or glass facades
BRP	Balance Responsible Party
DAM	Day-ahead market
DER	Distributed Energy Resources
DSO	Distribution System Operator
PV	Photovoltaics
TSO	Transmission System Operator

Foreword

The Nordic electricity system has a high share of renewables and also a vibrant market for trading and exchanging electricity. This has provided security-of-supply and also relatively stable and low electricity costs. Increasing volumes of intermittent renewable electricity sources, predominantly wind and solar photovoltaics, can however pose stress to this system. Energy storage, additional electricity production or grid re-enforcement in congested or weak parts of the grid can abate potential failures.

Distributed electricity production and self-consumption has gained considerable attention in recent years. The Nordic countries have various systems in place to promote that stakeholders, both operators, energy communities as well as individual households can engage in distributed electricity production and self-consumption. This includes legal frameworks, tax and support schemes.

This report provides an overview of the development of distributed electricity production and self-consumption in the Nordics and how it might evolve in the future. Furthermore, it analyses and describe the effects of such developments on system integrity, production volumes and profitability. Finally, it identifies national and/or common Nordic challenges or perceived barriers to distributed generation and self-consumption of electricity. It also addresses how local energy storage may interplay with distributed electricity production and self-consumption.

The Nordic Working Group for Renewable Energy (AGFE) was established by the Nordic Council of Ministers and is coordinating cooperation on policy development among the five Nordic countries in the field of renewable energy.

The following report is the result of a study undertaken by SWECO and Oslo Economics on behalf of AGFE. This report - Nordic distributed electricity production and self- consumption - is a result of a process, starting in 2018 and was completed in May 2019. During the period there have been a written review process as well as a workshop with experts from industry and policy makers.

The Nordic Working Group for Renewable Energy would like to thank all those who have participated in this process.

The Nordic Working Group for Renewable Energy

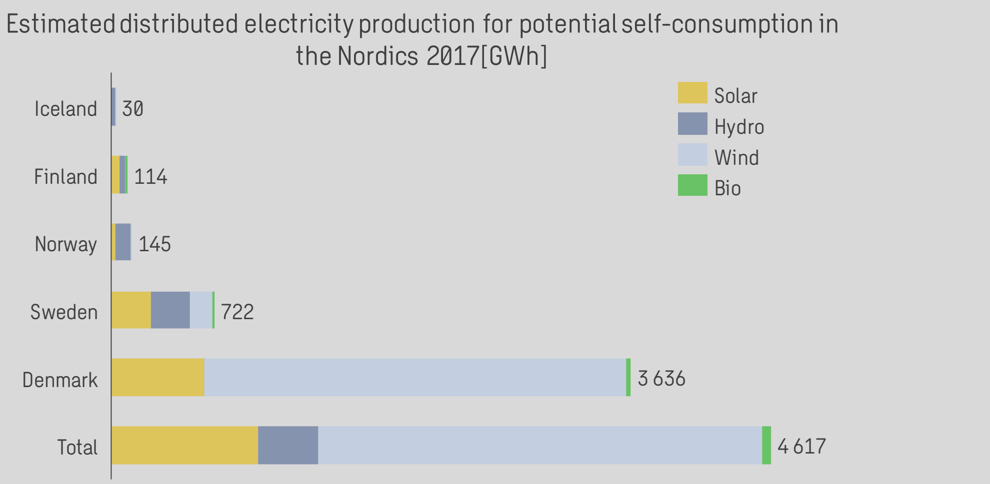
Executive Summary

In this study, *distributed electricity production and self-consumption* is interpreted in line with art. 21 and 22 in the revised Renewable Energy Directive (2018/2001/EU) as being defined as "distributed electricity production with regards to installed capacity (<1 MW), even if no self-consumption is linked to them" and as *on-grid electricity production and consumption of renewable electricity.* The definition for *renewable self-consumers* is defined based on the REDII directive as "final customer(s) who generates renewable electricity for its own consumption, and may store and sell self-generated renewable electricity, provided that, for non-household renewable self-customers, those activities do not constitute their primary commercial or professional activity." Furthermore, *sound development of distributed electricity production and self-consumption* is interpreted that it should not face discriminatory or disproportionate procedures and that such producers should have the same rights and obligations as other producers.

The installed capacity of distributed renewable electricity production for self-consumption in the Nordics was about 2750 MW in 2017, an increase from the 1880 MW in 2005, despite different trends for the various technologies. While micro-scale ageing wind power in Denmark and Sweden stands for about three quarter of the installed capacity, it has been decreasing for a while as a consequence of natural phase-out at the end of their technical lifetime. It is mainly the photovoltaic installations that have been increasing during 2005-2017, while distributed hydropower has remained constant.

In energy terms, it is estimated that about 4,6 TWh electricity that potentially could be used for self-consumption were produced in the Nordic countries in 2017, the majority of it – 3,6 TWh - in Denmark, followed by Sweden and Norway, see figure 1 below.

Figure 1: Estimated distributed electricity production for potential self-consumption in the Nordics 2017



Source: Sweco estimates, Oslo Economics estimates

The regulatory mapping shows that most Nordic countries have a regulatory framework in place that promotes the development and installation of distributed electricity production. The exception is Iceland where there, at least on a national level, there are no specific regulations for distributed production and self-consumption initiatives. The general regulatory framework and the regulations and instruments that specifically facilitates distributed production and self-consumption have many similarities between the countries, although the definitions of prosumers, the specific design of the regulations and the level of support differs somewhat.

Distributed production and self-consumption of electricity is quite strongly supported in all Nordic countries relative to consumption based on centralized production. Regarding PV for the household sector specifically, the overall finding is that Denmark historically has had the most generous support system but has later significantly decreased its support due to very rapid household PV deployment. Sweden is assessed to be the country currently having the highest support levels for household PV, and perhaps also the most complex as the total support will be achieved through multiple exemptions, tax incentives and policy instruments. Compared to Sweden, Norway and Finland seems to have a somewhat less generous support system, although it is difficult to compare the level on a general basis (since the regulations and instruments differs somewhat between the countries the level of support could be dependent on the specific actor or instalment). As mentioned above Iceland do not seem to have in place specific regulation and incentives for DES.

Households and businesses in the Nordic countries have the right to have their production facilities connected to the grid and to sell excess electricity to the DSO or a power supplier. The prices for the excess electricity are dependent on the respective contract between the prosumer and the buyer but is in most cases equivalent or similar to the relevant spot price. In addition, all countries (except Iceland) have different types of investment support or tax deduction schemes for the installation of PV-systems or other types of distributed electricity production (at least for labour/installation cost).

In addition to support schemes and tax deductions specifically directed towards installation of small-scale distributed production, the different Nordic countries have in place general/technology neutral support schemes for renewable electricity production in general such as electricity certificates or national tendering schemes. To what extent these instruments are available also to small-scale producers/prosumers varies between the countries. Other regulations, such as the licensing and authorization procedures, that may affect the administrative burden of installing solar PV panels, small wind turbines or other distributed electricity production facilities, also differ between the countries.

There are very few if any barriers to a sound development of distributed electricity production and self-consumption in the Nordics. While the definition of barriers for the development of distributed electricity production and self-consumption depends on the context, the aim of this report is mainly to identify barriers which limits a *sound development*, i.e. that distributed electricity production and self-consumption should not face *discriminatory or disproportionate procedures* and that such *producers should have the same rights and obligations as other producers*. In that sense, the policy frameworks support distributed electricity production and self-consumption and there are no discriminatory or disproportionate procedures. Through implementation of regulations that supports distributed electricity production and self-consumption in the Nordics, one may say that the barriers (costs) have been reduced, or the drivers (expected gains) have been enhanced.

However, this report also studies factors that market actors *perceive a*s barriers. These *perceived barriers* may limit the development of distributed electricity production but may not be actual barriers for a sound development according to the definition used in this report. The study identifies several general limiting factors for development of distributed electricity production/self-consumption which are the same across the Nordics (as well as other countries). *Perceived barriers* include policy related barriers such as complexity of the regulatory regime, specific definitions for which electricity production that can receive supports as well as uncertainty regarding future policy outlook.

The potential future development of distributed renewable electricity production and self-consumption in the Nordics is described by means of an outlook with a rather large outcome space. The outlook shows an outcome space for potential development of the distributed electricity production potentially used for self-consumption in the Nordics growing from currently about 5 TWh (2017) to 10-24 TWh (2040) in the upper end of the outcome space, the majority of this potential- 19 TWh – being solar PV.

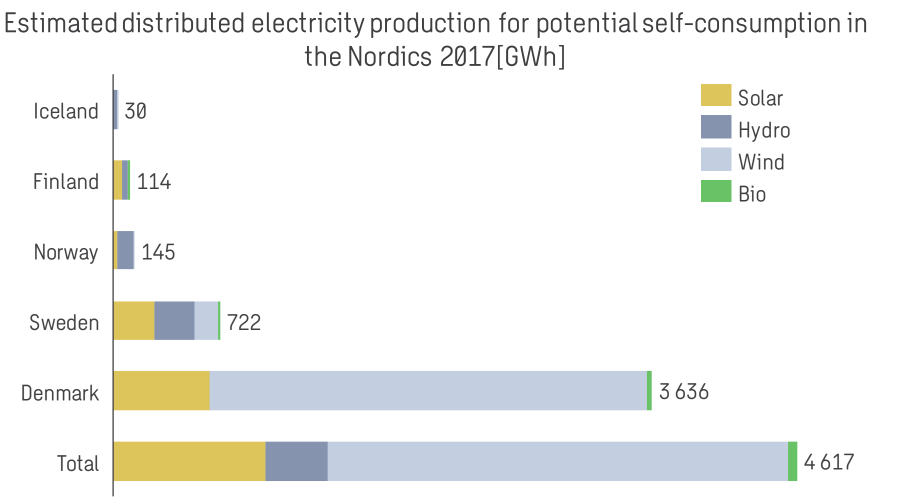
Sammanfattning

I den här studien tolkar vi *distribuerad elproduktion och egenanvändning* i linje med art. 21 och 22 i RED II som definieras som "distribuerad elproduktion med hänsyn på installerad effekt (<1 MW), även om ingen egenanvändning är knuten till dem" samt som *nätansluten elproduktion och konsumtion av förnybar el*. Vi följer RED II-definitionen som säger att *egenproducenter av förnybar el* är definierade som slutkonsument(er) som genererar förnybar el för eget bruk, samt kan lagra och sälja egenproducerad förnybar el, förutsatt att - för icke-hushåll med egenproduktion av förnybar el - dessa aktiviteter inte utgör deras primära eller yrkesverksamma aktivitet. Dessutom, tolkar vi en *sund utveckling av distribuerad elproduktion och egenanvändning* som att den inte ska utsättas för diskriminerande eller oproportionerliga förfaranden samt att sådana producenter ska ha samma rättigheter och skyldigheter som andra producenter.

Den installerade kapaciteten för distribuerad förnybar elproduktion för egenanvändning i Norden uppgick till cirka 2750 MW år 2017, en ökning från 1880 MW år 2005 trots olika trender för olika teknologier. Medan den åldrande småskaliga vindkraftproduktionen i Danmark och Sverige under en 1 MW står för cirka tre fjärdedel av den installerade kapaciteten, har den minskad under en tid som en följd av naturlig utfasning vid slutet av sin tekniska livslängd. Det är främst de solkraften som har ökat under 2005-2017, medan fördelad vattenkraft har varit relativt konstant.

Vi uppskattar att cirka 4,6 TWh el som potentiellt kunde användas för egenanvändning producerades i Norden 2017, varav merparten - 3,6 TWh - i Danmark, följt av Sverige och Norge, se figur 1 nedan.

Figure 2: Distribuerad elproduktion som potentiellt kunde användas för egenanvändning i Norden (2017)



Source: Sweco uppskattningar, Oslo Economics uppskattningar

Vår kartläggning av de regulatoriska förhållanden visar att de flesta nordiska länder har ett regelverk som främjar utveckling och installation av distribuerad elproduktion. Undantaget är Island där det, åtminstone på nationell nivå, inte finns några specifika regler för distribuerad produktion och egenanvändning. Det allmänna regelverket och regler och instrument som speciellt underlättar för distribuerad produktion och självförbrukning har många likheter mellan länderna, även om definitionerna av aktörererna, reglernas specifika utformning och stödnivåen skiljer sig något.

Distribuerad produktion och egenanvändning av el stöds ganska starkt i alla nordiska länder i förhållande till elanvändning baserat på centraliserad produktion. När det gäller solkraft för hushåll har Danmark historiskt haft det mest generösa stödsystemet, men har senare avsevärt minskat sitt stöd på grund av mycket snabb utveckling av installationerna. Sverige bedöms vara det land som för närvarande har den högsta stödnivån för solkraft till hushåll och kanske också det mest komplexa eftersom det totala stödet kommer att uppnås genom flera undantag, skatteincitament och politiska instrument. Jämfört med Sverige verkar Norge och Finland ha ett något mindre generöst stödsystem, även om det är svårt att jämföra nivån generellt. Island har inte ha någon specifik reglering och incitament för DES.

Hushåll och företag i de nordiska länderna har rätt att få sina produktionsanläggningar anslutna till nätet och att sälja sin överskottsel till DSO eller en elhandlare. Priserna på överskottsmängden är beroende av respektive kontrakt mellan aktör och köpare men är i de flesta fall lika med eller ungefär lika med det aktuella spotpriset. Dessutom har alla länder utom Island olika typer av investeringsstöd eller skatteavdrag för installation av solkraft eller annan typ av distribuerad elproduktion (åtminstone för arbetskraft/installationskostnad).

Förutom stödsystem och skatteavdrag specifikt inriktade på installation av småskalig distribuerad elproduktion har de olika nordiska länderna generella/teknikneutrala stödsystem för förnybar elproduktion, såsom nationella upphandlingar eller elcertifikat. I vilken utsträckning dessa instrument finns tillgängliga för egenproducenter av förnybar el varierar även mellan länderna. Andra bestämmelser, såsom licensierings- och godkännandeprocedurer, som kan påverka den administrativa bördan för att installera solpaneler, små vindkraftverk eller andra distribuerade elproduktionsanläggningar, skiljer sig också åt mellan länderna.

Det finns få om några hinder för en *sund utveckling* av distribuerad elproduktion och självförbrukning i Norden. Fastän definitionen av hinder för utveckling av distribuerad elproduktion och självförbrukning beror på sammanhanget är syftet med denna rapport främst att identifiera hinder som begränsar en *sund utveckling* enligt den inledande definitionen, dvs att distribuerad elproduktion och egenanvändning inte ska utsättas för diskriminerande eller oproportionerliga förfaranden och att sådana producenter bör ha samma rättigheter och skyldigheter som andra producenter. I den meningen stöder de politiska ramarna distribuerad elproduktion och egenanvändning och det finns inga diskriminerande eller oproportionerliga förfaranden. Genom införande av regelverk som stöder distribuerad elproduktion och egenanvändning i Norden kan man säga att hinderna (kostnaderna) har minskat eller att de förväntade drivkrafterna har förbättrats.

I denna rapport studeras emellertid faktorer som marknadsaktörer *uppfattar* som hinder. Dessa uppfattade hinder kan begränsa utvecklingen av distribuerad elproduktion men behöver inte vara hinder för en sund utveckling enligt definitionen som används i denna rapport. Vi identifierar emellertid flera generella begränsningsfaktorer för utveckling av distribuerad elproduktion och egenanvändning, som är desamma över hela Norden (liksom andra länder). Upplevda hinder innefattar policyrelaterade hinder, till exempel regelverkets komplexitet, specifika definitioner för vilka elproduktion som kan få stöd och osäkerhet om framtida policyn.

Vi beskriver en potentiell framtida utveckling av distribuerad förnybar elproduktion och egenanvändning i Norden genom en utblick med ett ganska stort utfallsrum, baserad på osäkerheterna om framförallt teknologikostnadsutveckling och elpriser. Bilden visar att den distribuerade elproduktionen som potentiellt används för självförbrukning i Norden växer från för närvarande cirka 5 TWh (2017) till 10-24 TWh (2040) i den övre delen av utfallet, varav majoriteten av detta potential - 19 TWh - sol PV.

1 Introduction

1.1 Background

In recent years, we have seen a significant increase in the integration of distributed production and self-consumption foremost in the Continental European but also the Nordic power system. The development has been in line with the overall goals of the European energy policy of increased renewable power production and more active and independent power consumers. The development has been facilitated by generous support systems in many European countries and with the rapid development of cost-efficient RES-technologies (especially solar PV and wind), although some of these support schemes were not necessarily aiming at distributed production and self-consumption directly but RES-E in general. In the Nordic countries the installation of PV has reached 1231[1] MW (IRENA, 2018) at the end of 2017. Furthermore, the integration of distributed production and the prevalence of self-consumption has accelerated and is projected to accelerate with the development and integration of more storage technologies such as batteries and power-to-gas as well as necessary software and storage management solutions.

The increasing share of distributed electricity production brings about new challenges and opportunities in the European and Nordic power system and will require new solutions. It fundamentally changes the functioning of the grid (from the traditional one-way flow to a two-way-flow), it affects energy prices and revenues for existing power generators, and it challenges current market design and the regulation and financing of grid operations and investments. Distributed electricity production and self-consumption is increasing as an alternative and a supplement to conventional, centralized electricity production. It also empowers the consumers who traditionally have been passive market players with few other options than to purchase power from their supplier. At the same time, the development comes at a cost, both for consumers paying the support schemes through their electricity bill and the increased costs of grid reinforcements[2] (Sweco, 2017) and a more complex system operation.

While the integration of intermittent (and mainly distributed) electricity production to date often has led to greater fluctuations in electricity production and hence investment needs in the grid and challenges for system operators, this development may turn with a potentially higher prevalence of efficient storage and management systems as well as a suitable market design. One may foresee a power market where consumers are able to offer their services to the grid owners and system operators through aggregators, market solutions for flexibility or other system services. For example, a growing share of electrical vehicles as currently seen in Norway challenges the capacity in the local grids but may also serve as a resource for flexibility – and an opportunity to manage the loads in an efficient manner.

The proposal for a revised EU-directive on renewable energy (RED II) addresses self-consumption and renewable energy communities. More information about the development and effects of distributed electricity production and self-consumption in the Nordics (including non-EU countries Iceland and Norway) will be useful to governments and stakeholders. Negotiations on the amendment of the Renewable Energy Directive (RED) indicate that member states may have to report on self-consumption. The study could, in part, guide possible future reporting requirements.

The main purpose of this AGFE project is to provide useful decision support for governments and stakeholders by:

- providing an overview of existing relevant studies in the field.
- describing the size of distributed electricity production/self-consumption in the Nordic countries, historical growth and future growth scenarios, where key factors that constitute the core of those scenarios should be highlighted

[1] 1363 MW according to IEA-PVPS, http://www.iea-pvps.org/fileadmin/dam/public/report/statistics/2018_iea-pvps_report_2018.pdf
[2] Distributed production may potentially increase or decrease the overall need for investments in the grid. However, since distributed electricity production stems from intermittent sources, the potential to reduce grid investments are often dependent on the availability of storage or management solutions.

- describing the different regulations/policies in the Nordic countries towards distributed electricity production/self-consumption and to what extent this issue is covered in national energy and climate strategies. This includes a review of a legal frameworks, tax and support schemes concerning distributed electricity production and self-consumption in Nordic countries
- describing the effects of distributed electricity production/self-consumption, in particular, describe the effects of distributed electricity production/self-consumption in a predominantly renewable electricity system (Nordic) vs. a predominantly fossil-based electricity system
- assessing the importance of local storage in relation to distributed electricity production/self-consumption (batteries, local thermal storage, storage in car batteries)
- also identifying national and/or common challenges or barriers to a sound development, such as legal frameworks, grid impact, tax and incentive schemes.

1.2 Definition of self-consumer and distributed electricity production

For the sake of clarity, we define *distributed electricity production and self-consumption, renewable self-consumer* and *sound development* for distributed electricity production and self-consumption below.

The definition of *distributed production* may vary across countries and with regards to different production technologies (i.e. solar PV, wind, small-scale hydro etc.). It is possible to define distributed production with regards to the ownership or use of the production facility, with respect to the installed capacity (equalling "distributed" with "small-scale", depending on technology) or based on other location characteristics (grid level to connect to)[3]. In a study for the European Commission (European Commission, 2015), we broader defined distributed energy resources (DER) to consist of *small- to medium- scale resources* that are connected mainly to the *lower voltage levels (distribution grids) of the system or near the end users*, with key categories being:

- **Distributed generation (DG):** power generating technologies in distribution grids. The category comprises variable renewable energy sources (VRES) that depend on fluctuating energy sources like wind and solar irradiation, but also dispatchable resources like cogeneration units or biogas plants
- **Energy storage:** batteries, flywheels and other technologies that demand electricity and supply electricity at a later point in time
- **Demand response (DR):** Changes of electric usage by end-users from their normal consumption patterns in response to market signals such as time-variable prices or incentive payments

In this study, we interpret the definition of distributed electricity production and self-consumption in line with art. 21 and 22 in REDII as being:

- Distributed electricity production is defined as *distributed electricity production with regards to installed capacity (<1 MW),* even if no self-consumption is linked to them. The category comprises variable renewable electricity sources, such as solar PV, wind etc.
- *on-grid* electricity production and consumption of renewable electricity. Thus, we only include on-grid.

Renewable self-consumers are (in revised REDII) defined as "final customer(s) who generates renewable electricity for its own consumption, and may store and sell self-generated renewable electricity, provided that, for non-household renewable self-customers, those activities do not constitute their primary commercial or professional activity.".

1. Individuals (final customer)
2. «Jointly acting»: Located in the same building or multi-apartment block
3. «Renewable energy community» (legal entity):

[3] For example, distributed production could refer mainly to small scale installations in private households/on private domain (solar PV, wind), or it could also comprise larger production facilities such as hydropower plants with installed capacity of up to 10 MW.

- Shareholders or members that are located in the proximity of the renewable energy projects owned and developed by the community
- Shareholders or members are natural persons, local authorities (also municipalities) or SMEs
- Whose primary purpose is to provide environmental, economic or social community benefits for its members or the local areas where it operates rather than financial profits.

While *sound development* can be addressed from an economical perspective (a cost-efficient/socio-economic optimal development), a political perspective (what is desired in terms active customers and more independence from larger, centralized production) or a technical perspective (what is possible to integrate with regards to system security/stability given a certain frame), in this report sound development is interpreted in line with REDII. In REDII, it means that distributed generation and self-consumption should *not face discriminatory or disproportionate procedures* and that such producers should have the same rights and obligations as other producers. Thus, the definition used in the report is one of many possible definitions.

2 Literature overview

2.1 Literature overview: Self-consumer and distributed electricity production

As a part of this study, we have identified several relevant written sources. In this section, we provide short summaries of the most relevant sources, referred to as ”key reports”, and briefly mention other written sources, referred to as ”other reports”.

The summaries of the “key reports” described in this document are structured as follows:

- Short description of the report
- When relevant: Findings in the report on
  - Distributed electricity production and self-consumption
  - Overview of current framework conditions, regulations and tax schemes
  - Effects of distributed electricity production/consumption on different power systems
  - Challenges or barriers to the development of distributed electricity production/self-consumption
  - Future growth scenarios
  - Importance of local storage in relation to distributed electricity production/self-consumption

2.2 Literature overview – EU

2.2.1 KEY REPORT 1: SWECO (2015) STUDY ON EFFECTIVE INTEGRATION OF DISTRIBUTED ENERGY RESOURCES FOR PROVIDING FLEXIBILITY TO THE ELECTRICITY SYSTEM

Short description

The study focuses on the efficient market integration of Distributed Energy Resources (DER) in order to provide flexibility to the power system. Flexible DER can provide services to fill flexibility gaps on the local and on the transmission level. The technologies needed are available, the challenge is to adjust to the institutional set-up and the technical environment to make them market ready. The report is written by a consortium led by Sweco, on behalf of the European Commission.

Distributed electricity production and self-consumption

Because Variable Renewable Energy Sources are mainly connected to the distribution grids, their expansion puts a focus on local integration challenges and they therefore increase the complexity of distribution grid management. There are plenty of options to provide flexibility on the distribution grid level. Their potential is not fully utilised. The study gives an overview on the characteristics of available flexibility options from DER. The study found that customers will be central in the transition to a low carbon electricity system, customers having their own production are likely to become more common.

Overview of current framework conditions, regulations and tax scheme

The value of flexibility varies significantly both on a geographical level and a wider time horizon. In many cases the market value is still likely to be a limiting factor for DER participation since true value of flexibility is not always revealed in the market prices. As the power system is changing the demand for flexibility is likely to increase. At the same time the supply of flexibility from traditional sources is likely to decrease. DERs could be important contributors of flexibility to bridge this gap. Flexibility from regulators, TSOs and DSOs and a readiness to adapt rules and regulations that can support developing business cases are important

Challenges or barriers to the development of distributed electricity production/self-consumption

Market rules and product definitions are historically designed to fit with the needs of central generators. While there is a process of adjusting these to accommodate new resource providers, there is more to be done. For example, minimum bid size and bid increments have been lowered substantially in day-ahead markets (DAM). However, minimum bid size and bid increments remain high in many balancing markets. This constitutes an important barrier for DER market participation. Furthermore, activation rules could also have significant impact on the possibilities for demand side participation.

Future growth scenarios

For the market to cope with significant supply volatility, changes are needed in how electricity is consumed. The future is likely to bring distributed (small-scale) generation of electricity. The prosumers both generate and consume electricity and with a more volatile price pattern, business opportunities will arise where then prosumers take a natural part in the value chain. The prosumer is anticipated to have a stronger relation with one or several of; suppliers, Balance Responsible Parties (BRPs), the DSO/TSO. Furthermore, the prosumers might become complex actors as they will procure additional flexibility in terms of energy storage schemes.

2.2.2 KEY REPORT 2: EUROPEAN COMMISSION (2017) STUDY ON RESIDENTIAL PROSUMERS IN THE EUROPEAN ENERGY UNION

Short description

The study aims at gathering evidence and data on the drivers, regulatory aspects and economic performance in small-scale self-generation for residential consumers over the life-cycle of investment. The focus of the study is on solar PV technology.

Distributed electricity production and self-consumption

No Member State has a precise definition of the term 'residential prosumers'. However, countries have adopted equivalent concepts and several of the countries that define prosumers in relation to their production element, refer to the installation size or generation capacity. Most Member States have simplified procedures for setting up residential prosumer installations. Member States generally enable prosumers to feed the surplus of their electricity production into the grid.

Overview of current framework conditions, regulations and tax scheme

There is no harmonized regulatory framework for residential prosumers in the EU, and Member States take different approaches. Member States differ in terms of financial incentives given to prosumers. Alongside net-metering the most used incentives to support the development of energy generation from RES have been feed-in tariffs or premiums, but there is no strong harmonized structural approach to prosumer support. Other measures like tax reductions, capital subsidies and loans or other forms of investment support are also applied but their form and shape varies broadly across Europe.

Challenges or barriers to the development of distributed electricity production/self-consumption

In the short-term, continued roll-out of solar PV faces challenges, as increasing the share of intermittent renewables on the grid could lead to increasingly peaky electricity supply, causing grid congestion and stability issues. In many Member States, policies and regulatory measures have been designed to reduce this risk by compensating for electricity offloaded to the grid at variable, time-dependent rates to better match electricity supply and demand (e.g. through Feed-in Premiums). However, the effect of these measures is constrained by consumers' limited control over time-of-day electricity consumption.

Despite these short-term challenges, it is envisaged that, in the medium term, improvements in demand response and roll-out of smart meters, battery and grid storage technologies, as well as increases in electricity demand and synergies with technologies such as electric vehicles, will create opportunities for solar PV capacity to further increase. To achieve this, surely a comprehensive policy and regulatory framework must be put in place at the EU level.

Future growth scenarios

The baseline scenario in the report assumes that under a continuation of current policies, residential solar PV capacity in the EU28 is projected to nearly double (from 17GW estimated capacity in 2016 to 32GW estimated capacity in 2035). There is considerable uncertainty in the baseline solar PV projections, which are dependent on key assumptions about the future development of CAPEX and OPEX costs, electricity prices, interest rates, self-consumption ratios and consumer preferences.

Future rates of take-up are highly affected by policy and by the development of new complimentary technologies. For example, an increase in the number of households with an electric vehicle would lead to a projected increase in installed capacity by 2030 in the scenario, as the potential technology synergies would increase the attractiveness of PV.

2.2.3 KEY REPORT 3: MASSON ET AL. (2016) REVIEW AND ANALYSIS OF PV SELF-CONSUMPTION POLICIES

Short description

The report aims at providing a comparative analysis of existing mechanisms supporting the self-consumption of PV electricity in key countries all over the world and to highlight the challenges and opportunities associated to their developments.

Distributed electricity production and self-consumption

The report describes the current state of self-consumption in 19 different countries, among them are Denmark, Finland and Sweden.

Overview of current framework conditions, regulations and tax scheme

The report identifies 13 policy measures used to support self-consumption. The policy measures are divided between PV for self-consumption, excess PV electricity and other system characteristics and varies among the studied countries. A financial model estimates the economic impact in five business cases on the prosumer, the electricity market (including TSO, DSO and electricity consumers), and the government.

Challenges or barriers to the development of distributed electricity production/self-consumption

Self-consumption of PV electricity presupposes that the cost of producing PV electricity is cheaper (at the time of investment or during the lifetime of the PV system) than the price that the consumer pays for his electricity. Without having reached this threshold, self-consumption will require additional financial incentives. Due to the various size of PV systems used for self-consumption, not all of them will be able to trade electricity directly on the electricity market. This raises the need for aggregation and intermediaries that will play on the market on behalf of PV producers. These intermediaries could be traditional utilities or specific electricity services companies.

Future growth scenarios

The report gives a temporary conclusion, self-consumption is only in its infant stage, with most countries probing regulations to frame its development. Most essential questions remain to be considered in order to ensure its smooth development. The report claims that one important issue is to identify whether the optimization of self-consumption locally should remain as the driver or if system stability could be the answer. If focus where to be shifted towards a system approach, PV systems used for system optimization could increase generation adequacy.

2.2.4 KEY REPORT 4: NORDIC ENERGY RESEARCH (2016) NORDIC ENERGY TECHNOLOGY PERSPECTIVES

Short description

The report sets out three macro-level strategic actions that will be central in achieving the climate targets of the Nordic countries in 2050:

- Incentivize and plan for a Nordic electricity system that is significantly more distributed, interconnected and flexible than today's.

- Ramp up technology development to advance decarbonization of long-distance transport and the industrial sector.
- Tap into the positive momentum of cities to strengthen national decarbonization and energy efficiency efforts in transport and buildings.

Distributed electricity production and self-consumption

The analysis in the report demonstrates that if a carbon-neutral system is the target, it will likely cost less to transition to a more distributed electricity supply with a high share of wind than to maintain a system reliant on centralized nuclear and thermal generation. Higher shares of wind will require enhanced system integration across sectors and technologies, and among the Nordic countries. In addition, it will necessitate complementing existing dispatchable hydropower with other sources of flexibility to minimize integration costs.

The policy recommendations in the report:

- Strengthen incentives for investment and innovation in technologies and services that increase the flexibility of the Nordic energy system.
- Boost Nordic and European co-operation on grid infrastructure and electricity markets
- Take steps to ensure long-term competitiveness of Nordic industry while reducing process-related emissions
- Act quickly to accelerate transport decarbonization using proven policy tools

Challenges or barriers to the development of distributed electricity production/self-consumption

With rising shares of variable renewables in both Nordic and other European countries, it will be economically attractive to increase transmission capacities among countries. Seizing this trade opportunity depends on three things: build-out of wind capacity and necessary flexibility to handle variability, reducing Nordic demand through energy efficiency, and setting up the necessary interconnectors and domestic grid strengthening to enable trade.

Future growth scenarios

Wind power production in general is expected to increase five-fold in the analysed scenario in the report. The Nordic region seems less likely to see the solar PV boom other countries are experiencing. Growth is constrained by a limited solar resource, dense urban areas with less rooftop area and favourable conditions for competing wind power. The role of district heating will increase under strict climate policy targets, but the role of co-generation may become less important. Hydropower alone is not enough balancing the amount of intermittent power in the system. The high penetration of variable wind power will require balancing though a combination of flexible supply, demand response, storage and electricity trade.

2.2.5 OTHER REPORTS EU

In addition to the key reports, the following reports have been a part of our written sources:

- Sweco & Ecofys (2016): New Gameplan – RES Support in the Nordics;
- Ecofys (2017): Recent trends in Corporate Renewables Sourcing;

2.3 Literature overview – Norway

2.3.1 KEY REPORT 1: RESEARCH COUNCIL OF NORWAY (2016) NATIONAL SURVEY REPORT OF PV POWER APPLICATIONS IN NORWAY

Short description

The National Survey Report of PV Power Applications in Norway was published by The Research Council of Norway in 2016. It was used as input for the annual Trends in photovoltaic applications report published yearly by the International Energy Agency (IEA). The National Survey Report of PV Power Applications in

Norway seeks to give a status of PV in Norway and uses market data and sales numbers to analyse the PV market in Norway. It describes how much PV-generated electricity capacity that was installed in 2016, and in which segments the capacities were installed. To contextualize the level of PV in Norway in 2016, the report has included the historical development of PV installation from 2013 till 2016. In addition, it looks at different regulations and schemes relevant for PV power production.

Distributed electricity production and self-consumption

The report shows statistics of installed PV production capacity in Norway and splits the capacity into different segments. As is the standard in all IEA National Survey Reports, the installed capacity is split between grid-connected and off-grid installations. Grid-connected installations are split into battery-assisted PV (BAPV), battery-independent PV (BIPV) and Ground-mounted PV. BAPV and BIPV are then split into three segments each: Residential, Commercial and Industrial. The report does not disclose the share of the installed capacity that was deployed with the intention of self-consumption. The historical statistics go back to 2013.

The report for Norway shows that the installed capacity of grid connected BAPV was 10.4 MW in 2016. This comprised 3.0 MW Residential, 7.4 MW Commercial and 0.0 MW Industrial. Furthermore, the installed capacity of of-grid PV was 0.3 MW (residential/holiday homes) in 2016. The statistics show a very strong growth in installation of PV from 2015 to 2016 – up 336%.

Overview of current framework conditions, regulations and tax scheme

On a national level the report describes the following regulations/schemes; Enova subsidies, Renewable Energy Certificates (RECS), the climate-fund of the municipality of Oslo, the "prosumer scheme", and installation of new smart energy meters with two-way metering.

Future growth scenarios

The report briefly considers the future prospects of PV generated electricity and cites the Energi21-document (the Norwegian national strategy for research, development, demonstration and commercialization of new energy technology) (Norges Forskningsråd, 2018).

2.3.2 KEY REPORT 2: CICERO (2018) POWER FROM THE PEOPLE? DRIVERS AND BARRIERS

Short description

«Power from the people? drivers and barriers» was issued by the climate think thank CICERO in 2018. The report seeks to identify factors which contribute to, and hinder, Norwegian households in becoming prosumers of electrical energy. The report describes why certain people decide to become prosumers and what their experiences have been like. In addition, the report includes a description of how central players on the electricity market view the increasing number of prosumers.

Distributed electricity production and self-consumption

The report documents the historical development of PV capacity from 2004 until 2016. It shows that 2014 was a turning point in the development of prosumers in Norway, as the number of prosumers increased from less than 200 in 2014 to approximately 700 in 2016.

Overview of current framework conditions, regulations and tax scheme

On a national level, the report considers the following regulations/support schemes; Feed-in-Tariffs (FIT), Swedish-Norwegian Renewable Energy Certificates (RECS), Enova subsidies and municipal support schemes from Oslo, Hvaler and Fredrikstad. The report describes both the nature of the regulations/support schemes and the implications of the measures, considering which are more and less effective.

Challenges or barriers to the development of distributed electricity production/self-consumption

The report claims that the Norwegian government has done little in comparison with other, comparable countries to promote PV through financial measures. It concludes that Swedish-Norwegian Renewable Energy Certificates (RECS) are less relevant for households, due to high fixed costs. Other barriers covered in the report are transaction costs, installation, operation and maintenance costs, lack of knowledge about the technology and limited/lack of profitability.

Future growth scenarios

The report concludes that the increase of PV in Norway is caused by personal motivation within Norwegian households and the development of relevant technologies. The authors do not expect new regulations that will further incentivize households to become prosumers. The reason is that most electricity produced in Norway already stems from renewable sources.

Importance of local storage in relation to distributed electricity production/self-consumption

The report claims that the development of batteries could have a big impact on the number of prosumers. This is because it will allow households to consume more of the electricity they produce.

2.3.3 KEY REPORT 3: MULTICONSULT (2018) PHOTOVOLTAIC POWER IN THE POWER SYSTEM

Short description

"Photovoltaic power in the power system" (Norwegian: "Solcellesystemer og sol i systemet") was written in 2018 by Multiconsult in collaboration with Asplan Viak. The report seeks to give a situational description of the solar PV industry in Norway. It was ordered by the solar PV industry association "Solklyngen" to provide knowledge about solar PV energy technology for Norwegian businesses.

The report gives a situation description of PV in Norway. It shows the historical development from 2011 to 2017 in Norway and the global development of PV. The report also considers factors that might affect the future development of PV in Norway. Factors taken into consideration in the report include the price of electricity, the cost of installation, changes in regulations, technological development of batteries, and the implementation of smart meters.

Distributed electricity production and self-consumption

The report focuses on grid connected PV-installations. Findings from the report show that there is a strong positive trend in the installation of PV in Norway. The increase in installed capacity from 2016 to 2017 was at 59%. From 2015 to 2016, the growth rate was 336%.

Overview of current framework conditions, regulations and tax schemes

On a national level the report considers changes in the following regulations; energy based versus effect-based tariffs, Swedish-Norwegian Renewable Energy Certificates (RECS), Enova subsidies, municipal/regional support schemes and building regulation. The report discusses the implications of the measures. On an EU-level, the report considers the effect of the regulation requiring nearly zero-energy buildings (nZEB).

Effects of distributed electricity production/consumption on different power systems

The report claims that distributed production does not have substantial negative implications on the grid in Norway today. However, this might change over time if there is a strong increase in distributed PV production of electricity.

Challenges or barriers to the development of distributed electricity production/self-consumption

The report considers a range of factors that challenge the development of PV in Norway. Lack of knowledge about PV in the population, high investment costs, and a lack of investment support are deemed as the most substantial barriers.

Future growth scenarios

The report includes two growth scenarios. In the first scenario, growth is driven by willing households and predictable support schemes. In this scenario the production of PV generated electricity will be strong from 2016-2030, with a total production of 2.31 TWh in 2030 compared with 0.02 TWh in 2016. In the second scenario, EU-regulation requiring nearly zero-energy buildings is adopted from 2018. In this scenario the growth is even stronger, with a PV generated production of 4.75 TWh in 2030.

Importance of local storage in relation to distributed electricity production/self-consumption

The report claims that the development of batteries could have a big impact on the number of surplus consumers. This is because it will allow households to consume a larger share of their own electricity production. This could be financially beneficial for the prosumers and reduce the negative effects of distributed production on the grid.

2.3.4 KEY REPORT 4: THEMA (2018) DESCRIPTIVE STUDY OF LOCAL ENERGY COMMUNITIES

Short description

The study describes the current status of local energy communities in Norway. The study has identified 30 Norwegian projects related to local energy communities and concludes learnings from 5 international projects. These reference projects have been used identifying potential costs and benefits, barriers for development and regulatory recommendations.

Distributed electricity production and self-consumption

In the beginning of the report the authors state that there is no clear definition of local energy communities and that the definitions vary. The criteria used in the report are guidelines but not used strictly to exclude projects and includes; cooperation between minimum three parties, bidirectional power flows, local control, active participation of end-users and geographical conditions. Interviews were conducted with 15 of the identified projects and one of the main conclusions is that most of the identified projects are immature and under further development. Only 5 of the 30 projects involve investment that has been realised. Over 70% of the project owners are property developers and real estate owners.

Challenges or barriers to the development of distributed electricity production/self-consumption

The cited regulatory and commercial barriers to the local energy community development vary depending on the nature of the specific community. In general, the most important identified barrier was the absence of business cases, often due to the lack of an existing market or standard business arrangements. The report states that the most important perceived regulatory barrier is the steep learning curve faced by organizations outside the electricity sector and the information gap between the energy sector and other segments of the society. Other regulatory barriers cited are related to the cooperation with the DSO's and the tariff structures.

Future growth scenarios

The expected benefits from the projects are exclusively quantified in terms of saved energy. None of the projects had a clear idea of the expected economic benefits, hence the report could not draw any conclusions of the economic efficiency. Also, given the early development stage in many of the projects the level of uncertainty in the future development in these projects was expressed to be high and no clear growth scenario was presented in the report.

Policy recommendations

Given the large number of uncertainties, the reports avoids giving policy recommendations in this early stage. The report states that it is premature to change the current regulatory framework in an attempt to remove potential regulatory barriers found within the study. The advice given to NVE in the report is to divide the future actions in two steps: in the near-time to develop a regulatory sandbox and in the next step consider a broader regulatory reform opening up the framework for more diverse modes. The sand box solution in the first step should provide a clear standardised process for the granting of temporary regulatory exemptions that can give the energy communities the support they need in order to develop.

2.3.5 OTHER REPORTS NORWAY

In addition to the key reports, the following reports have been a part of our written sources:

- International Energy Agency (2017): Review of Energy Policy in Norway
- Idsø, Johanne (2017): Small-scale Hydroelectric Power Plants in Norway. Some Microeconomic and Environmental Considerations
- FNI (2016): Power from the People? Prosuming conditions for Germany, the UK and Norway

- Inderberg et.al. (2018): Is there a Prosumer Pathway? Exploring household solar energy development in Germany, Norway and the United Kingdom.
- NVE (2016a): Endringer i kontrollforskriften vedrørende plusskundeordningen
- Sæle, H. & Bremdal, B. (2017):Economic evaluation of the grid tariff for households with solar power installed
- NVE (2019a): Batterier i bygg kan få betydning for det norske kraftsystemet, report 66-2017
- NVE (2016b): Hva betyr elbiler for stomnettet?, report 74-2016
- NVE (2018a): Batterier i distribusjonsnettet, report 2-2018
- Thema Consuting Group (2017): Aggregatorrollen, fleksibilitetsmarkeder og forretningsmodeller i energisystemet, report 2017-20:

2.4 Literature overview – Sweden

2.4.1 KEY REPORT 1: SWEDISH ENERGY AGENCY (2017) NATIONAL SURVEY REPORT OF PV POWER APPLICATIONS IN SWEDEN

Short description

The National Survey Report of PV Power Applications in Sweden was published by The Swedish Energy Agency in 2017. It was used as input for the annual Trends in photovoltaic applications report (a study which analyses the sales of solar panels) published yearly by the International Energy Agency (IEA). The National Survey Report of PV Power Applications in Sweden seeks to give a situational description of PV in Sweden and analyses the sales markets of solar PV in Sweden. It describes how much PV-generated electricity capacity was annually installed between 1992-2017, the geographical distribution, PV module price data, and in which segments the capacities were installed. In addition, it looks at different regulations and schemes that are related when considering instalments of PV capacities.

Distributed electricity production and self-consumption

The report shows statistics of installed PV production capacity in Sweden. The segments of PV made in the report are standardized for all IEA National Survey Reports and split installed capacity into grid-connected and off-grid, domestic and non-domestic. Grid-connected instalments are split into BAPV, BIPV, Ground-mounted and Utility-Scale. BAPV and BIPV are then split into Residential, Commercial and Industrial instalments. The report does not discuss how much of the installed capacity was built with the intent of self-consumption.

The National Survey Report of PV Power Applications in Sweden shows that Sweden's installed grid connected capacities of 115.3 MW in 2017. The largest share was BAPV with 108.2 MW. The instalments were split between 41.9 MW on residential, 70.7 MW on commercial and industrial and 2,7 MW utility scale. A capacity of 2.3 MW was also installed off-grid (residential/holiday homes etc.). The historical development of installed capacity of grid connected PV installation year by year, goes back to 1992. It shows that the development has a strong positive trend with an increase in installation of 760% from 2013 to 2017.

Overview of current framework conditions, regulations and tax scheme

On a national level the report describes the following regulations/schemes; Additional tax deductions for feed-in, Capital subsidies, production-premium Renewable Energy Certificates (RECS), Guarantees of origin, tax credit for micro-producers of renewable energy, capital subsidy for storage of self-produced energy, energy tax on self-consumption, deduction of the VAT for PV systems, VAT on the revenues of the excess electricity, deduction of interest expenses, grid benefit compensation, collective self-consumption and indirect policy issues.

Future growth scenarios

The report briefly considers the prospects of PV generated electricity. The assumption of the report is that the Swedish PV market is in the short term expected to grow if not any radical changes happens. One example of a new reform, expected to lower the administrative burden is that need for applying for building permits when installing a PV system on a building was simplified from 1st August 2018. The off-grid market has shown stable installation values for a few years and the market development is expected to continue to be stable in the coming years. The market of large centralized PV systems is expected to grow since several utility companies have investments plans in PV systems. There is also an ongoing investigation of tax reform beneficial for micro production of renewable energy. In long term the Swedish PV market is in a good position to grow due to public interest, governmental strategy and political agreement. However, the market is still dependent on subsidies.

2.4.2 KEY REPORT 2: THE SWEDISH GOVERNMENTS OFFICIAL INVESTIGATIONS (2018) SMALL ACTORS IN THE ENERGY LANDSCAPE

Short description

In June 2017 the Swedish government decided to initiate an investigation about small actors in the energy landscape, their possibilities and challenges. The report describes challenges related to energy efficiency, storage and small-scale electricity production.

Distributed electricity production and self-consumption

According to the analysis the interest for small-scale electricity production in Sweden is high among the population. In a national survey in 2016, 59% of the households answered that they would like to produce their own electricity if possible and 15% already investigated the possibility. According to the report the small-scale hydropower has a long history and tradition in Sweden with about 2000 small-scale plants. The smallest plants are often used for self-consumption by the owners living close to the plant. The installations in small-scale wind power in Sweden is decreasing according to the analysis due to higher interests in large scale plants due to their better cost efficiency. Small-scale CHP with biofuels is mainly used for commercial usage and not mainly self-consumption.

Overview of current framework conditions, regulations and tax scheme

During the past years small-scale electricity production have been politically supported by several support schemes and subsidies in Sweden. These support schemes are often experienced as complex and administrative and the actors experiences a lack of reliable information about these support schemes. The Swedish Energy Agency have been assigned the responsibility to establish an information portal. There has also been criticism that the support schemes for small-scale electricity production have unclear purposes and results.

Challenges or barriers to the development of distributed electricity production/self-consumption

The barriers seen by small-scale actors described in this report are divided into three categories: financial, legal/administrative and social barriers. The barriers are often connected to costs and they are often followed in a given sequence. Overcoming these barriers can often be costly for smaller market players. Working together with other actors or larger market players (energy companies, aggregators, property owners etc.) can be an effective tool mitigating the risks and barriers. The barriers related to energy storage are analysed as mainly being financial.

Examples of identified barriers for small-scale producers in the investigation report:

- High initial investments costs and uncertain pay-back time due to volatile electricity prices
- Hidden investments costs (for example transaction and installations cost)
- Current regulation not adapted to small-scale actors
- Time consuming administration and administrative burden in support schemes
- Underestimation of advantages and rejection of technologic improvement even if they are economically feasible.
- Unwillingness to change lifestyle

2.4.3 KEY REPORT 3: SWEDISH ENERGY AGENCY (2016) PROPOSED STRATEGY FOR INCREASED PV USAGE IN SWEDEN

Short description

The Swedish Energy Agency have investigated a new strategy in order to increase the electricity production from PV and analyse how PV can contribute to the sustainability goal 100% renewable energy in Sweden. The report describes the increasing PV market in Sweden and analyses potential future scenarios.

Distributed electricity production and self-consumption

In order to contribute to the 100% renewable goal, the report states that electricity generated from PV could contribute with about 5-10% of the total electricity use in Sweden by 2040. The report describes and divides the development to reach the 2040 goals as three construction phases; establishment (today-2022), expansion (2022-2040) and continuous commercial development (2040-onwards). The different phases mean different challenges and barriers. The establishment phase demands customized support schemes, easy administration, a well-functioning market for installation services and increased knowledge. The second phase needs completeness for industrial size installations and integration of PV in the national energy system. In the final phase large scale PV installations needs to be feasible without subsidies and the main priority set by the report is cost effectiveness.

Overview of current framework conditions, regulations and tax scheme

In order to increase the PV market in Sweden the Energy Agency recommends new policy measures in order to stimulate the market. The report proposes a tax deduction for labour costs related to PV installations, replacement of electricity certificates for micro-production by expanding other support schemes and increased limits for feed in contracts. The report also states that the policy measures available today does not take into account the differences between the actors on the PV market. The report has identified large differences between small scale actors who install solar PV 0-68 kW and actors with large scale installations above 255 kW.

Challenges or barriers to the development of distributed electricity production/self-consumption

The identified challenges are related to the transmission- and distribution network. Power shortage at certain hours are also described as possible challenges. A future system with a large electricity production from PV is dependent on flexibility and storage. Other identified challenges are the environmental consequences related to the production of the PV modules.

2.4.4 OTHER REPORTS SWEDEN

In addition to the key reports, the following reports have been a part of our written sources:

- The Swedish Energy Agency (2017): Scenarier över Sveriges energisystem 2016
- The Swedish Energy Agency (2018a): Energiindikatorer 2018 – Uppföljning av Sveriges energipolitiska mål
- The Swedish National Institute of Economic Research (2018): Miljö, ekonomi och politik
- Sweco (2016): Future drivers and trends of the Swedish Energy Sector
- Swedish Energy Agency (2018b): Nätanslutna solcellsanläggningar 2017
- Regeringskansliet (2018): Riksrevisionens rapport om det samlade stödet till solel;
- Sweco and Samordningsrådet för smarta elnät (2014): Krav på framtidens smarta elnät – smarta nät;
- Elforsk (2014): Framtida krav på elnäten, report 2014:26
- Alvar Palm (2015): An emerging innovation system for deployment of building-sited solar photovoltaics in Sweden;
- Alvar Palm (2016): Local factors driving the diffusion of solar photovoltaics in Sweden: A case study of five municipalities in an early market;

- Alvar Palm (2017): Peer effects in residential solar photovoltaics adoption—A mixed methods study of Swedish users;
- Palm, J. (2018): Household installation of solar panels – Motives and barriers in a 10-year perspective;
- Palm, J. & Eriksson, E. (2018): Residential solar electricity adoption;
- Bygg & teknik (2018): Solenergi på kulturhistoriska byggnader.

2.5 Literature overview – Finland

2.5.1 KEY REPORT 1: LUT (2017) NATIONAL SURVEY REPORT OF PHOTOVOLTAIC APPLICATIONS IN FINLAND 2017

Short description

The National Survey Report of PV Power Applications in Finland was issued by the Lappeenranta University of Technology (LUT) in 2018. It was used as input for the annual Trends in photovoltaic applications report published yearly by the International Energy Agency (IEA). The National Survey Report of PV Power Applications in Finland seeks to give a status of PV in Finland. It describes how much PV-generated electricity capacity was installed in 2017, and in which segment the capacity was installed. To contextualize the development, a short historical perspective is offered. The report includes a description of the regulation of PV installations and power production in Finland.

Distributed electricity production and self-consumption

The report shows statistics of installed PV production capacity in Finland. The segments of PV made in the report are standardized for all IEA National Survey Reports and split in grid-connected and off-grid PV. Grid-connected installations are split into BAPV, BIPV and Ground-mounted. BAPV and BIPV are then split into the segments Residential, Commercial and Industrial. The report does not disclose the share of the installed capacity that was deployed with the intention of self-consumption.

The National Survey Report shows that there was installed 42.7 MW of grid connected BAPV in Finland in 2017.[4]. This was split between 13 MW Residential, 14.9 MW Commercial and 14.8 MW Industrial. By the end of 2017 the total grid connected installed PV-capacity was at 69.8 MW. The report claims that most installed capacities of PV production is intended for self-consumption. This is because there is no economic potential for utility-scale PV systems connected to the grid.

Overview of current framework conditions, regulations and tax scheme

On a national level the report considers the following regulations/schemes; MuniFin, COP21 targets, investment support/energy aid for renewable electricity production, and tax credits. The report also describes hourly-based-net metering for individuals, BIPV support measures and support schemes for energy storage.

2.5.2 KEY REPORT 2: PÖYRY (2017) THE POTENTIAL OF DISTRIBUTED ENERGY PRODUCTION IN FINLAND

Short description

Pöyry Management Consulting has assessed the potential for distributed energy production in Finland, a report ordered by the Finnish government. The report examines the technical and financial potential[5] of distributed energy production in Finland up to 2030. Distributed energy production is defined in the report as electricity and or heat production which is mainly used by the producer.

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[4] PV installations are included in the 2017 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2017, although commissioning may have taken place at a later date.

[5] The profitability of installing solar PV cells. In the report, internal rates of return (IRR) are calculated for different scenarios.

The report considers different sources for distributed electricity production. Production from PV, wind and hydroelectric power are included in the statistics. In addition, the report considers factors that might affect the development of decentralized production of electricity. Factors taken into consideration by the report include the spot price of electricity, the cost of installation, regulations/support, block chain technology, the Finnish datahub and the development of battery technology.

Distributed electricity production and self-consumption

Solar panels (PV-power) appear to have the largest potential for household electricity production on individual properties. According to the analysis, solar PV electricity production is already profitable in certain types of properties given that the produced energy can be used to replace purchased electricity and thus save costs occurring from energy and transfer fees and taxes. In addition, solar heating can be used to supplement all types of heating methods both in new and existing properties. In 2014 there were a total capacity of 11 MWp PV in Finland. The report refers to a study by the Finnish Energy Agency in 2015, which found there were 151 active small hydropower plants in Finland in 2013 (capacity up to 10 MW), 68 of which had a capacity of less than 1 MW. The study showed that 44% of total production capacity (all technologies) <1 MW came from hydropower and that 62% of production below 1 MW came from generators with a maximum capacity between 0.5 and 1 MW. Production of electricity from households was low, with a total capacity of 120 MW.

Effects of distributed electricity production/consumption on different power systems

Distributed energy production is not considered only from an economic perspective, current market and business models. The report suggests that distributed energy production may open new operating models which also create non-financial value[6] to customers and end-users.

Challenges or barriers to the development of distributed electricity production/self-consumption

The report looks into barriers for the development, and measures that can be implemented to help overcome such barriers. Barriers include low awareness and lack of competence about the positive effects related to distributed electricity production.

Future growth scenarios

In order to consider the potential future growth of decentralized energy production, the report looks at small-scale PV, wind and Hydro.

For PV produced electricity in Finland, the report looks at available rooftop area suitable for PV production and concludes that there is a potential capacity of 14.2 GW (13 TWh/year). The report includes an estimation of the development in installed rooftop power generation until 2030. The report expects strong growth, mostly in the commercial building segment.

For small wind power production, the report concludes that the development will be limited in the foreseeable future. For hydropower the report claims that further analysis would be required to reach a conclusion on future development, naming nature conservation as one of the largest obstacles.

Importance of local storage in relation to distributed electricity production/self-consumption

The report expects that that cheaper batteries will enable prosumers to store more excess production, which is likely to increase the value of distributed generation.

2.5.3 KEY REPORT 3: MINISTRY OF ECONOMIC AFFAIRS AND EMPLOYMENT (2018) A FLEXIBLE AND CUSTOMER-CENTERED ELECTRICITY SYSTEM

Short description

The report "A Flexible and customer driven Electricity System" was published by the Ministry of Economic Affairs and Employment in 2018. The report was prepared by a working group formed in 2016 by the Ministry of Economic Affairs and Employment to explore the potential of a smart electricity system. The goal of the working group was to make concrete proposals on how the customers could better engage in the markets and maintain security of supply. In the report, the working group gives recommendations on four main

[6] Non-financial value refers to benefits for the consumer apart from the direct value of the electricity/saved costs, for instance the perception of contributing to the reduction of greenhouse gas emissions or being self-supplied with electricity.

themes; The roles and rules in the electricity market, Market-driven incentives, sufficient technical preconditions, and cooperation across sectoral boundaries.

Distributed electricity production and self-consumption

The report claims that "The smart electricity system will work as a platform in the transition towards a more distributed and low carbon electricity system" – it will give customers better opportunities to participate in the electricity market, improve security of supply and cost-effectively create new business opportunities for companies.

The report considers the current state of different types of distributed electricity production, barriers and possible measures to improve market access. The report describes three types of energy communities were considered: i) within a housing company, ii) community crossing property boundary and iii) distributed/virtual community where the assets are connected through the common grid.

Overview of current framework conditions, regulations and tax scheme

On a national level the report describes the following regulations; distribution grid tariffs, proportional electricity tax, taxation of electricity storage, regulation of grid companies to support flexibility and building regulations. The report considers the implications of these regulations/schemes and provides recommendations. In addition, the following EU-regulation is described in the report: EU's Clean Energy Package, EU's cyber security regulations and EU energy tax regulation.

Effects of distributed electricity production/consumption on different power systems

The emphasis in the report is that demand response should be market based and also the DSOs should procure flexibility from the markets. It identified that large scale bi-directional transmission (or distributed generation) would increase the need for more detailed information from the generation assets for the DSOs and would also put pressure on data exchange. Demand response can be either de-crease in demand or increase in generation.

Challenges or barriers to the development of distributed electricity production/self-consumption

The report explains the factors affecting distributed electricity production. For instance, the report explains that a fixed tax based on energy consumption does not give price signals to consumers, but does not, on the other hand, recommend proportional electricity taxation. Another challenge is related to the distribution of electricity becoming bi-directional. The report explains that the new system will need cost-effective approaches in the planning and operating of the grid, including the management of bottlenecks, fault situations, voltages and reactive power through market-based mechanisms. With regards to building regulations, the report claims that supplementary plans for electrical wiring, Heating, ventilation, and air conditioning (HVAC), plumbing and automation are essential to control electricity and energy consumption.

Importance of local storage in relation to distributed electricity production/self-consumption

The report considers the importance of electricity storages, explaining that it can be used for several purposes. One function derived from storage is increased profitability from distributed production. Storage will enable the consumer to save self-generated electricity and consume it when prices are high. A battery storage would also allow consumer to capitalize on the variations in the electricity market, selling excess electricity when prices are high and buying when prices are low. This could contribute to lower price volatility in the market for electricity. Furthermore, storages can be used to assist frequency control. Furthermore, storages could improve the security of supply by creating a more flexible electricity grid. To be able to reap the described benefits, it is emphasised in the report that that the operation of storage should be market based. Therefore, the monopoly companies should be allowed to operate storage only in limited situations. (Ministry of Economic Affairs and Employment of Finland, 2014)

2.5.4 OTHER REPORTS FINLAND

In addition to the key reports, the following reports have been a part of our written sources:

Ruggiero et al. (2015): Transition to distributed energy generation in Finland: Prospects and barriers

2.6 Literature overview – Denmark

2.6.1 KEY REPORT 1: PA ENERGY (2016) NATIONAL SURVEY REPORT OF PV POWER APPLICATIONS IN DENMARK

Short description

The National Survey Report of PV Power Applications in Denmark was published by PA Energy in 2016. It was used as input for the annual Trends in photovoltaic applications report published yearly by the International Energy Agency (IEA). The National Survey Report of PV Power Applications in Denmark seeks to give a situational description of PV in Denmark. It describes how much PV-generated electricity capacity was annually installed between 2005-2017, PV module price data, and in which segments the capacities were installed. In addition, it looks at different regulations and schemes that are related when considering instalments of PV capacities.

Distributed electricity production and self-consumption

The report shows statistics of installed PV production capacity in Denmark. The segments of PV made in the report are standardized for all IEA National Survey Reports and split installed capacity into grid-connected and off-grid. Grid-connected instalments are split into BAPV & BIPV and Ground-mounted. BAPV and BIPV are then split into Residential, Commercial and Industrial instalments. The report does not discuss how much of the installed capacity was built with the intent of self-consumption.

The National Survey Report of PV Power Applications in Denmark shows that Denmark's installed grid connected capacities of 71 MW in 2016. The installed grid connected capacity was split between ground mounted installations, 51 MW, and BAPV & PIPV, 20 MW. The installed off-grid capacity was only 0.4 MW in 20016. The historical development of installed capacity of grid connected PV installation year by year, goes back to 2005. It shows that the development had a strong positive trend in 2012 with an increase in installation by 2440% from 16.7 MW to 407.6 MW between 2011 and 2012.

Overview of current framework conditions, regulations and tax scheme

On a national level the report describes that there was a small number of support schemes for grid connected PV still active in 2016. These support schemes were all expected to be completely phased out before end of 2017. The report also states that no renewable energy technology specific support schemes are to be expected in the near future.

Future growth scenarios

A new energy plan from 2020 and onwards is being prepared and discussed on the political level. The new energy plan is expected to provide a more level playing field for PV in the future Danish energy system.

2.6.2 KEY REPORT 2: ENERGINET (2016) PV AND BATTERIES IN DENMARK

Short description

The report analyses possible future developments for PV in Denmark. The analysis is based on the 2016 prices, tax levels and the possibility of net settlements. The analysis shows that even without incentives from taxes and grants, the solar PV power plants can be economically feasible and profitable in the period 2025 and beyond.

Distributed electricity production and self-consumption

The scenarios in the report shows that total installed capacity increase could be substantial and approximately rise to about 4-6.5 GW in 2040, depending on described scenario. The analysis shows that a large expansion of PV in the electricity system has a limited effect on the electricity market price.

Challenges or barriers to the development of distributed electricity production/self-consumption

An expansion of solar PV cell and battery capacity can have significant consequences the operation and expansion of the Danish electricity system. The report suggests as PV mainly will be connected to the electricity grid close to where electricity consumption is. Hence, the transmission grid is used to a lesser extent to supply the underlying distribution grid when the solar PV cells produce the most. In some cases, the transmission grid will be used to transport electricity from areas with surplus to areas with deficits. A significant expansion with photovoltaic solar cells also makes balancing the power system more challenging.

Future growth scenarios

The future growth is mainly depending on the expected price drops on PV systems and a continuous price decrease. The analysis also describes the economy of battery solutions in combination with PV. The result is very sensitive to changes in market conditions. If the current framework is preserved, the analysis shows that the combi-system can pay off after 2020. Combined PV and battery systems are expected to spread as the price of batteries decreases. A combined PV and battery systems increase the level of being self-sufficient. The system does not however make the owner independent of the grid, mainly due to seasonal variations.

2.6.3 KEY REPORT 3: ENERGINET (2018) SMALL PRODUMERS INTERPLAY IN THE FUTURE ENERGY SYSTEM 2030

The report analyses a possible future scenario to illustrate the possibilities and challenges of distributed electricity production 2030.

Distributed electricity production and self-consumption

Significant fall in prices for solar PV cells and batteries in recent years can in the longer term give households incentive to achieve a significant share self-supply of electricity. Households can achieve a degree of self-sufficiency in the establishment of a solar PV power plant in combination with a battery for storing excess production from the solar cells. Prosumer solution also consist of other technologies such as micro CHP plants, heat pumps, etc.

Overview of current framework conditions, regulations and tax scheme

The investment analysis in the prosumer solutions shows that under current framework conditions it is not privately economically advantageous to invest in a photovoltaic system with the sole purpose of producing and selling power to the grid. The analysis shows that a feasible prosumer solution is a PV system connected to a battery storage. The need for seasonal storage and the electricity demand during winter makes is necessary to be grid connected, as an off-grid solution would not be feasible.

Challenges or barriers to the development of distributed electricity production/self-consumption

Since off-grid solutions are not feasible for prosumers, due to seasonal storage, prosumers are predicted to still be depending on stable grid connections. The distribution grid is therefore regularly used throughout the year either export of surplus electricity from the solar cell plant or as backup in periods. The challenges of the distribution grid are not analysed in the report, but the challenges are addressed as an important issue.

Future growth scenarios

The electricity price, CO2-pices, battery prices but also the number of European prosumers is expected to have a significant impact on the Nordic number of prosumers. Due to the interconnections between the Nordic countries and the rest of Europe is the European development an important factor when analysing the future growth in the market of prosumers.

2.6.4 OTHER REPORTS DENMARK

In addition to the key reports, the following reports have been a part of our written sources:

- Danish Energy Agency (2018a): Danish energy and climate outlook 2018
- International Energy Agency (2017): Review of energy policy in Denmark
- Danish energy agency (2019a): Technology neutral support scheme (incl. onshore wind, and solar)
- Danish energy agency (2019b): Technology support scheme Solar PV
- Danish energy agency (2019c): Technology support scheme for household wind turbines

- Energinet (2018a): Systemperspektiv 2035 - Hovedrapport
- Energinet (2018b) Systemperspektiv 2035 – Baggrundsrapport,
- Energinet (2018c): Appendix to Systemperspective 2035 - Modelling of Energy Plants
- EUDP (2017): EUDP Strategy
- Danish Energy Agency (2016a): Bekendtgørelse om nettoafregning for egenproducenter af elektricitet,
- Danish Energy Agency (2017): Bekendtgørelse om ændring af bekendtgørelse om nettoafregning for egenproducenter af elektricitet
- Danish Tax Agency (2019): Taxation electricity
- Danish Energy Agency (2018b): L 190 - Forslag til lov om ændring af lov om fremme af vedvarende energi, lov om elforsyning og lov om Energinet
- Danish energy agency (2019d): Support scheme for Energy development and demonstration projects

2.7 Literature overview – Iceland

2.7.1 SUMMARY OF LITERATURE OVERVIEW ICELAND

We have not identified any written sources dealing with distributed electricity production in Iceland specifically. We note that the electricity production in Iceland is fully renewable. In a response to the European commission, the Icelandic ministry of industries and innovation wrote that "There is no need for special methods to ensure that renewable energy sources are given priority as the production is 100% renewable energy" (Icelandic Ministry of industries and Innovation, 2014).

2.7.2 VARIOUS WRITTEN SOURCES ICELAND

The following sources are of some relevance to distributed electricity production in Iceland:

Icelandic Ministry of Industries and Innovation (2014): The Icelandic National Renewable Energy Action Plan for the promotion of the use of energy from renewable sources in accordance with Directive 2009/28/EC and the Commission Decision of 30 June 2009 on a template for the national renewable energy

- National Energy Authority Iceland (2019a): Hydropower Plants in Iceland
- N. Nawri et al (2013): The Wind Energy Potential of Iceland.
- National Energy Authority Iceland (2017): Energy Statistics.

3 Distributed electricity production and self-consumption in the Nordics 2005-2017

The installed capacity of distributed renewable electricity production for self-consumption in the Nordics was about 2750 MW in 2017, an increase from the 1880 MW in 2005, despite different trends for the various technologies. While micro-scale ageing wind power in Denmark and Sweden stands for about three quarter of the installed capacity, it has been decreasing for a while as a consequence of natural phase-out at the end of their technical lifetime. It is mainly the photovoltaic installations that have been increasing during 2005-2017, while distributed hydropower has remained constant.

In energy terms, we estimate that about 4,6 TWh electricity that potentially could be used for self-consumption were produced in the Nordic countries in 2017, the majority of it – 3,6 TWh - in Denmark, followed by Sweden and Norway.

3.1 Methodology

The statistic overview aims at covering the development of distributed electricity production within the Nordics during the years 2005-2017. For all technologies except photovoltaics – where 100% are seen as distributed energy units, this analysis defines all production units below 1 MW as potential distributed energy units. Since the International Energy Agency divides the PV installations between 'distributed' and 'centralized' units, this report includes all installations within the distribution category into the small-scale segment.

The electricity produced by grid-connected generators with a maximum installed capacity of 1 MW can be split in the following categories (NVE, 2018b):

- Electricity production intended for self-consumption (by households and businesses producing mainly for their own consumption)
- Other electricity production

Since not all the energy produced in the small-scale production units below 1 MW is generated with the purpose of self-consumption, this report has analysed the market in all the Nordic countries. Estimates were made of the share of the production capacity that are potentially *generated and used for self-consumption*, mainly based on ownership information (private persons or small businesses are expected and counted for as prosumers), in some cases also estimates by branch organisations or other experts.

These estimations therefore only provide an approximation of the *energy produced* in the production units that are *installed for potential self-consumption*, but *not self-consumption itself*. Note that this study estimates the total amount of electricity produced in these distributed units and does not split the production between what is actually used for self-consumption and what is delivered to the grid. Figure 5 shows an overview of the electricity produced in units meant for self-consumption in the Nordics 2017.

Note therefore that this report estimates the total amount of electricity produced in these distributed units and does not split the production between what is actually used for self-consumption and what is sold.

To perform the analysis and collecting data we have used written sources, national regulators/energy agencies data, national registers and performed interviews, mainly with member driven energy associations. In this chapter, we will first describe the statistical overview for all the Nordic countries divided per technology. Secondly, we will describe the national data, the historical development in each country and other relevant findings.

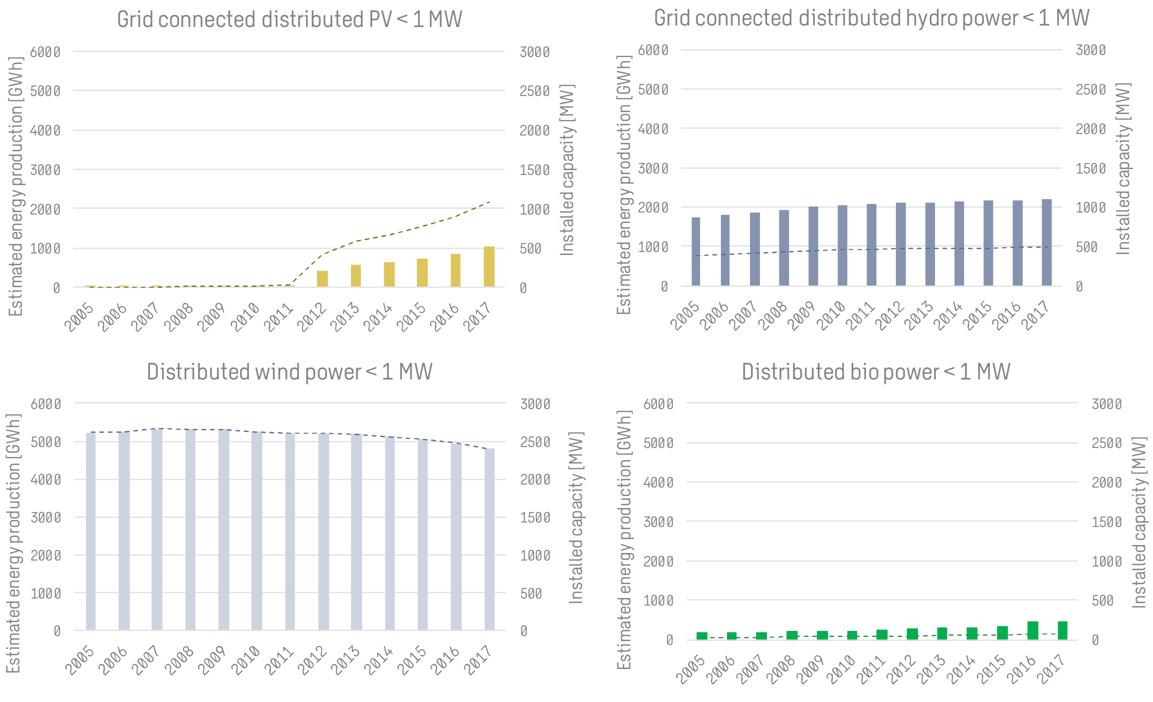
3.2 Statistical overview Nordics

The installed capacity of distributed renewable electricity production for self-consumption in the Nordics was about 2750 MW in 2017, a slight increase compared to the installed capacity in 2005, see Figure 4. The largest growth is due to the increased installed capacity in photovoltaics, mainly in Denmark 2011-2012. The installed amount of photovoltaics is also increasing due to increased interest and installed capacity in Sweden 2016-2017.

Since 2005 the installed wind power capacity in small-scale units, below 1 MW, has decreased and the small-scale units are replaced by large scale wind power turbines. The installed capacity in small-scale wind power is largest in Denmark followed by Sweden.

The small-scale hydropower has a long history mainly in Norway and Sweden. Many small-scale production plants are located to support local farms and businesses with self-consumption. The Swedish and Norwegian energy agencies however, do not have complete and detailed registers of the small-scale production units and hence the development is difficult to estimate.

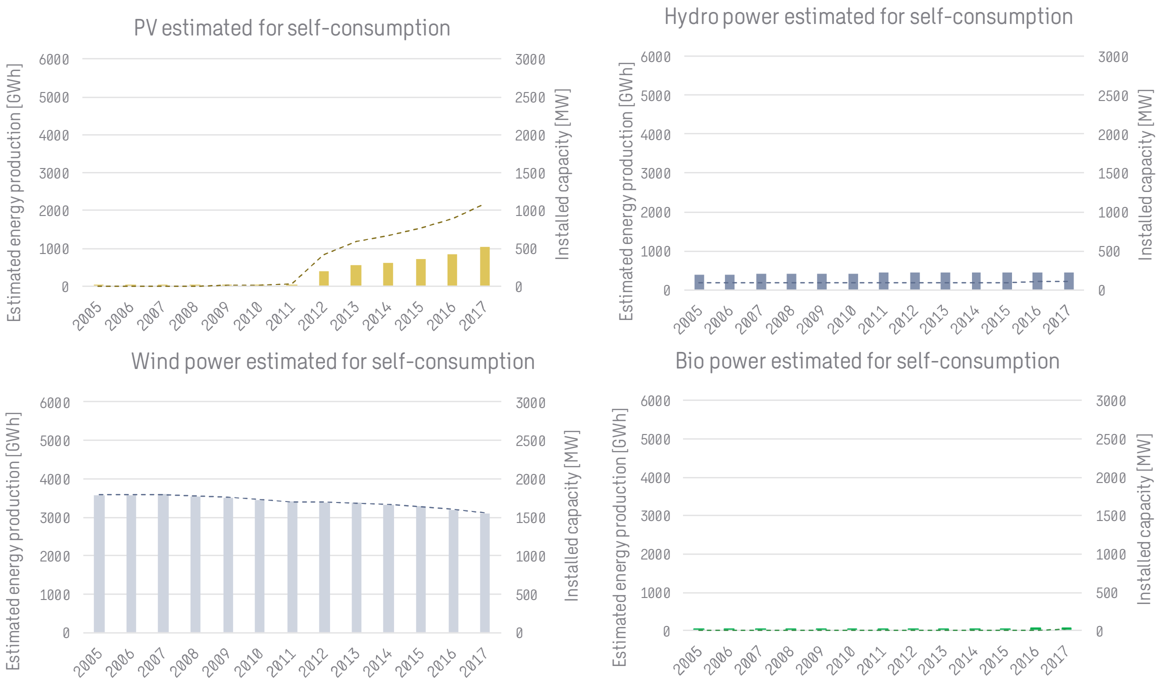
Figure 3: Summary of installations below 1 MW in the Nordics 2005-2017, total generated electricity (bars, primary axis) and installed capacity (line, secondary axis)



Source: Sweco, IEA-PVPS (2017a), Danish Energy Agency (2019e), Finnish Energy Agency (2019), Swedish Energy Agency (2019a), NVE (2019b), National Energy Authority Iceland (2019b)

Figure 4 shows the estimated units installed with the purpose of self-consumption in the Nordics 2005-2017, which naturally is assessed to be the same (such as solar) or lower than the values in Figure 3.

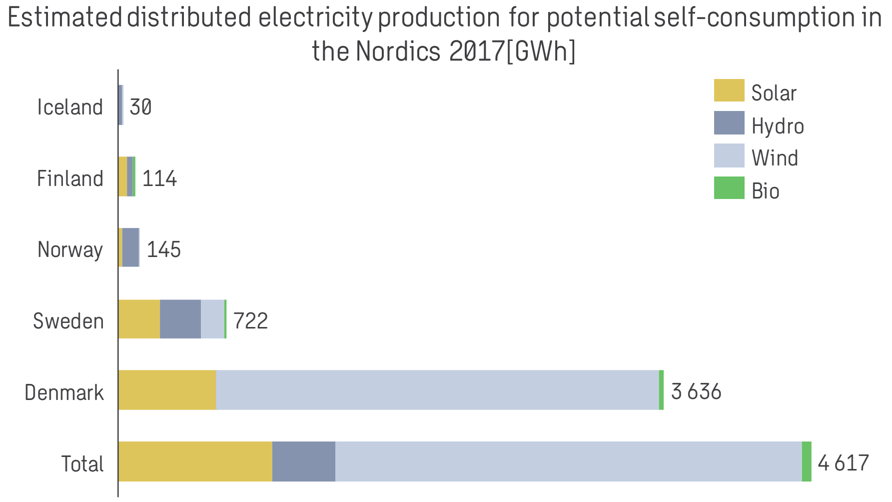
Figure 4: Summary, units for self-consumption in the Nordics 2005-2017, total generated electricity (bars, primary axis) and installed capacity (line, secondary axis)



Source: Sweco, IEA-PVPS (2017a), Danish Energy Agency (2019e), Finnish Energy Agency (2019), Swedish Energy Agency (2019a), NVE (2019b), National Energy Authority Iceland (2019b)

Note that this study estimates the total amount of electricity produced in these distributed units and does not split the production between what is actually used for self-consumption and what is delivered to the grid. Figure 5 shows an overview of the electricity produced in units meant for self-consumption in the Nordics 2017.

Figure 5: Estimated distributed electricity production for potential self-consumption in the Nordics 2017



Source: Sweco estimates, Oslo Economics

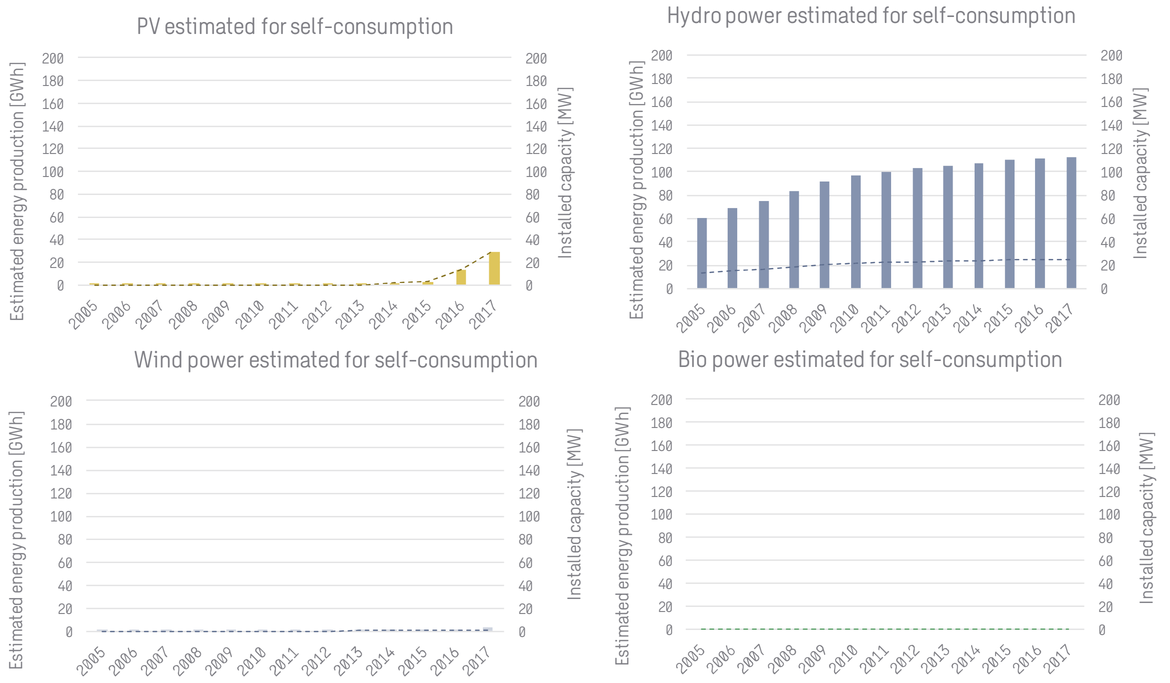
3.3 Statistical overview – Norway

The distributed electricity production in Norway is mainly hydropower but also solar PV to some extent. The amount of installed PV in Norway increased during 2016 and 2017, reaching 31 MW, see Figure 6. The installed capacity in hydropower units below 1 MW was about 202 MW in 2017, of which only a smaller share of private owner or small businesses is assumed to produce for self-consumption.

We estimate that the total prosumer production capacity in Norway in 2017 consists of:

- 31 MW of solar PV power (~25 GWh)
- 25 MW of hydropower (~112 GWh)
- 1,25 MW of wind power (~3,5 GWh)
- Total: 57,2 MW of prosumer power (~140,5 GWh)

Figure 6: Summary, units for self-consumption in Norway 2005-2017, total generated electricity (bars, primary axis) and installed capacity (line, secondary axis)



Source: Sweco, NVE (2019b), IEA-PVPS (2016a; 2018a)

3.3.1 Solar PV

The market for solar PV in Norway is split between grid-connected systems and solar PV to off-grid applications. Until 2014, the PV market in Norway was driven mainly by the installation of off-grid systems. However, the installed capacity of grid-connected systems increased a ten-fold from 0.1 MW in 2013 to 1.4 MW at the end of 2014, becoming the main segment of the PV market. In 2016 and 2017 there was a large growth of the installed PV capacity, driven both by installation of household and commercial on-grid systems. In 2017 the installed capacity was 45 MW, of which 31 MW was distributed grid-connected PV's.

Based on our knowledge of solar PV power production in Norway, the installed capacity could almost exclusively be classified as prosumer production (100% of 31 MW). PV-panels in Norway are significantly more profitable when installed "behind the meter" because self-consumption allows the owner to save grid tariffs and electricity taxes, described in more detail in Chapter 4.2.2. Therefore, the facilities are mainly roof-mounted PV-panels or systems installed by private persons or companies and based on self-consumption business models. We are not aware of any stand-alone centralized PV-production facility in Norway. Multiconsult has estimated that the total annual electricity production of PV-cells in Norway is below 200 GWh (Solenergiklyngen, 2018). As with the installed capacity, we classify the total PV-production as prosumer production. The amount of full load hours in Norway is estimated to 800 hours/year.

3.3.2 Hydropower

Norway has a long history of small-scale hydropower electricity production. In the early development of the Norwegian power system (1920-1940), small-scale hydropower played a significant role. In 1946 about 1 800 plants with a capacity of less than 1 MW were in operation. With larger plants being more efficient, less costly etc. many small plants were decommissioned and by 1990 only 100 small-scale plants were still in operation.

In 2002, the Norwegian government set a goal to enhance construction of small hydropower plants in Norway. To achieve this goal, the government undertook a comprehensive program including assessing the potential for small hydro development in Norway, investing in research and education, and providing economic incentives for small hydro development (HydroWorld, 2008).

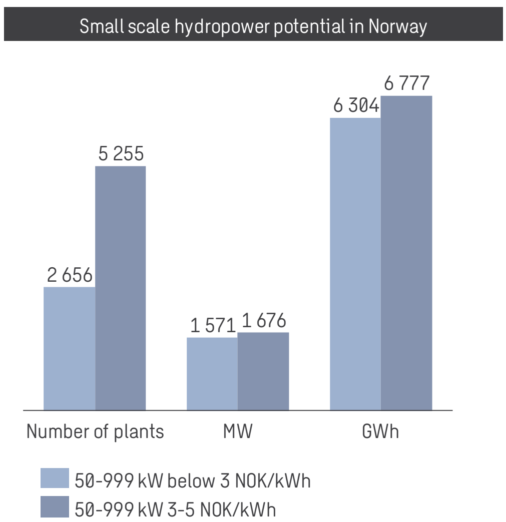
Small-scale hydroelectric power plants in Norway are classified into three categories: "small power plants" have an installed effect between 1 and 10 MW; "mini power plants" have an installed effect between 100 kW and 1 MW; and "micro power plants" are power plants with an installed effect of less than 100 kW. In 2017, NVE estimated that the total number of small-scale hydropower plants with installed capacity below 1 MW was 560, with a total installed capacity of 180 MW and an annual electricity production about 0.8 TWh. In 2018 the corresponding number of small-scale hydropower plants were 580, with a total installed capacity of about 200 MW (NVE, 2019c).

Due to the lack of data, we have made a rough estimate of the amount of prosumer hydro production in Norway. We have been in contact with two hydropower small scale hydro power owners in Norway, in addition to the association of small-scale producers (Småkraftforeningen). The association of small hydropower plant owners approximated in 2012 that about 60% of the small-scale hydropower plants below 1 MW were mini hydro plants (100 kW-1 MW) and 40% were micro hydro plants (up to 100 kW). Over 350 small-scale hydropower projects (<10 MW) have been commissioned in Norway since 2003 (iha, 2017).

Form the NVE database we see that the installed capacity in plants below 1 MW during 2005-2017 were about 100 MW. The total installed capacity in 2017 was about 202 MW. In the register we see that 25 MW of the small-scale units below 1 MW are registered on private owners, associations or have unknown owners. The large-scale production is registered on energy companies or corporations. This gives us the estimation that about 12% of the distributed electricity production is used for self-consumption.

By using GIS-analysis the Norwegian energy agency performed growth potential overview for small-scale hydropower in 2004 (NVE, 2004).The mapping and analysis showed that the potential for small-scale hydropower with installed capacity below 1 MW and production costs below 5 NOK/kWh was about 3 GW with a delivered energy potential of 13 TWh, see Figure 7. According to the analysis, the number of small-scale hydropower plants could potentially reach about 8 000 if all potential rivers were to be used for small-scale hydropower production.

Figure 7: Estimated potential for small-scale hydropower in Norway



Source: Sweco, NVE (2004)

3.3.3 WIND POWER

In 2017 almost 2% of the electricity production in Norway was from wind power plants. The number of installed wind turbines was 468 and the total installed capacity was 1188 MW (NVE, 2019d). Almost all wind turbines were installed in wind power parks with two or more installations joint together, the largest with in total 68 turbines. Only four of the installed turbines was standalone turbines and out of those only two meet the criteria of an installed capacity below 1 MW (NVE, 2019e). Of the only two small-scale wind power plants in operation in Norway one is owned by a local energy company as a part of an NVE research project, Andøy Energi AS, and the other is registered on a farm owner and was installed in 2015. The plant connected to the farm can produce up to 225 kW of electric power. The farmer intends to sell the excess electricity to the grid (Samferselinfra, 2018).

As mentioned above, we are only aware of one single prosumer wind production plant in Norway. This prosumer wind farm has a power capacity of 225 kW. Given a capacity factor of 0.3 (Vindportalen, 2019) (and 8760 hours per year), we estimate that the wind mill produces around 225 kW*0.3*8760 h per year = 591300 kWh per year (0.6 GWh).

3.3.4 OTHER SOURCES

There are at the moment a hand full research project on wave and tidal power. These are often below 1 MW located at the coast of Norway. These projects are still in their development stage and are not considered to be designed for self-consumption.

3.4 Statistical overview – Sweden

The estimated approximate installed distributed electricity production in Sweden was in 2017 40% small-scale wind power, 30% PV and 30% small-scale hydropower. The total amount of installed distributed electricity production was about 1000 MW.

The installation of PV has increased during the past 5 years and is now 294 MW. There is no statistical data on the small-scale hydropower in Sweden. Interviews with the small-scale hydropower association gave us information that the number of small-scale hydropower plants has decreased since the 1950's and the 1960's but that it during the past 10 years should have been stable. The current data from the Swedish Energy Agency (2019b) gives us reason to estimate the installed capacity in small-scale hydropower to about 235 MW.

The estimation of self-consumption is based on the electricity certificate register. In the register all the companies and private owners accepted for electricity certificates are listed. This does not give a full picture but are used for estimations since the register gives understanding about the share of private owners.

We estimate that the total prosumer production capacity in Sweden in 2017 consists of:

- 294 MW of solar PV power (279 GWh)
- 61 MW of hydropower (275 GWh)
- 75 MW of wind power (150 GWh)
- 3 MW of bio power (18 GWh)
- Total: 432 MW of prosumer power (722 GWh)

Figure 8: Summary, units for self-consumption in Sweden 2005-2017, total generated electricity (bars, primary axis) and installed capacity (line, secondary axis)

Source: IEA-PVPS (2017a), Swedish Energy Agency (2019c)

3.4.1 Solar PV

Until the early 2000s, the Swedish solar PV market almost exclusively consisted of a small but stable off-grid market where systems for holiday cottages, marine applications and caravans have constituted the majority. Since 2007 more grid-connected than off-grid capacity has been installed annually and Sweden had about twenty times more grid-connected PV capacity than off-grid capacity at the end of 2017. The grid connected market is almost exclusively made up by roof-mounted systems installed by private persons or companies built on self-consumption business models. About 34% of the installed grid connected PV power is privately owned systems on single family houses and approximately 62% is built on company, agriculture or public buildings.

The installation rate of PV continues to increase in Sweden. A total of approximately 117.6 MW were installed in 2017 means that the total national installed capacity increased to about 322 MW. About 90% of the installed capacity is grid-connected distributed solar PV. So far only a couple of relatively small centralized PV parks, 4% of the grid-connected market, has been built. In 2017 three installations above 1 MW was connected to the grid and the installed capacity increased from 4.32 MW to 7.76 MW. The cumulative capacity in installed off-grid PV was about 15 MW year 2017.

Based on our knowledge of solar PV power production in Sweden, approximately the installed capacity named 'grid connected decentralized' in the PVPS report could almost exclusively be classified as prosumer production (100% of 294 MW). The electricity production of photovoltaics in Sweden is 950 kWh/kW[7] (IEA-PVPS, 2017a) and thus the electricity production 279 GWh in the self-consumption installations.

The size distribution of solar PV in Sweden mainly smaller installations. In 2017 about 12 900 of the installations performed was in production units below 20 kW and 2 400 of the installations was 20-1000 kW, se Table 1. The total installed capacity however is more evenly distributed. Only a few installations above 1000 kW has been installed in Sweden before 2017, see Figure 9.

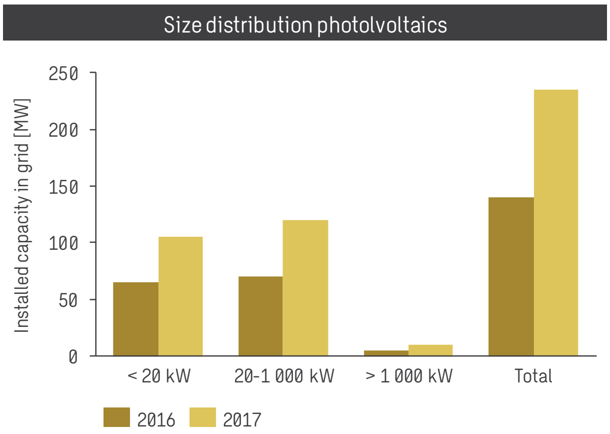
[7] although the Swedish Energy Agency deems the figure of 950 kWh/kW as too high

Table 1: On grid PV below 1 MW in Sweden 2017

2017	Number of installations	Installed capacity [MW]
< 0.02 MW	12 863	103.84
0.02-1.00 MW	2 407	119.38

Source: SCB (2019)

Figure 9: Size distribution of photovoltaics in Sweden



Source: Swedish Energy Agency (2018b)

3.4.2 Hydropower

In Sweden, the first hydropower plants used for producing electricity were commissioned in the 1880s. The major expansion of hydroelectric power in Sweden took place in the 1940s - 1970s. In 2013 the total number of hydropower plants in Sweden were about 2000 out of which 1700 have an installed capacity of maximum 1.5 MW. Plants with installed capacity below 1.5 MW produce about 2.6% of the total hydropower electricity, see Table 2. The total installed hydropower capacity in Sweden is 16200 MW of which 1050 MW is installed in plants below 10 MW (SOU 2013:69).

Table 2: Size distribution hydropower plants in Sweden 2013

Installed capacity	Number of plants	% of total production
>10 MW	208	94%
1.5 - 10 MW	187	3.9%
125 kW – 1.5 MW	~680	2.1%
< 125 kW	~1030	0.5%

Source: Statens Offentliga Utredningar (SOU 2013:69)

The construction of new hydro plants has largely ceased, due to environmental and political considerations. There is no complete list of installed small-scale hydropower plants and therefore hard to estimate the installed capacity in plants below 1 MW. Small-scale hydropower plants are mainly installed in the southern parts of Sweden. Small-scale hydropower plants are often used for self-consumption and local electricity production i.e. in farms and countryside estates. Small-scale hydropower is mainly installed in naturally flowing water, without dams or water storage. The regulating capacity in the small-scale hydropower in thus limited (SOU 2013:69).

Since there is no national data on the installed small-scale hydropower plants, the number of plants and installed capacity is hard to estimate. The small-scale hydropower association in Sweden (Jacobson, 2019) estimates that the total installed capacity in small-scale hydropower plant was about 1000 MW in 2017 and that the development since 2005 has been stable. The association states that a number of plats has been decommissioned since 2005, but since then energy efficiency measures has increased the capacity in existing plants thus the total installed capacity has been stable.

The small-scale hydropower association has identified barriers for future development such as environmental standards and permits.

The small-scale hydropower in has a long and rich history in Sweden. The small-scale hydropower association estimates that there are more than 1000 small-scale power plants but there is no complete national register of grid connected plants. This means that the share of small-scale production and also the amount of self-consumption is hard to estimate. SOU estimates that about 2.5% of the produced hydropower is generated in plants below 1.5 MW. The hydropower production is about 60 TWh. The hydropower association estimates that the number of full load hours (FLH) is about 4500-5000 per year in the Swedish small-scale hydropower. The Swedish Energy Agency database (of installations within the electricity certificate system) of installed hydropower plants shows that 235 MW of the installed hydropower capacity is in units below 1 MW. This corresponds to 1060 GWh. About 25-26% of the registered small-scale hydro plants are registered on private owners and can thus be expected to be used for self-consumption. The estimation om 26% self-consumption in the plants below 1 MW means that the total installed capacity for this is 61 MW and the electricity production for self-consumption 275 GWh.

3.4.3 Wind power

In 2016 was 12.3 % of the electricity in Sweden produced by wind power. The total installed capacity in all wind power has increased with about 6000 MW since 2006 and was about 6611 MW in 2017. In ten years, the installed capacity increased with more than 800%, see Figure 10. For wind power, 75 MW of the installed wind power capacity below 1 MW, in total 415 MW, was registered on private owners. The approximated annual electricity consumption in the plants below 1 MW are approximated in the register to 1550 GWh, and 150 GWh is estimated to be produced in plats used for self-consumption. The increase in small-scale wind power turbines is not as extensive.

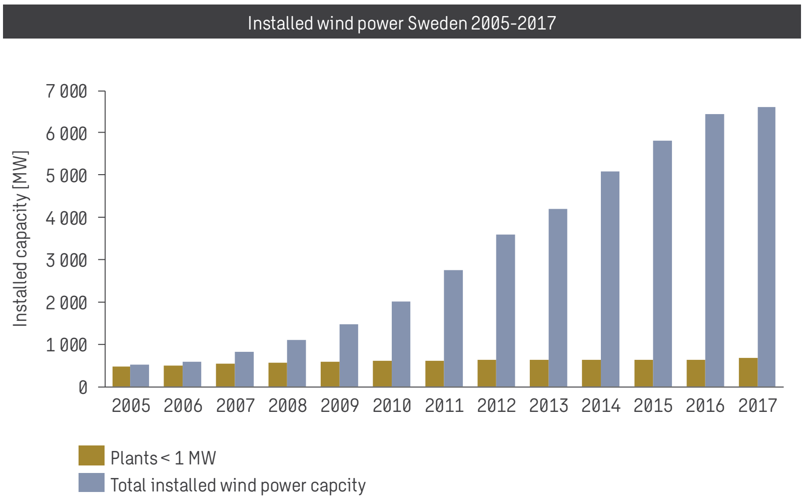
Year 2003, i.e. at the time the electricity certificate scheme was introduced, there were approximately 230 MW installed in wind power turbines with capacity below 1 MW. Only a few installations were turbines above 1 MW[8]. In the Swedish national register of green certificates and guarantees of origin, CEASAR, the installed capacity in small-scale wind power plants below 1 MW have increased since 2003 from 230 MW to about 415 MW in 2017.This means that the small-scale wind power production has not been increasing as extensively as the total wind power capacity in 2005-2017.

The Swedish Wind power association (Ruin, 2019) believes that this is due to a technology shift towards larger turbines with higher efficiencies. The association also believes that there has been a drawback of small-scale wind power installations due to an increase of PV systems. The wind power association has observed that the number of installations for self-consumption on i.e. farms has decreased and believes that the competition with PV might be one of the reasons. Small-scale wind power installations are more technical challenging than PV, the wind power production and wind conditions are harder to estimate, and the small-scale wind power is not as feasible as PV systems.

For wind power 75 MW of the installed wind power capacity below 1 MW, in total 415 MW, was registered on private owners. The approximated annual electricity consumption in these are approximated in the register to 150 GWh.

[8] The Swedish Energy Agency, Vindkraftens utveckling 1982–2014

Figure 10: Total installed wind capacity in Sweden 2005-2017



Source: Sweco, Swedish Energy Agency (2019c)

3.4.4 Bio power

There is a large number of heating plants with installed capacity below 10 MW. These plants have traditionally been regarded as inappropriate for electricity production since high operation costs make them economically unfeasible with a traditional steam turbine. New technology however makes electricity production possible in these small-scale heating plants. In 2017 there were 18 plants and 7 industrial facilities identified as small-scale (i.e. with heat production below 10 MW and electricity production below 3 MW). This type of plants qualifies for electricity certificates, but the technology is yet in testing scale and not yet mature (Svebio, 2017). Small-scale CHP with biofuels is mainly used by larger scale professional users and mainly not for self-consumption (SOU 2018:76).

There is essentially no existing market for cogeneration in Sweden for installed capacities less than 1 MWe. However, some CHP units in the range of 100–400 kWe were built in the early 1990s. It was estimated that about 30–40 mini-cogeneration plants were in operation in Sweden during this period. In 1990-2000 however, most of small-scale bio CHP was built for demonstration and research purpose (European Commission, 2004). In 2001 only 6 installations of CHP below 1 MWe (5140 kW in total) were still in operation. One was industrial and five in energy sector, based on the Swedish NOx-registry (Salomon Popa, et al., 2011).

The bio energy plants are mainly registered on energy companies and heat producers. About 20% however, are registered on private owners or farmers. This means that the estimated self-consumption in the bio power sector is 3 MW with a total electricity production of 18 GWh.

3.4.5 Other

In the statistics of approved plants in the Electricity Certificate scheme is one wave power plant identified in 2016. The plant is a test- and demonstration project for wave power with the installed capacity of 0.9 MW along the west coast of Sweden.

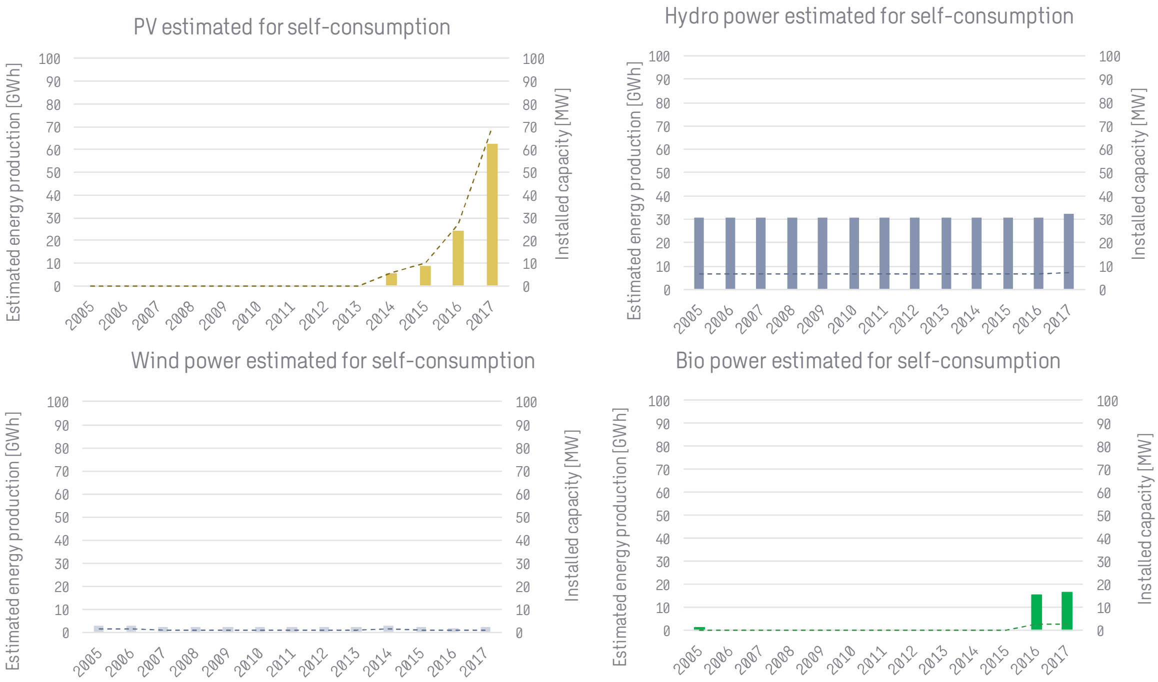
3.5 Statistical overview – Finland

In 2017, the total amount of installed capacity in small-scale electricity production units below 1 MW connected to the grid, was 140 MW. The distributed energy source with largest share of the installed capacity was PV. Since 2015 has small scale PV connected to the grid increased from 10 MW to 70 MW in Finland. The small-scale hydropower is about 36 MW and the small-scale wind 18 MW. In Finland most of the small-scale electricity is used for off-grid solution for i.e. summer cottages. Figure 11 shows self-consumption in Finland 2005-2017.

We estimate that the total prosumer production capacity in Finland in 2017 consists of:

- 70 MW of solar PV power (63 GWh)
- 7.2 MW of hydropower (32.6 GWh)
- 1 MW of wind power (2,2 GWh)
- 2,7 MW of bio power (16,6 GWh)
- Total: 80,9 MW of prosumer power (114,1 GWh)

Figure 11: Summary, units for self-consumption in Finland 2005-2017, total generated electricity (bars, primary axis) and installed capacity (line, secondary axis)



*Source: Sweco, Energiavrasto (2019), IEA-PVPS (2018b), *interpolated data*

3.5.1 Photovoltaic

The PV market in Finland has historically been concentrated to small off-grid systems. There are more than half a million holiday cottages in Finland, and a significant proportion of them has an off-grid PV system. The amount of off-grid PV capacity in Finland is estimated to be around 10 MW with a yearly increase of 0.3 MW. Since 2010, the number of grid-connected PV systems has slowly started to increase and in 2017 was the installed capacity in grid connected systems more than double the off-grid capacity. In 2017 the installed capacity in grid connected system was estimate to about 70 MW. Only between 2016 and 2017 the installed grid connected capacity increase from 27 to 70 MW. No centralized grid connected systems has been reported as installed during 2005-2017.

The grid-connected PV systems are mainly roof-mounted systems for public and commercial buildings and individual houses.

Based on our knowledge of solar PV power production in Finland, approximately the installed capacity named 'grid connected decentralized' in the PVPS report could almost exclusively be classified as prosumer production (100% of 70 MW). The electricity production of photovoltaics in Finland is 800-950 kWh/kW and thus the electricity production 66.5 GWh in the self-consumption installations.

3.5.2 Hydropower

Finland has a register for all grid connected power plants above 1 MW installed capacity. This however means that no statistical data is provided from the Finnish Energy Agency about the installed small-scale production units below 1 MW before 2016. In 2016 the energy agency started collecting data and an estimation of the installed capacity in small-scale energy plants was presented. The total installed small capacity was estimated to 132.4 MW in 2016 and 17.7 MW in 2017.

The installed capacity in small-scale hydropower in Finland was approximated to about 36 MW in 2017. The number of small-scale hydropower plants given Guarantees of Origin between 2005-2017 was 6 and the total installed capacity about 6 MW.

The Finnish Small Hydropower Association estimated that there were 68 small-scale hydropower plants in Finland below 1 MW in 2013. The total installed capacity in these plants was 34 MW and the annual produced energy was in average 133 GWh.

There is no national register of small-scale hydropower plants in Finland. The Finnish Energy Agency estimates that the installed capacity in plants below 1 MW was 34 MW in 2017. If the same share of self-consumption as Sweden is applied this means that 7.2 MW of the small-scale production units are used for self-consumption. According to the Finnish Hydropower association the small-scale applications are mainly used to provide farms or other business with electricity and can thus be considered as self-consumption. With the same about of full load hours as the Swedish hydropower this is 32.4 GWh.

3.5.3 Wind power

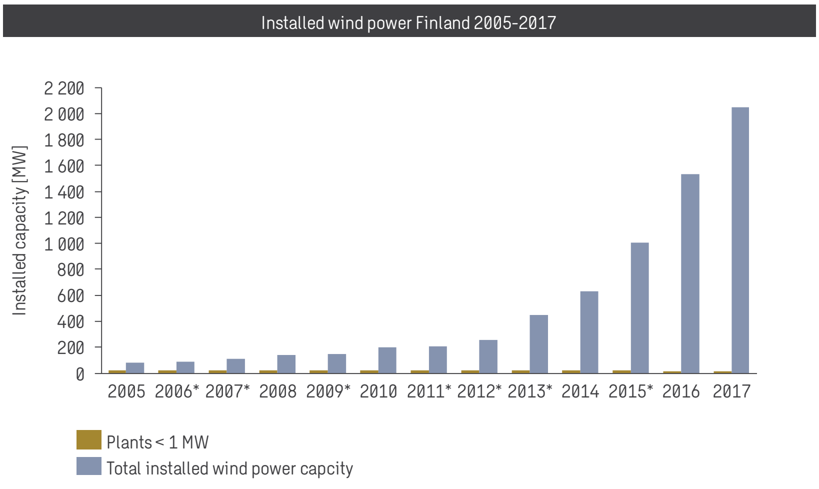
The installed capacity in small-scale wind power in Finland was approximated by the Finnish Energy Agency to about 18 MW in 2017. In 2005-2017 about 300 wind power plants was given Guarantees of Origin. Out of these only two plants were small-scale wind power plants with installed capacity below 1 MW.

Since 2005 the installed wind power capacity in Finland has increased to about 2000 MW. The amount of installed small-scale turbines has though been decreasing since 2005, see Figure 12. In the register of wind power projects in Finland about 5% of the projects in 2005 was owned by private owners or associations. This amount is expected to be the same in 2017 but of the projects initiated during 2005-2017 almost all projects are industrial and large scale. The amount of 1 MW used for self-consumption in 2005 is therefore expected to be constant 2005-2017. If the expected amount of full load hours of the Finnish wind power is 2000h, this corresponds to an electricity production of 2 GWh annually.

In 2005, the Finnish Wind Power Association estimates that 23 MW of the installed wind power capacity was in turbines below 1 MW. The association collects annual data of wind power installations. Since year 2000 the average size of installed wind turbines is above 1 MW, see Figure 13. Since 2005 until 2014 the total capacity in installed turbines below 1 MW has been varying between 20-23 MW. The Finnish Energy Agency estimated that the capacity decreased due to decommissions, to 16 MW in 2016.

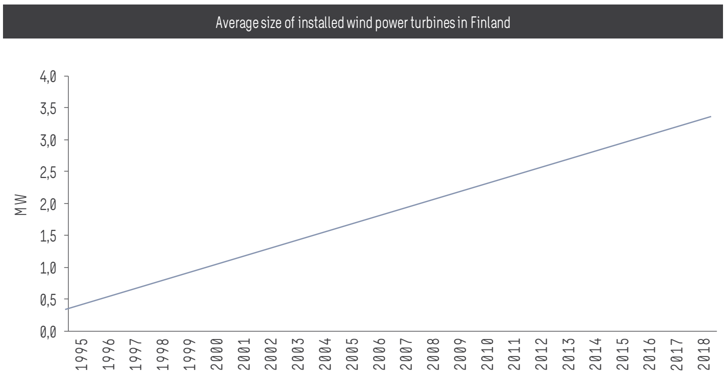
In 2018 no new wind power turbines, neither large or small-scale, was installed due to changes in the feed-in premium system. 75% of the small-scale turbines below 1 MW are standalone turbines. The Finnish Wind Power Association states (Mikkonen, 2019) that the installed capacity in small-scale wind power plants used for self-consumption is hard to estimate since there are no national data on this. The focus in Finland has been on industrial scale wind power and the small-scale users are not registered.

Figure 12: Total wind power capacity in Finland 2005-2017



Source: Finnish Wind Power Association (2019)

Figure 13: Average size of installed wind power turbines



Source: Finnish Wind Power Association (2019)

3.5.4 Bio power

In Finland, natural gas CHP is a more common technology for small-scale heat and power production. Biomass-based small-scale installations are widely used but mainly for heat only. The installed capacity in small-scale biopower in Finland was approximated by the Finnish Energy Agency to about 16 MW in 2017 (2018). In 2000 the estimated small-scale bio CHP in Finland was 1 MWe (in total 10 plants) (European Commission, 2004).

Due to lack of detailed data for Finland, the amount of bio power used for self -consumption is assumed to be about the same in the same level as in Sweden since the number of small-scale bio power units are similar. The installed capacity assigned for self-consumption is hence estimated to 3 MW with electricity production of 18 GWh annually.

3.6 Statistical overview – Denmark

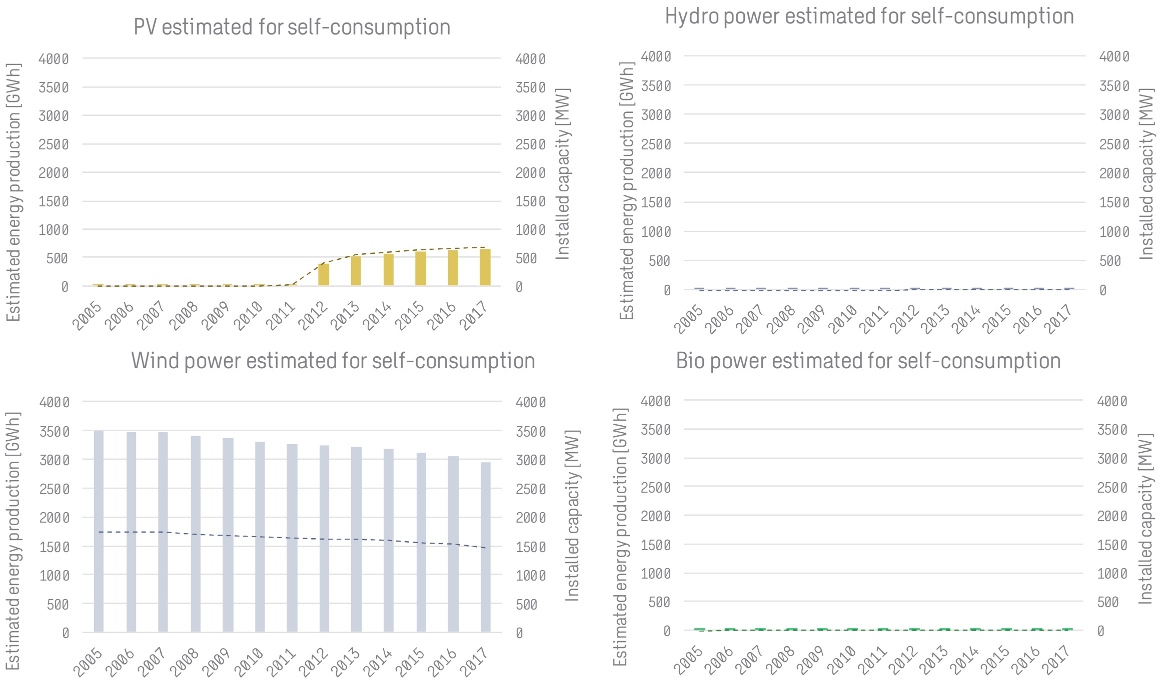
The distributed small-scale electricity production is higher in Denmark compared to the other Nordic counties. The total amount of installed distributed energy was about 2740 MW. Of these was 1967 MW small-scale wind power, 690 MW was PV and 45 MW was turbines using biogas from electricity production.

The PV installations increased enormously in 2011-2012 and the installed capacity rose from 16 to 407 MW. The installed capacity in small-scale wind power is on the other hand decreasing due to replacement of small turbines with more efficient larger ones.

We estimate that total prosumer production capacity in Denmark in 2017 consists of:

- 690 MW of solar PV power (655 GWh)
- 0.2 MW of hydropower (0.8 GWh)
- 1475 MW of wind power (2951 GWh)
- 5 MW of bio power (30 GWh)
- Total: 2170 MW of prosumer power (3636 GWh)

Figure 14: Summary, units for self-consumption in Denmark 2005-2017, total generated electricity (bars, primary axis) and installed capacity (line, secondary axis)



Source: Sweco, IEA-PVPS (2017a; 2017b; 2017c; 2016a), Danish Energy Agency (2019e)

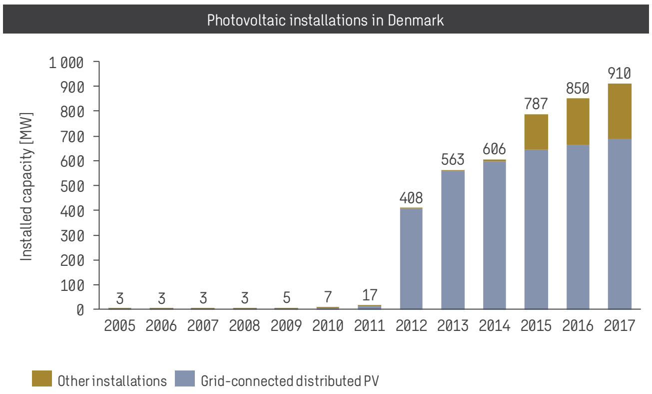
3.6.1 Photovoltaic

The Danish PV market grew extensively in 2012 and the total installed PV capacity grew from 16.7 MW in 2011 to about 407.8 MW in one year. About 99% on the installed capacity in 2012 was grid-connected distributed PV. Since 2015 the number of grid-connected centralized PV plants have increased with about 220 MW and also the number of off-grid PV systems have increased. In 2017 about 75% of the total PV installations (corresponding to 690 MW) was of grid connected and distributed PV systems and the installed capacity, see Figure 15. The most common installed PV systems are below 20 kW, see Figure 16.

The Danish PV market was disrupted in 2013-2017 by abrupt political initiatives to curb the PV market growth and by the uncertainties of the actual feed-in-tariffs due to the dispute between Denmark and the European Commission.

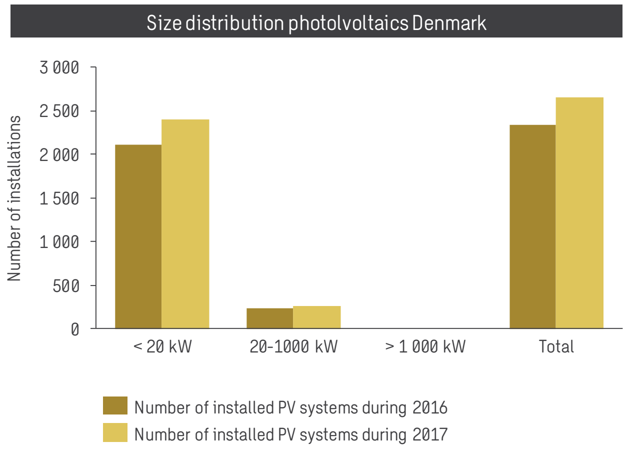
Based on our knowledge of solar PV power production in Denmark, approximately the installed capacity named 'grid-connected decentralized' in the PVPS report could almost exclusively be classified as prosumer production (100% of 690 MW). The electricity production of photovoltaics in Denmark is 900-1000 kWh/kW and thus the electricity production 655 GWh in the self-consumption installations.

Figure 15: Installed PV systems in Denmark 2016-2017



Source: IEA-PVPS (2017d; 2016b)

Figure 16: Size distribution of installed PV systems in Denmark during 2016 and 2017



Source: IEA-PVPS (2017d; 2016b)

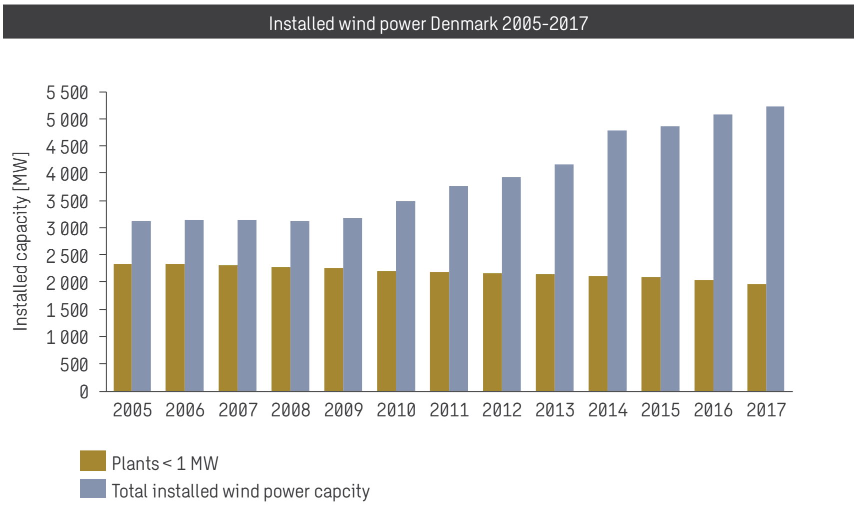
3.6.2 Wind power

In 2017 the highest-ever levels of wind energy provision were set in Denmark, 43.4% of Denmark's electricity consumption were supplied by land and sea wind turbines. The electricity production from wind power has almost doubled in Denmark since 2008. In 2017 the total installed wind power capacity was 5476 MW, compared to about 3000 MW in 2009. The small-scale electricity production in wind turbines with capacity below 1 MW has however decreased. In 2005 the installed capacity in small-scale turbines were 1790 MW, but due to decommissioning the installed capacity has decreased to about 1420 MW in 2017, see Figure 17.

In 2010 was more than half of the installed capacity in small turbines below 1 MW, but since then the number of large turbines has increased. In 2017 was about one third of the installed capacity in small-scale wind turbines, see Figure 18.

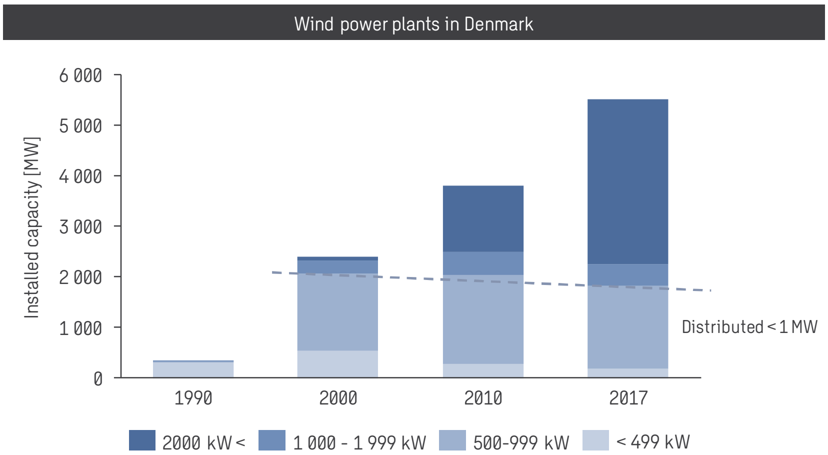
The Danish wind power Association estimated that about three quarters of the installed wind power in Denmark was privately owned by individuals or cooperatives in 2013 (Danmarks Vindmølleforening, 2019; Climate Policy Info Hub, 2019). This share is also applied estimating the share of production used for self-consumption in Danish wind.

Figure 17: Total installed wind capacity in Denmark 2005-2017



Source: Sweco, Danish Energy Agency (2019f)

Figure 18: Size distribution of wind Power plants in Denmark



Source: Danish Energy Agency (2019f)

3.6.3 Hydropower

The development of capacity installed in small-scale hydropower plants has been stable since 2005 with about 3.7 MW installed capacity in plants below 1 MW. In the period between 2005-2017 two small-scale hydropower plants have been installed, one 25 kW and the other 22 kW.

In the Danish Energy Agency's register of grid connected plants in 2017 seven small-scale hydropower plants below 1 MW was registered on private owners or associations. The average power in these plants was 20-50 kW and the total capacity in this segment was 0.2 MW. If the amount of full load hours in the Danish small scaly hydropower is 4500 as estimated in Sweden, this corresponds to an electricity production of 0.8 GWh.

3.6.4 Bio power

Small-scale electricity production from bioenergy in Denmark is mainly using biogas as fuel. During the past years small-scale biogas producers has mainly used the biogas for electricity production. The support schemes for biogas production has been generous and the number of bio gas production units has been growing and the size of the plants has increased. The policy in the last 5 years has been supporting upgrading of biogas instead of electricity production, which means that many of the larger plants has shifted info upgrading instead of electricity production. In smaller plants however, biogas is mainly used for electricity production supporting farms, gardens and other businesses with self-produced electricity.

The current government however, communicated in the summer of 2018 that the current support schemes for biogas are to be removed. This means that the Danish Energy Agency expects that the amount of new installations in biogas electricity production is to be decreased.

The installed capacity in electricity production from bioenergy has been growing annually the past ten years with approximately 1-2 MW per year. The installed capacity in small-scale electricity production by biofuels was 2017 about 45 MW.

In the national register the small-scale biopower plants uses mainly biogas to produce heat and electricity. About 20-30 of the plants below 1 MW in Denmark was registered on private owners or associations. The owners are farmers, garden owners and other businesses. The total capacity in biopower plants used for self-consumption can thus be approximated to about 6 MW based on the plants registered on private owners as bio power plants. Some of the private small-scale plants in the registry has not specified the fuel typ. This means that the estimate self-consumption could potentially increase with 3 MW, depending on fuel types in these plants. If the amount of full load hours is the same as in Sweden, 6000 h, the energy produced for self-consumption is 30 GWh if the installed capacity for self-consumption is 6 MW.

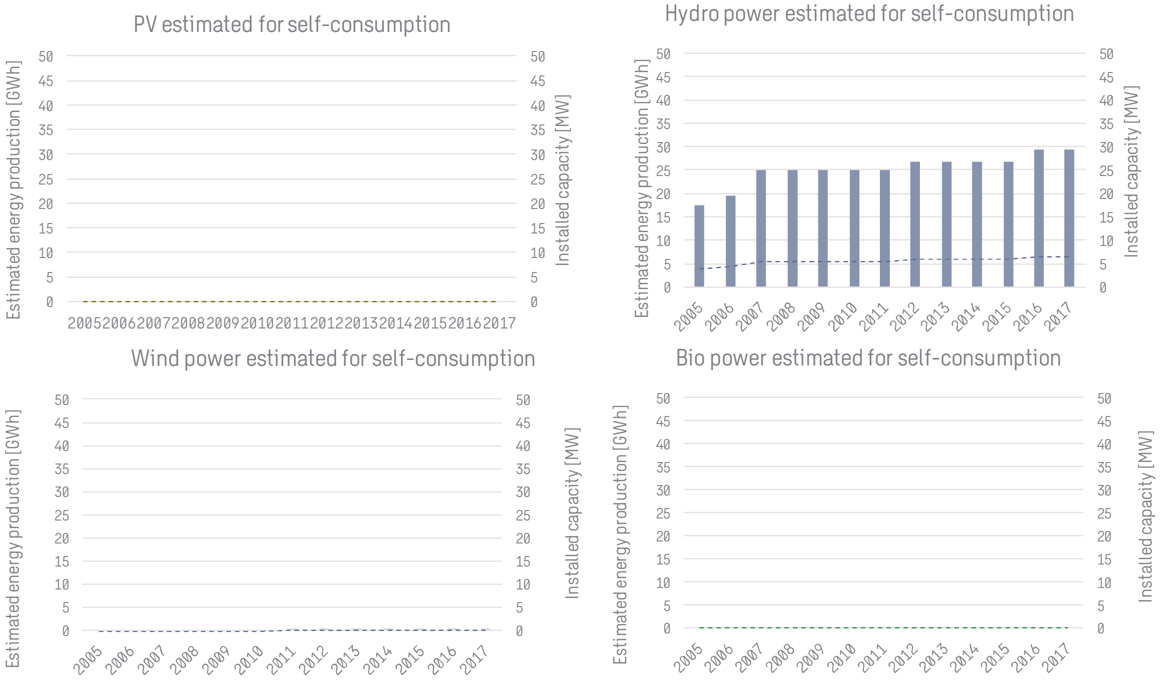
3.7 Statistical overview – Iceland

In Iceland the main sources for distribute electricity production is hydropower. Since geothermal power and hydropower is dominating in the Icelandic energy system it is hard for other energy sources to compete with the large-scale production. 10 MW of the installed hydropower in Iceland are in units below 1 MW. Only a few wind power projects in small-scale wind has been installed in Iceland. None of the installed geothermal power plants is considered to be small-scale. There is however a growing interest in Iceland for distributed electricity production such as solar.

We estimate that total prosumer production capacity in Iceland in 2017 consists of:

- 6.6 MW of hydropower (29,5 GWh)
- 0.03 MW of wind power (0.06 GWh)
- Total: 6,6 MW of prosumer power (29,5 GWh)

Figure 19: Summary, units for self-consumption in Iceland 2005-2017, total generated electricity (bars, primary axis) and installed capacity (line, secondary axis)



Source: Sweco, National Energy Authority Iceland (2019c)

3.7.1 Photovoltaic

The use of photovoltaic power in Iceland is limited due to limited solar irradiance. There are however some small-scale off-grid solutions installed. Estimations shows that about 6,7 MW solar PV is installed on Iceland, but mostly off grid. One example is the city of Reykjavik that has chosen to install PV driven parking meters (iflscience, 2017). There are also factories for producing silicon used in solar PV modules located in Iceland.

3.7.2 Hydropower

The total installed hydropower capacity in Iceland was about 2000 MW in 2017. The hydropower plants are mainly large scale, the largest Fljótsdalsstöð is 690 MW. There are however also some small-scale hydropower plants. Since 2005 about 4 MW new small-scale hydropower has been installed in Iceland. In 2017 the installed hydropower capacity in small-scale plants below 1 MW was 10 MW (22 plants).

In the register of plant connected to the Icelandic grid, 17 of the small-scale hydropower plants with installed capacity below 1 MW, was marked “small-scale” in the owners field in the national register. The total installed capacity in these plants was 6.7 MW.

3.7.3 Wind power

In 2017 there was three installed wind turbines in Iceland. The capacity of the turbines was 30 kW, 1.2 MW and 1.8 MW. The smallest was installed 2011 and is the only small-scale turbine below 1 MW and was installed by a farmer to produce electricity to his house and farm. The turbine covers 70-75% of the electricity demand of the farm and farmer sells the excess electricity from windy hours to the grid (Skessuhorn, 2013; Skessuhorn, 2010).

Only the smallest of the three wind power plants in Iceland are known to be used for private electricity consumption.

3.7.4 Geothermal power

There are six geothermal plants in Iceland that also produces electricity. The larges geothermal plant is 300 MW and the total installed capacity in geothermal power is 700 MW. The smallest geothermal plant is however 3.2 MW, thus no plants can be classified as small-scale distributed production units. New technologies have new been introduced to the market, using small scale geothermal technology. These technologies were not in place in 2017, but could potentially be interesting for Icelandic conditions in the future.

4 Overview of current framework conditions, regulations and tax schemes

Our regulatory mapping shows that most Nordic countries have a regulatory framework in place that promotes the development and installation of distributed electricity production. The exception is Iceland where there, at least on a national level, there are no specific regulations for distributed production and self-consumption initiatives. The general regulatory framework and the regulations and instruments that specifically facilitates distributed production and self-consumption have many similarities between the countries, although the definitions of prosumers, the specific design of the regulations and the level of support differs somewhat.

Distributed production and self-consumption of electricity is quite strongly supported in all Nordic countries relative to consumption based on centralized production. Regarding PV for the household sector specifically, the overall finding is that Denmark historically has had the most generous support system but has later significantly decreased its support due to very rapid household PV deployment. Sweden is assessed to be the country currently having the highest support levels for household PV, and perhaps also the most complex as the total support will be achieved through multiple exemptions, tax incentives and policy instruments. Compared to Sweden, Norway and Finland seems to have a somewhat less generous support system, although it is difficult to compare the level on a general basis (since the regulations and instruments differs somewhat between the countries the level of support could be dependent on the specific actor or instalment). As mentioned above Iceland do not seem to have in place specific regulation and incentives for DES.

Households and businesses in the Nordic countries have the right to have their production facilities connected to the grid and to sell excess electricity to the DSO or a power supplier. The prices for the excess electricity are dependent on the respective contract between the prosumer and the buyer but is in most cases equivalent or similar to the relevant spot price. In addition, all countries (except Iceland) have different types of investment support or tax deduction schemes for the installation of PV-systems or other types of distributed electricity production (at least for labour/installation cost).

In addition to support schemes and tax deductions specifically directed towards installation of small-scale distributed production, the different Nordic countries have in place general/technology neutral support schemes for renewable electricity production in general such as electricity certificates or national tendering schemes. To what extent these instruments are available also to small-scale producers/prosumers varies between the countries. Other regulations, such as the licensing and authorization procedures, that may affect the administrative burden of installing solar PV panels, small wind mills or other distributed electricity production facilities, also differ between the countries.

To identify and describe relevant framework conditions, regulations and tax schemes (hereby simply named "regulations"), we have used written sources, in-house knowledge of relevant national and EU-regulation and conducted interviews, mainly with national regulators.

We have primarily focused on regulations which are specific to distributed production and consumption of electricity, i.e. that differs from the general regulatory framework for other/centralized electricity production and associated consumption. For instance, relevant framework conditions will comprise definitions of distributed production, support schemes and specific grid tariffs and tax rules.

In this chapter, we will first briefly describe relevant EU-regulation and policy. Secondly, we will give an overview of the relevant regulation in the Nordic countries, before we describe the regulation in each country specifically.

4.1 Overview of regulation in the EU

The EU is in the process of updating its energy policy framework in a way that aim to facilitate the clean energy transition and an overall agreement was reached late 2018. The latest proposal (as agreed) for a directive on common rules for the internal market in electricity proposes several measures to promote distributed electricity production in the EU. For instance, the new market design requires Member States to put in place appropriate legal frameworks to enable the activities of local energy communities[9] (European Commission, 2019).

The aim of the new policy framework is to bring regulatory certainty and incentivise renewable transition, flexibility, empowering of consumers as well as multiple other objectives. The clean energy package aims to empower European consumers to become fully active players in the energy transition and sets out two new targets for the EU for 2030: a binding renewable energy target of at least 32% and an energy efficiency target of at least 32.5% (with a possible upward revision in 2023) (European Commission, 2019).

The package consists of multiple updated directives and many of them will impact distributed energy resources and self-consumption. The main directives with impact on the conditions for distributed electricity production and self-consumptions are:

- Energy Performance in Buildings
- Renewable Energy
- Energy Efficiency
- Electricity Regulation

The Energy Performance in Buildings directive's main target is to achieve improved energy efficiency in buildings. The agreed revised version of the directive states that "In the calculation of the primary energy factors for the purpose of calculating the energy performance of buildings, Member States may take into account renewable energy sources supplied through the energy carrier and renewable energy sources that are generated and used on-site", i.e. stricter energy efficiency requirements can be fulfilled by renewable energy (EUR-Lex, 2018a).

The Renewable Energy directive identifies the need to establish a regulatory framework which would empower renewables self-consumers to generate, consume, store, and sell electricity without facing disproportionate burdens. It furthermore states that citizens living in apartments should be able to benefit from consumer empowerment to the same extent as households in single family homes. The directive also state that renewables self-consumers should not face discriminatory or disproportionate burdens or costs and should not be subject to unjustified charges. As a general approach, the directive state that member states should as a principle not apply charges to electricity individually produced and consumed by renewables self-consumers within the same premises. In order to limit the impact on the electricity markets, the exemption from charges could be limited to small installations with an electrical capacity of 30 kW or less. The directive also allows for member states to apply non-discriminatory and proportionate charges to renewable self-consumers (from 1 Dec 2026) if the overall share of self-consumption installations exceeds 8% of total installed capacity in a member state (EUR-Lex, 2018b).

The Energy Efficiency directive includes regulation on metering and states that energy should be metered and billed correctly, should have remote reading, provide billing information free of charge etc. These measures can promote deployment of distributed energy production (EUR-Lex, 2018c).

Additionally, one part of the package seeks to establish a modern design for the EU electricity market, by increasing flexibility, more market-orientation and improve the integration of renewables. The EU Commission writes on their webpage "These new rules also aim to put consumers at the heart of the transition – in terms of giving them more choice, strengthening their rights, and enabling everyone to participate in the transition themselves by producing their own renewable energy and feeding it into the grid" (European Commission, 2019).

[9] Local energy community: an association, a cooperative, a partnership, a non-profit organisation or other legal entity which is effectively controlled by local shareholders or members, generally value rather than profit-driven, involved in distributed generation and in performing activities of a distribution system operator, supplier or aggregator at local level, including across borders

4.2 Overview of regulation in the Nordic countries

4.2.1 Overview of regulation in the Nordic countries

In this section, we will give an overview of relevant regulation in the Nordic countries. We have divided the relevant regulation in the following categories:

Definition of distributed production and self-consumption: The properties of electricity production which are used to differentiate distributed production from other/large scale production. The definitions vary between the Nordic countries and specify which installations that are subject to specific regulations or support schemes for distributed production and self-consumption.

Market access: The rules which regulate how consumers may produce their own electricity, consume it and sell excess electricity.

Prices for excess electricity: Specific pricing-rules or typical prices that the prosumers receive for the sale of excess electricity.

Grid production tariffs: Specific rules regarding the grid production tariffs of prosumers (compared to large scale producers). Prosumers who sell excess electricity can potentially be charged a grid production tariff (like other/ large scale electricity producers). However, there are exceptions to this in several of the Nordic countries. There are some factors which may justify a lower or zero grid production tariffs for prosumers. For instance, they are often situated in net consumption areas, where new production may reduce grid losses.

Grid consumption tariffs: Distributed production and self-consumption can substantially reduce the total energy consumption from the grid. Depending on the grid-tariff structure, and the regulation for distributed production and self-consumption, this will reduce the total grid bill of the prosumers. Grid tariffs largely based on energy use, will give bigger savings for prosumers rather than grid tariffs based on capacity use. However, as the total cost of the grid is mainly determined by the maximum capacity (W), rather than total energy use (Wh), a large part of the grid cost savings of the prosumers must be paid by other consumers to cover the cost of the power grid (NVE, 2017). Thus, a grid tariff mainly based on energy use, as opposed to capacity use, can be viewed as an incentive for consuming less energy from the grid (either through energy efficiency or distributed production and self-consumption), relative to the purchase of electricity from others/large scale production.

Taxes: In several countries, electricity consumers pay special taxes on electricity consumption, as well as value added tax/VAT) on both electricity consumption and grid tariffs. Distributed production and self-consumption of electricity can reduce both electricity consumption and grid costs. Therefore, the presence of electricity taxes and VAT on all electricity consumption except for self-consumption, constitutes an incentive to buy less electricity from the grid, for example through distributed production and self-consumption.

Investment support for households: Another way of incentivizing distributed electricity production is to give direct investment support and/or tax reductions for households who invest in distributed production. Investment support may be granted from national bodies or local municipalities.

Investment support for businesses: Similar as for households, national or local governments may choose to give direct support (grants), loans and/or tax cuts to businesses that choose to invest in distributed production.

General support schemes for renewable electricity production: In many countries, there are incentives to promote renewable/ zero emission electricity production. Examples include the Swedish-Norwegian Renewable Energy Certificate Scheme (RECS) and the voluntary support scheme Guarantees of Origin (GOs). The design of such support schemes can influence the profitability of distributed electricity production relative to other production/ large scale production.

Other relevant regulation: In addition to the mentioned factors, other parts of the regulation may influence the development and installation of distributed electricity production. This can for example be the tax exemption (applied in Sweden at 60 öre/kWh) for electricity fed into the grid. Additionally, the regulatory process of allowing new production facilities may differ between small-scale prosumer installations and large-scale production.

Table 3 shows an overview of regulations specific to distributed production and self-consumption of electricity in the Nordic countries, i.e. the differences from the general regulatory framework applicable to other/centralized electricity production and associated consumption. As there are no definition, nor any specific regulation for installations for distributed production and self-consumption in Iceland[10], the country in not included in the table.

Table 3: Overview of the regulation of distributed production/self-consumption in the Nordic countries

Regulation	Norway	Sweden	Finland	Denmark
Definition of self-prod. and -cons. (basis for specific regulation)	Prosumer scheme when excess production is <100 kWh at any time (kWh/h)	Several definitions, dependent on regulation/context.	Different limits for tax- and grid tariffs exemptions.	Separate provisions for small producers – below <50 kW for solar PV (measured by the inverter size), and < 25 kW for windmills
Market access	Prosumers can sell electricity to an electricity supplier.	Prosumers can sell electricity to an electricity supplier.	Prosumers can sell electricity to an electricity supplier.	Prosumers can sell electricity to an electricity supplier or the local DSO.
Prices for excess electricity	Depends on contract. Often hourly spot-price	Depends on contract. Often hourly spot-price or better.	Depends on contract. Often hourly spot-price.	Depends on the contract, and the sales group, but often hourly spot-price.
Grid production tariffs	Prosumers pay zero or low fixed prod. tariffs. The variable tariff component differs between DSOs (can be negative)	Prosumers (net users) with installed capacity <43.5 kW and <63 A pay no feed-in cost. Producers with installed capacity <1500 kW have some tariff reduction	Production tariffs vary between DSOs (can be negative)	Availability charges for the grid are by law applicable for the DSO where prosumers deliver to the grid.
Grid consumption tariffs	Prosumers save the variable tariff component during hours of self-usage (example of ~0.38 NOK/kWh excl. VAT).	Prosumers save the variable tariff comp. during hours of self-usage (around 30-45 öre/kWh (excl. VAT)) DSO pay mandatory "grid benefit" 2-6 öre/kWh	Prosumers save consumption tariff during hours of self-usage (example of ~0.03 EUR/kWh excl. VAT)	Prosumers save consumption tariffs during hours of self-usage. The tariff savings are cost true and dependent of the local DSO tariffs.
Taxes	Savings of electricity-tax and VAT on grid-tariffs and energy during hours of self-usage (~0.39 NOK/ kWh in total) No resource rent tax on wind, solar PV and hydro <10MW	Savings of electricity-tax during hours of self-usage (~0.35 SEK/kWh exc VAT) if below certain kW (solar PV 255 kW, wind 125 kW and bio 50 kW).	Exempt from electricity-tax (~0.028 EUR/kWh) if production <800 000 kWh and VAT on grid-tariffs and energy during hours of self-usage	Savings of electricity taxes during hours of self-usage (~0.028 EUR/kWh) Costs for capacity installed in households can to some extent be deducted from household income.
Support households	Standard support of 10000 to 28750 NOK (mostly relevant for houses, not apartment buildings)	60 öre/kWh tax deduction (if same connection point, <100 A, max 18000 SEK/y, max same feed-in as outtake) Investment support for energy storage, 60% of investment		No public investment support.

[10] Iceland has separate provisions in the regulation for small-scale production, defined as installations below 100 MW.

Support businesses	Examples of support of several MNOK	60 öre/kWh feed-in (if same connection point, <100 A, max 18000 SEK/y, max same feed-in as outtake). Investment support renewable energy for farmers, 40% of investments	Up to 25% investment subsidy available for renewable energy technologies and energy efficiency investments. New technologies may be grant-ed higher subsidies.	No public investment support for smaller units.
General support schemes	Electricity certificates /GOs practically inaccessible	Investment support solar PV (30% of inv. cost up to 37000 + VAT/ kW, max. 1.2 MSEK). Electricity cert., one cert. per MWh for 15 years, market-based price. Some opportunities to receive GOs	GOs practically inaccessible (traded in MW)	Technology-neutral national tendering scheme where larger units can apply. GOs practically inaccessible
Other relevant regulation	Easy licensing/ authorization + building regulation	Reduced labour costs for houseolds– 30% support of installation cost (for example appr. 9% of total cost for solar PV panel installation).	Municipal efforts Tax deduction for labour costs. Up to 45% tax credit for the labour cost	Tax deduction for labour costs up to 12200 DKK per person which can be used when installing RES, ex. PV

Sources: Overview from IEA Photovoltaic Power Systems Programme, National Survey reports (IEA, 2019), various sources. See country sections for references.

4.2.2 Regulation in Norway

Definition of distributed production and self-consumption

The Norwegian Regulation of Grid Operations (Ministry of Petroleum and Energy Norway, 2018), gives prosumers the right to be connected to the grid (NVE, 2019f). Prosumers ("plusskunder") are defined as "end users with consumption and production behind the meter, from which no more than 100 kW is put into the grid at any time. A prosumer may not have a licensed power plant or licensed trade behind the meter".

Prosumers may use self-consumed electricity free of charge. During hours of self-consumption, the prosumer can avoid cost for electricity and the variable electricity grid cost, as well as electricity consumption taxes, VAT, and the Electricity Certificate cost. Grid tariffs and VAT applies for all sale of self-produced electricity fed into the power grid. The Norwegian energy regulator (NVE) plans to change the regulation so that in the future, prosumers can distribute self-produced electricity for consumption within an apartment building and/or a building community, without taxes and grid tariffs (NVE, 2018c).

Market access

In terms of market access, prosumers may sell excess electricity both to the DSO (Distribution System Operator, however not allowed after the electricity hub is implemented) or to an electricity supplier (trader). If the DSO does not want to buy excess electricity, the prosumer must enter into a prosumer-contract with an electricity supplier that offer such contracts.

Price of excess electricity

The prices for excess electricity depend on the contract between the prosumer and the DSO/electricity supplier. In many cases, prosumers receive the hourly spot price for their excess electricity. In other cases, the prosumer receives a fixed price for the electricity. Some electricity suppliers also offer solar PV investment deals.

Grid production tariffs

Prosumers with excess production<100 kW are exempt from the fixed production grid tariff which other producers are charged (NVE, 2019f). Consumers (mainly companies) with excess production of more than 100 kW at any time (measured as 100 kWh/h) are not exempt from the fixed production grid tariff. Until recently such large prosumers, e.g. the food distribution company ASKO, had incentives to limit production to 100 kW, rather than paying a fixed production grid tariff. To incentivize large prosumers to produce more than 100 kW, regulation has been changed so that they are charged a production grid tariff of 0.013 NOK/kWh for excess production, instead of the fixed production tariff (TU, 2018).

The variable component of the production grid tariffs is set by the local DSO in accordance with relevant regulation. The variable component will vary according to the marginal loss in the relevant grid area and may be positive or negative. As an example, the variable production tariff for prosumers in the grid area of BKK (Norwegian DSO) is negative, meaning that the DSO pays prosumers a grid fee for each kWh of excess production. BKK justifies this by the fact that most prosumers contribute to reducing the marginal loss of the grid (BKK, 2019). In areas with a production surplus, the marginal loss increases with increased production, resulting in a positive variable production tariff.

If connection of the production facility requires grid reinforcements, the connection costs are forwarded to the person or company that requests the connection/own the production unit.

Grid consumption tariffs

During hours of self-consumption, the prosumers avoid the variable component of the electricity grid tariff. In the current grid-tariff structure in Norway, prosumers can reduce their own total grid bill significantly. Savings vary depending on the tariff structure and level of the local DSO. For instance, prosumers in the Hafslund DSO area (where tariffs are relatively low) can reduce their bill by 0.38 NOK/kWh excl. VAT and 0.48 NOK/kWh incl. VAT (Hafslund Nett, 2019). In other DSO areas, where the grid tariffs are higher, the savings of the prosumer may be larger. As the total cost of the grid is mainly determined by the maximum power (W), rather than total energy use (Wh), part of the grid-tariff cost savings of the prosumers is currently paid by other consumers. (expert, 2019) (Swedish Energy Market Inspectorate, 2012)The Norwegian energy regulator, NVE, plans to change the tariff structure so that tariffs to a larger extent reflect the actual cost drivers in the grid (NVE, 2017). If this is realized, and capacity tariffs (cost/W) to some extent replace energy tariffs (cost/Wh), the financial incentives for distributed generation and self-consumption may decline.

Taxes

Consumers (households and businesses) are exempt from paying electricity-tax and value added tax on self-produced electricity. Consumption of self-produced electricity can reduce the energy bill of prosumers by a total of 0.39 NOK/kWh on average (SSB, 2019). By contrast, other/central power producers, must pay electricity tax on the consumption of self-produced electricity, except for the electricity used directly in the production process (Skattedirektoratet, 2018).

Furthermore, distributed production (solar PV, wind and small hydro (<10 MW)) does not pay resource rent[11] tax paid by large hydro producers in Norway of 35.7% (which is paid in addition to normal company tax).

Investment support for households

The main direct support scheme for distributed electricity production in households is from the government agency Enova. Enova is a Norwegian state-owned enterprise which contributes to re-duced greenhouse gas emissions, development of energy and climate technology and a strengthened security of supply. Enova supports the installation of distributed electricity production in households (usually solar PV panels) ranging from 10000 up to 28750 NOK (Enova, 2019a). The application for support must be made by individual home owners. In practice, it has been difficult for home owners in apartment buildings to apply, because they have to make a coordinated decision.

In addition to this government agency support scheme, there have been examples of municipal support schemes for distributed electricity production before the government scheme was established (Dagsavisen, 2017).

[11] Resource rent is income generated by an exclusive access to a limited resource

Investment support for businesses

Enova does not have a standardized support scheme for distributed electricity production in businesses. However, Enova has several support schemes for innovative energy and energy saving solutions (Enova, 2019b). For instance, Enova supported the building of a new swimming hall with modern energy solutions, including solar PV panels, with 9.9 million NOK (Enova, 2016).

General support schemes for renewable electricity production

The joint Norwegian-Swedish electricity certificate scheme is intended to increase renewable electricity production in both countries. In this system, producers of renewable electricity receive one certificate (RECS) per MWh of electricity they produce for a period of up to 15 years (Ministry of Petroleum and Energy Norway, 2019). Since the minimum fee for taking part in the certificate scheme is 15000 NOK, the market is practically inaccessible for prosumers (Norsk Solenergiforening, 2019). The same applies for Guarantees of Origin (GOs), a voluntary support scheme, which is also traded in MWh.

Other relevant regulation

The construction of new electricity production usually requires licenses/allowances both from energy/environmental authorities and from local building authorities (NVE, 2019g). However, there are less stringent requirements for distributed electricity production. In most cases, the installation of solar PV panels neither requires licenses from energy authorities, nor from local building authorities (Norsk Solenergiforening, 2019). The construction of small wind farms (less than 1 MW) only requires a license from local building authorities (OED & KMD, 2015).

In addition, building regulation and energy efficiency requirements may affect the incentives for distributed energy promotion. For instance, the Norwegian "Byggeteknisk forskrift (TEK17)" opens for allowing higher energy usage in buildings which produce their own renewable energy.

4.2.3 Regulation in Sweden

Definition of distributed generation and self-consumption

In Sweden there is not a clear definition for prosumers. The overall definition of prosumers can however be expressed as electricity users with self-generation that during some hours feed in electricity to the grid. However, different conditions must be fulfilled in order to receive different types of supports.

Market access

Prosumers may sell excess electricity to an electricity supplier. Currently, approximately 50% of Sweden's electricity suppliers offer to buy excess power from micro producers. The prices the prosumers receive varies, but in general they offer at least the equivalent to NordPool spot prices. Many electricity suppliers also offer solar PV investment deals (Elskling, 2017).

In Sweden it is mandatory for DSOs to connect electricity generation. Exemptions can be made, such as recently at the Swedish island Gotland, where the DSO in 2017 announced that they temporarily will stop connection of new generation (including micro-production) due to capacity issues in the grid (Helagotland, 2017). However, the DSO cannot reject micro-production where there already is a feed-in connection (The Swedish Energy Market Inspectorate, 2017).

Price of excess electricity

During hours of self-usage, the cost for both electricity and the variable electricity grid cost can be avoided. The electricity cost is usually spot-price plus balancing cost, electricity certificate and supplier margin. The variable electricity grid fee varies a lot between different DSOs in Sweden but is usually around 30-45 öre/kWh (excl. VAT) for smaller electricity users.

Grid production tariffs

The DSOs also need to pay a mandatory feed-in payment, "grid benefit". This varies depending on DSO but is usually around 2-6 öre/kWh. The reasoning behind this is that electricity feed into the low voltage grid lower the losses of the DSO and therefore the DSO's costs.

Grid consumption tariffs

A production asset which can deliver a capacity of 1500 kW or less should (according to the Swedish electricity law) only pay the grid cost associated with metering, calculation and reporting. A one-time connection fee should be applied. According to the electricity law, an electricity user with a fuse of maximum 63 A and which can deliver a capacity of 43.5 kW or less should not pay any feed-in tariff. This only applies to net electricity users. The actual grid costs and how these exemption rules are quantified varies a lot between different DSOs, broadly speaking between 10-120 öre/kWh.

Taxes

The Swedish energy tax on electricity is 34.7 öre/kWh (43.38 öre/kWh inc VAT) 2019[12] (The Swedish Consumer Energy Markets Bureau, 2019). Electricity producers with a total installed capacity below 50 kW hydro or thermal, 125 kW wind or 255 kW solar PV are fully exempted for energy tax on electricity usage. Facilities below 255 kW belonging to organizations with a total installed capacity above 50 kW hydro or thermal, 125 kW wind or 255 kW solar PV pay 0.5 öre/kWh. The background for this is EU state aid rules, and Sweden is seeking to fully exempt also these facilities from energy tax on electricity. For electricity users owning/operating electricity generation above 50 kW hydro or thermal, 125 kW wind or 255 kW solar PV full energy tax is applied on their electricity usage (Ministry of Finance, 2016).

Investment support for households

In Sweden there is a specific support system for renewable small-scale electricity. The support is 60 öre/kwh, provided as a tax reduction deducted from the annual income tax. Both households and organizations can receive this support. In order to be able to receive the tax exemption, the micro production facility should have the same connection point both for feed-in and electricity usage and the fuse should be 100 A or less. Maximum 18000 SEK/year can be received per person/organization (corresponding to 30000 kWh/year) (Swedish Tax Agency, 2019).

Investment support can be received in general for renewable electricity production (i.e. including large-scale, see "General support schemes for renewable electricity production").

Sweden has a specific investment support for grid-connected energy storage. This support covers up to 60% of investment cost up to maximum 50000 SEK. The energy storage must be connected to distributed generation and self-consumption of power (Swedish Energy Agency, 2016).

Investment support for businesses

As described under "Investment support for households", the tax deduction of 60 öre/kWh for households is available also for business (with small fuse i.e. low electricity usage).

Investment support can be received in general for renewable electricity production (i.e. including large-scale, see "General support schemes for renewable electricity production"). There is also a specific investment support scheme for farmers, garden companies and reindeer herding businesses. This support can be granted for different types of renewable energy including bioenergy, wind power, solar PV power and more. The support can cover up to maximum 40% of the cost, and cost must exceed 100000 SEK. Conditions applies regarding what type of costs that the support can be used to cover (type of energy, type of work costs that can be covered etc) (Swedish Board of Agriculture, 2018).

General support schemes for renewable electricity production

There is a specific investment support for solar PV generation. The support is granted for up to 30% of investment cost and can be granted to all sizes of solar PV installations and to households, organizations and companies. The expenses which can be granted support can be maximum 37000 SEK + VAT per kW and maximum 1.2 million SEK (Swedish Energy Agency, 2018c).

In the National Budget for 2019 the investment support budget for solar PV support is decreased with 440 MSEK compared to previously proposed budget. In 2018, a statement by The Committee on Industry and Trade proposed that the support level should be reduced to 15% as soon as possible. (The Committee on Industry

[12] Some municipalities in the north of Sweden pay lower energy tax on electricity. Additionally, multiple electricity users such as certain industries are partly or fully exempted from energy tax on electricity.

and Trade, “Utgiftsområde 21 Energi”, 2018) The Government has however not yet taken decided to reduce the support level (Swedish Energy Agency, 2018d).

The joint Norwegian-Swedish electricity certificate scheme is intended to increase renewable electricity production in both countries. In this system, producers of renewable electricity receive one certificate per MWh of electricity they produce for a period of up to 15 years (Ministry of Petroleum and Energy Norway, 2019). Unlike in Norway, there are quite low entry barriers to receiving electricity certificates in Sweden and many small installations (including households) participate in this system. As mentioned above, one certificate is received per MWh produced renewable energy and the price is market based. The price has varied a lot over the years and was from mid-2017 to mid-2018 on average 12.6 öre/kwh (Swedish Energy Agency, 2018e).

Other relevant regulation

In Sweden a tax deduction of 30% is applied on household services such as labour cost for installing solar PV panels. The 30% tax deduction on installation costs corresponds to approximately 9% of total solar PV investment cost. The labour tax deduction cannot be combined with investment support (Swedish Energy Agency, 2018b).

In August 2018, regulations concerning deployment of solar PV panels in Sweden was simplified. (Swedish Energy Agency, 2018b).

4.2.4 Regulation in Finland

Definition of distributed generation and self-consumption

There are several definitions that are relevant when considering the incentives for self-consumption and production in Finland. Self-consumption can be described as consumption of electricity which has not been transferred by the grid (Vero, 2016). Small-scale electricity production is defined in the law as a unit of power plants with a total max power of 2000 kVA (Finlex, 2013). Other relevant limits are 100 kVA (power limit for micro production) and 800000 kWh (energy limit for tax exempt small-scale production) (Vero Skatt, 2016).

There have been tests of virtual metering in apartment buildings (LUT, 2017) and discussions of changing legislation to encourage distributed electricity production in energy communities (Ministry of Economic Affairs and Employment of Finland, 2018). However, as of 2018 special regulation of self-consumption only applies to individual households and companies and not energy communities (Ministry of Economic Affairs and Employment of Finland, 2018).

Market access

Prosumers can sell excess electricity through the grid (LUT, 2017). According to the Ministry of Economic Affairs and Employment of Finland, self-consumers have market access to sell excess electricity with the same conditions as other producers.

Price of excess electricity

The price of excess electricity depends on the contract. In June 2017, most electricity retailers have announced offers to buy surplus electricity from micro-PV plants. In general, the companies pay the Nord Pool Spot Finland area price of the surplus electricity although there are exemptions and companies offering “special deals” (such as for example the opportunity to use excess electricity generation for EV charging (Fortum, 2019)). In other cases, excess electricity is sold at a fixed rate (LUT, 2017). Some companies also charge a fee for the offtake of surplus electricity. These fees (such as for example fixed monthly fees) are for example often applied if the offtake agreement is not with the company the electricity is purchased from.

Grid production tariffs

Grid production tariffs are set by the DSOs according to local conditions. The savings of grid production tariff therefore vary, but is not higher than 0,87 cents/kWh as is the top limit for the variable feed-in tariff in Finland according to EU-regulation. Some companies do not charge the feed in tariff for the smallest producers as the cost of charging the fee will outweigh the income. For instance, the DSO Helen Sähköverkko (in the Helsinki-region) neither charges nor pays production tariffs for small-scale production (Helen Sähköverkko, 2016).

Other DSOs, for instance Vasa Elnät, charge small-scale producers a production transmission fee (Vasa Elnät, 2018).

Grid consumption tariffs

The saving during hours of distributed electricity production and self-consumption is the variable tariff component. According to the grid-tariff structure in Finland, household grid consumption tariffs are to a large extent a function of consumed energy (Wh) (NordREG, 2015). Prosumers consuming their own electricity production are not always charged extra to finance the transmission and/or distribution grid (LUT, 2017), but may be charged a monthly fee for self-generators depending on the local DSO company (as described above). As an example, regular/small customers of the DSO Helen Sähköverkko can reduce their grid consumption bill by approximately 0.03 EUR/kWh excl. VAT, and 0.04 EUR/kWh incl. VAT, by using self-produced electricity (Helen Sähköverkko, 2018). It should however be noted that Helen is one of the cheapest DSO companies, and that the split between the fixed and varied portion of the distribution fee varies depending on electricity consumption and DSO area.

Taxes

Small-scale producers with an annual production below 800000 kWh (prosumers) are exempt from paying tax for electricity consumed on their own site (Vero Skatt, 2016). This tax exemption can reduce the tax bill of prosumers by around 0.028 EUR per kWh, including VAT, of consumed self-produced electricity (Helen Sähköverkko, 2018). By contrast, large power producers must pay electricity tax for the consumption of self-produced electricity. The tax exemption applies also to the emergency preparedness contribution (0.013 c/kWh). Also, revenues generated through sales of electricity are tax free, when the revenue generated through the off-take agreement is modest (Vero Skatt, 2014).

Investment support for households

Individuals may get a tax credit for the labour cost component of electricity installations[13]. The sum is 45% of the total labour cost, including taxes. The maximum tax credit for a person is 2400 EUR per year (LUT, 2017).

Investment support for businesses

The Ministry of Economic Affairs and Employment grants investment support/energy aid for the renewable electricity production. This energy support is particularly intended for promoting the introduction and market launch of new energy technologies. So far, the Ministry has granted a 25% investment subsidy of the total costs of grid-connected PV projects. Companies, communities and other organizations are eligible for the support. For the agricultural sector, an investment subsidy is also available for renewable electricity production from the Agency for Rural Affairs. The subsidy covered 40% of the total investment costs in 2018 (LUT, 2017).

General support schemes for renewable electricity production

Guarantees of origin (GOs) is voluntary "support scheme" available in most European countries. Guarantees of origin are granted as blocks of MWhs. Hence, the system is not easily accessible for micro-generation (LUT, 2017). There are however in Sweden several utilities which buys GOs from smaller producers in Sweden, so this is a potential additional revenue source for distributed electricity producers.

Other relevant regulation

Several Finnish municipalities have installed PV systems on their own buildings and are planning new housing areas that are prepared for PV-production (LUT, 2017).

4.2.5 Regulation in Denmark

Definition of distributed generation and self-consumption

No strict definition is officially applied to the distributed energy systems, or prosumers, meaning that variations occur across sectors and institutions. In most parts of regulation concerning support of renewable energy including PV and onshore wind turbines, smaller energy producing units (for self-consumption) are

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[13] This is technology neutral and does not apply to renewables e.g. PV only. In fact, it also applies to electricity produced with fossil fuels.

described as systems up to nominal values of 50 kW (Danish legal information, Bekendtgørelse om nettilslutning af vindmøller og solcelleanlæg and Bekendtgørelse af lov om fremme af vedvarende energi). In most publications from the Danish TSO Energinet dk the limit is 1-10 kW (Energinet, 2018d).

Market access

Self-consumption is allowed in Denmark (IEA, Review and analysis of PV self-consumption policies, 2016). Prosumers may sell excess electricity to the grid or to any electricity supplier based on independent contracts with the DSO. All grid-connected PV and onshore wind turbines designed within a consumption system (e.g. a household) needs to apply for a permit at the Danish Energy Agency. In the permit the technical guidelines for connection are stipulated as well as the desired production group (see below) for the electricity production unit. Today there are up to six differentiated production groups set up for the production of PV's.

In Denmark it is mandatory for DSOs to connect electricity generation. The costs for the connection of the production units are forwarded to the owners of the production units. Previously the cost was covered by the grid operator (DSO), but recent changes to the regulation makes the local DSO able to forward grid reinforcements and connection costs to the producers. There are differences according to the size and where in the grid the connection is required to be reinforced. As a general rule under the new scheme all connection costs are forwarded to the energy producing unit's owner (Danish Energy Agency, 2018c; 2018d; 2018e; 2016b).

Price of excess electricity

As mentioned above, sale prices, taxation and time resolution are divided into six differentiated sales groups. Most of these has a prerequisite that the seller makes their own negotiated agreement with the DSO purchasing the excess electricity (Danish Energy Agency, 2019g).

Sales prices of surplus electricity production as well as the time resolution for pricing differs under the six sales groups. Sales prices for the excess production can therefore be sold under very different pricing models. Most hourly pricing schemes requires the sales to be independently negotiated with the local power supplier, while more coarse time resolution on pricing as well as annual average prices can be obtained if a set of specific criteria are met. From 2019 new PV units mainly for self-consumption purposes are transferred to a single new pricing regime named the "flex settlement". One of the six production groups offer the chance to sell excess production at the instant prices following the spot prices from the Nord Pool exchange. (Danish Energy Agency, 2019g; Danish Energy Agency, 2018f; Danish Energy Agency, 2018c).

During hours of self-usage, the cost for both electricity and parts of the variable electricity grid cost can be avoided (including the PSO tariff). The variable electricity grid fee varies a lot between different DSOs in Denmark but is usually around 0.4 eurocent/kWh (ex. VAT) for smaller electricity users.

Grid production tariffs

As mentioned above the regulation has been updated so that developers are required to pay for grid reinforcements caused by installed PVs or onshore wind installations. Updated regulation transferring connection cost to potential wind and solar PV developers is expected to further decrease interest in new developments of household size installations.

Grid reinforcements made to the upstream installations can sometimes be covered by general development funds from all energy uses if major changes are required. This can vary depending on the size and where in the grid reinforcement is required. However, as a main rule under the new scheme all connection costs are forwarded to the energy producing unit's owner.

In Denmark the DSO's and the TSO Energinet.dk are entitled to charge an additional production tariff on top of the normal net tariff structure for energy producing units. At the transmission level all energy producing units are charged an electricity production tariff. DSO's are obliged to exempt smaller (decentralised) RES producing units included under certain offtake agreements[14]. These agreements cover most of the installed distributed energy systems (RES). Decentralized production units exempted from the production fee includes

[14] Dependent on which of the six sales groups the energy producing unit is registered under

household wind turbines up to 25 kW and PV units up to 50 kW and other RE production units up to 11 kW (§ 59 from (Danish Energy Agency, 2019), § 52 from (Danish Energy Agency, 2018b)).

The Danish Energy Association has developed a series of technical and administrative guidelines for operation strategies for DSOs toward decentralised production units. In these it is recommended not to charge RES producers under 6 kW as it will require a separate metering.

Grid consumption tariffs

Similar to the grid production tariff DSOs can charge a consumption tariff on the total consumption of energy users which also has electricity production. The calculation of the energy charges is based on the total consumption with the gross electricity production of the installation deducted.

The grid consumption tariff are charges in order to cover the DSO's cost for grid O&M and will typically be calculated from standardized net tariffs for consumption with costs for grid loss and grid reinforcements deducted (Energiklagenævnets afgørelse af 11/05/2005 (J.nr. 11-213).

One aspect related to smaller producers is the gross electricity production used to calculate the size of the grid consumption tariff. In typical installations smaller electricity producing units which lack separate production metering a calculated value is instead used. This value is calculated based on methodology from the Danish taxation authorities and the TSO. For PV producing units the calculated value is determined by the size of the installed capacity of the unit, with an estimated annual production of 800 kWh for each kW installed.

Taxes

Today no direct tax incentives for distributed electricity production are in place, except the exclusion of part of electricity taxes for self-consumption for households. This includes savings of electricity taxes during hours of self-usage according to market prices (~0.028 EUR/kWh).

Tax benefits associated with the ownership of PV units differ between SMEs and households, mainly due to SMEs already being exempted from most electricity taxes. Based on the organizational setup of the producing unit different appreciation and hence taxation measures can be implemented.

Depreciation of installed capacity in households can to some extend be deducted from household income if certain accounting principles are applied. These rules are not specifically implemented as a way to support the development of distributed energy systems, but rather to simplify for small electricity production units.

Investment support for households

Household wind turbines (<25kW) previously had their own support scheme but this has been phased out due to socioeconomic considerations. Locally household wind turbines have been contested in both local planning procedures due to visual and audio pollution making them generally unwanted in urban areas

Deployments of photovoltaic solar cells in Denmark has been characterised by classic boom-bust cycles. To a large degree, regulation to support the introduction of especially household solar PV installations was based on linear projections of both price developments and efficiency gains. Disruptive changes in cost and efficiency made the support schemes for solar cells extremely attractive and led to a rapid deployment and expansion of solar cells in the years 2012-2013. This resulted in a rapid depletion of the budget for this support scheme. The depletion of funds and subsequent budget overrun for the support scheme in turn led to several unsuccessful attempts to adjust the scheme. The result was an amendment of the subsidy scheme for photovoltaic solar modules, the so-called "instant settlement" in May 2017. Hence, after 31 December 2017 no net deduction can be applied for. (Danish Energy Agency, 2019).

There is however a notable private initiative to support the development of distributed PV in Denmark. Since the public support for small-scale renewable energy has been discontinued, Viva Energy A/S together with suppliers and partners in the solar PV industry, established a fund from which households and organisations can apply for support. In order to receive the support, the facility must be a Viva Energy-facility delivered by Viva Energy or their partners. The support is possible to apply for all photovoltaic solar systems connected to the electricity grid. The support is 0,6 DKK/kWh for the calculated electricity surplus during the first five years (maximum 50% of annual production). Hybrid facilities with lithium batteries can receive additional 3000

DKK, and 2000-5000 DKK extra can be added due to the design of the panels. The total support for the facility is around 10 000-20 000 DKK, but there is no upper limit (Viva Energi, 2019).

For organisations the excess power production can be maximum 15% of total generation. As an example, the support for a 50 kW facility is 45000 DKK excl. VAT.

Investment support for businesses

There is no investment support to businesses for distributed electricity production and usage in Denmark today.

General support schemes for renewable electricity production

The promotion of onshore turbines has had high priority in order to meet climate objectives and to lower electricity prices. In recent years there has been a policy shift towards favouring large offshore wind farms over onshore wind developments. In the new Energy Agreement, three offshore farms are planned with a combined capacity of 2400 MW while onshore wind farms are planned to be limited to roughly half of today's number of wind turbines (Danish Ministry of Energy, Utilities and Climate, 2018). In the Energy Agreement of 2018, onshore turbine development has been limited to only include the replacement of existing onshore turbines with new and more efficient turbines.

The "instant settlement" in May 2017 included the discontinuation of the subsidy scheme for onshore wind in February 2018 which is planned to be replaced in 2018/19 by a technology-neutral tendering scheme (Danish Ministry of Energy, Utilities and Climate, 2018). This is currently operating under a trial period and has included an annual budget of ≈ 1 mil €. The technology-neutral tendering has resulted in agreed contracts with a total of six projects for the first period, with three solar PV and three wind projects awarded an average of 0.0004 and 0.00003 EUR/kWh respectively.

As mentioned under "Investment support for households", an amendment of the subsidy scheme for photovoltaic solar modules, the so-called "instant settlement", was made in May 2017.

Other relevant regulation

In Denmark there is a tax deduction for labour cost (håndværkerfradrag) up to 12000 DKK per person which can be used when installing solar PV panels or other energy related installations in houses. The deduction is approximately 27% and covers salaries (not materials). (Danish Customs and Tax Administration, 2019). Even though the tax deduction from labour cost is only partially directed towards installation of energy producing installations such as PV, it is currently the most substantial incentive to the installation of PV for households in Denmark.

4.2.6 Regulation in Iceland

According to the Icelandic Ministry of Industry and Innovation, there has not yet been implemented any specific regulation on prosumers or self-consumption in Iceland.

There is a support system in place for the research of the potential for hydropower. There is no support for the installation of electricity production, but some mechanisms to reduce the risk in the initial phases.

The energy act Nr. 65/2003 has separate provisions for small-producers, which are mainly small-hydro plants. For instance, small producers of under 100 kW do not need a production license (art. 4). Two relevant regulatory documents are:

Althingi Parliament (2003): The electricity act (in Icelandic)

Reglugerdasafn (2005): Related regulation on production (in Icelandic)

5 Challenges or barriers to the development of distributed electricity production/self-consumption

There are very few if any barriers to a *sound development* of distributed electricity production and self-consumption in the Nordics. While the definition of barriers for the development of distributed electricity production and self-consumption depends on the context, the aim of this report is mainly to identify barriers which limits a *sound development*, i.e. that distributed electricity production and self-consumption should not face *discriminatory or disproportionate procedures* and that such *producers should have the same rights and obligations as other producers*. In that sense, the policy frameworks support distributed electricity production and self-consumption and there are no discriminatory or disproportionate procedures. Through implementation of regulations that support distributed electricity production and self-consumption in the Nordics, one may say that the barriers (costs) have been reduced, or the drivers (expected gains) have been enhanced. As we have seen, all Nordic countries except Iceland aim to incentivise distributed electricity production and have introduced policy instruments supporting this (i.e. policy drivers).

However, this report also study factors that market actors *perceive* as barriers. These *perceived barriers* may limit the development of distributed electricity production but may not be actual barriers for a sound development according to the definition used in this report. We however identify several general limiting factors for development of distributed electricity production/self-consumption which are the same across the Nordics (as well as other countries). These include limited knowledge regarding distributed electricity production and its possibilities, transaction costs and installation costs.

***Perceived barriers* include policy related barriers such as complexity of the regulatory regime, specific definitions for which electricity production that can receive supports as well as uncertainty regarding future policy outlook.** The complexity of the regulatory regime can make it harder for potential producers (households, companies) to overlook the system and potential support schemes and increase transaction costs. Specific definitions for which electricity production that can receive supports results in that some potentially interesting distributed electricity production is "left out" and do not receive support. This increase transaction costs and installation costs. The third perceived policy barrier identified – uncertainty regarding future policy outlook – increase risk and therefore actors (households, companies etc) willingness to invest.

However, a regulatory framework supporting distributed production will by itself also give rise to some *perceived* regulatory barriers. The perceived barriers differ between the countries, dependent on the design of their regulative framework. However, this study's mapping shows some general aspects regarding regulatory barriers and drivers.

5.1 Background: key drivers for distributed electricity production globally, and the presence in the Nordic region in different countries

When analysing drivers and policy barriers in the Nordic countries, it is important to keep in mind the main drivers for the development of distributed power production and self-consumption globally, and to what extent those are present in the Nordics.

- Natural resources and proximity to them
- A perceived business case

The natural resource conditions for small-scale hydro, bio, geothermal, wind and solar varies in the Nordics and compared to the Continent, e.g. with hindsight to solar radiation. Also, the proximity of these resources to the potential producer and self-consumer is important, which limits the potential for e.g. distributed hydro and geothermal power.

An important aspect of the business case for distributed electricity production and self-consumption are the electricity cost the final consumer has to pay, including grid tariffs, taxes and subsidies. This total cost is generally – except for Denmark - much lower in the Nordics than in other countries such as Germany and therefore the incentives for own distributed production and self-consumption are much lower.

Another aspect of the perceived business case is the production cost side. Strong technological and commercial development has improved the business case of distributed electricity production relative to alternative sources. The global increase in distributed electricity production is largely synonymous with a global growth in the installations of solar PV (and to some extent batteries, growing from a very low level) (BloombergNEF, 2018). This means that the economics of distributed electricity production largely reflects the economics of the solar PV/battery combination. Growth in solar PV has been, and is expected to be, strongest in areas with good solar conditions, electricity demand for cooling (when the sun shines), high energy prices and grid costs (and or/ low grid quality) and a low share of renewable electricity production. For instance, Bloomberg New Energy Finance expects that consumer PV and behind-the-meter batteries will make up 44% of all electricity production capacity in Australia by 2030-2040% (BloombergNEF, 2018).

Hence, the total benefits of distributed (PV) electricity production, and especially the profitability of investing in solar PV production, are expected to be lower in the Nordic countries, than in several other countries. In other words, some of the main drivers behind the global increase in distributed production, are to a less degree present in the Nordic region. Other drivers, such as the reductions in technology costs on the other hand affects the Nordic region similar to other countries.

In light of this, one may say that the most important limiting factor to an (even) faster deployment of distributed electricity production is simply the lack of profitability of such investments compared to the alternative, which is consumption of electricity from the power grid. The specific policy measures directed at distributed electricity production, and especially the support schemes and tax deductions, are however affecting the overall profitability of such investments. As we have seen in Denmark, the deployment of PV solar production in the household sector rose dramatically in a period where technology costs came down while at the same time the support level were held constant, thus increasing the expected private profitability of PV solar investments. On the other hand, the deployment rate fell significantly when the overall support level, and hence the expected profitability, was lowered.

5.2 General findings on findings barriers and drivers in the Nordics

While the natural framework conditions for PV solar production seems to be an important limiting factor to the deployment of distributed production in the Nordic region, this does not necessarily represent a barrier as such. What is to be considered a barrier will depend on the context and the objective of the policy area of question. If the object is to facilitate an unlimited growth of distributed electricity production, all limiting factors may be considered a barrier, including also the lack of sufficient support schemes to make the investments profitable. If the object on the other hand is a socio-economically optimal development, the barriers may be related strictly to market failures that is not corrected through policy measures.

In this study, we have primarily been asked to discuss barriers to a "sound development", meaning that distributed electricity production and self-consumption should not face discriminatory or disproportionate procedures.

However, the study also discusses factors that market actors perceive as barriers. These barriers may limit the development of distributed electricity production, but is not necessarily actual barriers for a sound development, according to the definition.

The overall finding is that there are few, or no barriers for a sound development of distributed power production in the Nordics. In general, there is in place a regulatory framework which supports distributed electricity production and self-consumption, also relative to centralized production and related consumption.

In general, it is therefore difficult to see that distributed production and self-consumption face discriminatory or disproportionate procedures hindering a sound development.

There are however several factors that may be perceived as obstacles to households and businesses considering investments in distributed electricity production and self-consumption. For instance, investments in local distributed hydropower production for self-consumption requires local access to the resource. The installation of roof-top PV-cells can represent a considerable financial investment and/or pose an administrative burden for potential prosumers. The application for subsidies or necessary procedures for receiving tax deductions will also represent an administrative burden for the consumers. These are not barriers in the sense that the distributed electricity production face discriminatory or disproportionate procedures, but are still perceived as barriers for stakeholder considering to invest in distributed electricity production.

In the public debate, several policy barriers for distributed electricity production in the Nordics are highlighted. An overarching barrier is the complexity of the regulation, consisting of several policy instruments, exemptions and incentives for distributed production and self-consumption, and where a varying set of definitions apply. This increases the administrative burden and transaction costs associated with understanding and applying for different support schemes or tax deductions. Additionally, the regulation has been developed and changed continuously, often without a transparent and clearly communicated long-term policy objective – leaving the actors with a political risk. Additionally, all decisions are not fully rational from an economic point of view, and investments may be hindered due to limited knowledge and expectations of high transactions costs.

The main drivers and perceived barriers are summarized in Table 4. Many of the drivers and barriers are present and to a large extent similar in all countries, including barriers related to limited knowledge and installation costs as well as the drivers related to environmental concern/marketing value and potential cost savings. Both transaction costs and the perceived regulatory barriers and drivers may on the other hand vary between the countries.

Table 4: Key drivers and key perceived barriers in all Nordic countries

Key perceived barriers	Key drivers
Knowledge • Limited knowledge regarding DES and its possibilities	**Preferences of households and businesses** • Environmental concern • Marketing/social value • Perceived increased security of supply
Transaction cost (administration) • Time consuming processes • Resistance towards inconvenience	**Commercial and technological development** • Cost reductions • Technology development/ Decreasing installation costs • High/increasing electricity and grid prices makes self-generation more interesting • Perceived by some as reducing risk
Installation cost • Significant upfront cost	**Electricity and grid prices** • Potentially increasing electricity and grid prices that promote distributed production
Regulation which may hinder distr. prod • Differs between countries, outlined in more detail below. Some regulatory	**Regulation which may promote dist. prod.**

development such as more capacity based DSO tariffs and development towards 15-minute metering periods might reduce distributed generation and self-consumption's profitability.	Differs between countries, but in general, the following regulation promotes distributed electricity production in the Nordics: • Grid tariffs based on energy use (savings) • Electricity-tax exemption for self-consumption • Investment support (Direct/tax deduction) • General RES-E production support Some countries also have additional regulation promoting distributed production

Source: CICERO (2018), Oslo Economics (2019), SOU 2018:76, Sweco (2019)

Especially the perceived regulatory barriers differ between countries and also between segments of potential prosumers. For instance, regulation regarding distributed electricity production and self-consumption may be less beneficial for apartment buildings than for individual houses (detached and attached houses) in some countries. In the following chapters we will discuss perceived barriers related to the design of specific regulation and support schemes in each country. When relevant, we will describe differences in the perceived barriers and drivers between segments. We also describe how different regulatory changes (planned or requested from certain stakeholders) may affect drivers or barriers. We do not make a comprehensive assessment of the impacts of such regulatory changes or give advices to whether these should be made or not

Apart from barriers related to increase DER, there are also some potential negative impacts that increase DER can have, and these impacts can limit the DER growth potential. These include market resistance/reluctance, sustainability of materials used, impact on grid (such as reverse flows, unstable grid etc) as well as resulting in a higher share of intermittent power production in the system. These barriers/negative impacts on not analysed in-depth in this report but are taken into consideration when formulating our scenarios, see 6.

5.3 Norway specific barriers

This study lists factors that market actors *perceive a*s barriers. These factors may limit the development of distributed electricity production but may not be actual barriers for a sound development. The perceived drivers and barriers for investments in distributed power production in Norway vary between different segments and technologies.

The distributed hydro production segment mainly consists of farms and businesses which are located near micro/very small hydro plants. Because of the geographical limitation of hydropower prosumption, political promotion measures could be ineffective and give unintended consequences[15].

As in the other Nordic countries PV is the growing segment within distributed power production. According to the CICERO-study "Power from the people - Driving forces and obstacles", the household PV-segment is currently made up of people with a special interest in environment and technology. That is, for most individual home owners in Norway, the sum of barriers has been perceived larger than the sum of drivers for installing PV. According to CICERO, softer measures, such as information measures, could potentially lead to increased DES investments. In addition, the commercial and technological development is likely to lead to lower costs for home owners, making distributed power production more attractive. However, based on examples from countries with strong growth in distributed power production, CICERO considers that more drivers in the form of further regulation promoting distributed production would be required in Norway. Specifically, they suggest that a generous and stable feed-in-tariff could lead to more prosumers.

[15] Specifically, further financial incentives (in addition to grid tariff and tax savings), could lead plant owners to invest in private grids to direct power directly to their farm/home/business, replacing the distribution grid, without increasing total renewable power production.

Based on our knowledge of the largest business roof-top PV-projects, this segment consists of businesses for which rooftop-solar PV may provide cost savings (energy, grid and tax cost savings), possibly a reasonable return on investment, and for which it may provide a positive marketing value. As for individual home owners, we consider that distributed PV-production in the business segment could be promoted (if desired) by introducing further "positive" regulatory measures (support schemes) which either increases revenues or decreases costs associated with distributed production (if politically desirable). It should however be noted that this is not a barrier for a sound development, but rather something that could promote PV installations (if that would be a target).

Apart from the more general barriers described above and in Chapter 5.2, there are some Norwegian specific regulatory-related perceived barriers which has been identified, see Table 5.

Table 5: Perceived policy and market barriers in Norway

Perceived policy and market barriers in Norway	Impact	Comment
Electricity grid capacity tariffs	Grid cost savings from distributed generation and self-consumption may be reduced if the grid tariff structure are changed towards capacity tariffs (as proposed by NVE to obtain a more cost-reflective tariff, see chapter on regulation).	Even if the trend towards capacity tariffs is considered negative for the profitability of solar PV and other types of self-generation production/consumption, it could also have benefits such as creating incentives for demand response, development and increased use of batteries.
Barriers for apartments buildings	As of today, most households with distributed production are houses (attached and detached). Apartment buildings with DES are rare. This can be explained by several reasons, among them: • Need to coordinate many neighbours to make a common investment decision and apply for Enova investment subsidy • Regulation and technical solutions for the distribution of self-produced electricity for consumption within an apartment building and/or a building community without paying taxes and grid tariffs are not yet ready.	The planned changes to the Norwegian prosumer-scheme will reduce the perceived regulatory barriers for the distribution and consumption of self-produced electricity within an apartment building. Perceived barriers related to the coordination between neighbours will remain but might be reduced with technical and commercial development.

Source: Oslo Economics, Sweco, NVE (2019b)

5.4 Sweden specific barriers

This study lists barriers that market actors *perceive* as barriers. These barriers may limit the development of distributed electricity production but may not be actual barriers for a sound development. Apart from the more general perceived barriers (see Chapter 5.2) there are some perceived Sweden specific regulatory related barriers which has been identified, see Table 6.

The solar commission has listed several perceived barriers for distributed energy resources which are referred to multiple times in Table 6. However, the perceived barriers are valid for all DES unless specified otherwise.

Table 6: Perceived policy and market barriers in Sweden

Percieved policy and market barriers in Sweden	Impact	Comment
Complexity of the regulatory regime	Significant perceived transaction costs in order to understand all policy instruments and apply for all support and exemptions	Simplified support systems for solar PV and other RES could reduce transaction costs. This has been brought up many times including in the Swedish Energy Agency's solar strategy, in the government's investigation and by the Swedish solar commission. Proposals such as removal of the investment support and lower capacity size limit for participating in the electricity certificate system and instead having a "solar-ROT" (increased tax exemption on household services when installing solar PV) could reduce this perceived barrier.
Unclear savings (especially for smaller producers)	The 60 öre/kWh premium is given as a tax exemption on income tax, which does not show a clear connection between solar PV investment and energy bill savings	Having the premium as a deduction on electricity bill would clarify connection. Would however require further examination.
Policy outlook uncertainty	Uncertainty to make investments due to uncertainty regarding future policy	The policy has changed a lot during recent years, driven by technology development, willingness to incentive renewables, EU compliance etc. As the technology matures it is likely that the policy can be more stable going forward.
Trend towards electricity grid capacity tariffs	Lower variable electricity grid tariff	The Swedish solar commission propose that maximum 50% of the electricity grid fee is fixed. Even if the trend towards capacity tariffs is bad for solar PV and other self-generation it has other benefits such as creating incentives for demand response and a creating better cost-reflecting tariffs.
Tax exemption only applies if the electricity is "behind the meter". i.e. is not transported over concession grid	Stakeholders owning multiple building, also the ones in close proximity of each other, cannot use their self-generated	The Swedish solar commission propose that tax exemption should apply also when electricity is moved between

	electricity in other buildings if they want tax exemption	building. The rule regarding that tax exemption is not allowed if distributed over concession grid was however put in place 2016 and motivated by that only electricity which does not use the public grid should have the benefits of tax exemptions and that the way organisations organize themselves should not impact energy tax cost. There is an ongoing investigation regarding IKN-grids. The outcome of this investigation might lead to the possibility for property owners to transfer electricity between different buildings within the same premise, without passing the grid subject to concession. (Översyn av regelverket för nätkoncessioner Dir.2018:6 , 2019)
Tax exemptions only for installations below 50 kW hydro or thermal, 125 kW wind or 255 kW solar PV	Larger decentralized systems cannot use tax exemptions	The Swedish solar commission propose that tax exemption should apply also for larger installations. However, this is not assessed by the Government to be in compliance with EU law.
Building permit requirements solar PV	Administrative costs related to applications for building permits	In August 2018 an exemption was introduced which simplifies for solar PV panels so that no construction permit is required if the panels follow the shape of the building and some other conditions are fulfilled.
Environmental permits hydropower	Due to EU's water framework environmental permits for hydro will be reviewed.	Sweden has set a plan for reviewing all environmental permits for all hydropower in Sweden. A number of small-scale hydropower plants will be required to scale-down or decommission their operations.

Source: CICERO (2018), Oslo Economics (2019), SOU 2018:76, Sweco (2019), Solelskommissionen (2019)

5.5 Finland specific barriers

This study lists barriers that market actors *perceive a*s barriers. These barriers may limit the development of distributed electricity production but may not be actual barriers for a sound development. Apart from the more general perceived barriers (see Chapter 5.2) there are some Finland specific perceived regulatory related barriers which has been identified, see Table 7.

Table 7: Perceived policy and market barriers in Finland

Perceived policy and market barriers in Finland	Impact	Comment
Requirement for applying for a building and action permit vary from one municipality to another	Contact with municipal building supervision authority is recommended prior to investment decision. Such discussions add a level of complexity and might be time consuming.	Solar panels are generally speaking permitted to be installed without a separate building or action permit, however different municipalities have different permitting processes.
Permission is required from the distribution system operator for connecting a generation installation to the electricity grid	There are some 80 different distribution system operators in Finland and consequently also significant number of grid connection procedures and guidelines. In some instances, the technical requirements set by the distribution system operator can limit the types of generation installations that can be installed.	Several companies are now offering especially solar panel installations to residential houses as turn-key deliveries, which reduces the complexity related to the grid connection process but can also result in an increased cost. Installation works may only be conducted by a skilled person with electrical installation permits.
Differences in the contractual conditions between the energy companies with regard to offtake agreements	Some companies charge a fee for the offtake of surplus electricity, while some are willing to purchase the electricity with the spot price. Monthly fees can be applied, especially if the offtake agreement is not with the company electricity is purchased from, which limits the possibility to compete one's electricity supply contract.	Sales of surplus electricity is enabled; the producer is only obligated to sign an offtake agreement with the selected energy company.
Electricity tax applied to installations with rated generation capacity > 100 kVA	Installation smaller than 100 kVA are not mandated to pay the electricity tax (2.793 c/kWh) nor the emergency preparedness contribution (0.013 c/kWh) for the electricity generated for own consumption or for the surplus electricity sold to the grid. Larger installations might perceive this as a barrier. Please note however that installations above 100 kVa need to register for tax but only pay if production exceeds 800 000 kWh.	The tax guideline that has been effective since May 2015 has improved the profitability of small-scale generation installations and contributed in the increase in solar panel installations to residential buildings. The upper limit may serve other purposes such as limiting market distortions.
Trend towards electricity grid capacity tariffs	Grid cost savings from distributed generation and self-consumption may be reduced if	Capacity traiffs can reduce incentives distributed generation and self-consumption but it

	the grid tariff structure is changed towards capacity tariffs	could also have benefits such as creating incentives for demand response, development and increased use of batteries.
Limited availability of subsidy schemes to support the investments	For private individuals, the only financial instrument available to incentivize an investment in e.g. solar panels is the tax credit for household expenses which can be applied for the installation works. The tax credit is capped to 2400 EUR/person per year. Companies, municipalities and other organizations may be eligible to receive support for small-scale electricity investment projects.	Additional investment subsidies for private individuals would create a stronger incentive for investments, but no such schemes are currently foreseen. However, even if the limited support can be perceived as a barrier by some stakeholders today it does not mean that it is a barrier for a sound development.

Source: Motiva (2012), Finnish Energy (2016)

5.6 Denmark specific barriers

This study lists barriers that market actors *perceive a*s barriers. These barriers may limit the development of distributed electricity production but may not be actual barriers for a sound development. Apart from the more general perceived barriers (see Chapter 5.2) there are some Danish specific perceived regulatory related barriers which has been identified, see Table 8.

Table 8: Perceived policy and market barriers in Denmark

Perceived policy and market barriers in Denmark	Impact	Comment
Complexity of the regulatory regime	Due to the regulatory set up, and frequent regulatory changes support systems has previously been perceived as complex. This also increase policy uncertainty. In addition; the taxation and depreciation rules applied as well as the possibility to receive income tax deduction on the installations, have further contributed to the support schemes being perceived as complex.	The new regulatory regime includes no direct support for DES systems. This does increase transparency in the regulation can be perceived by market as to little incentives for distributed electricity generation and self-consumption. With future installations all PV's are regulated under a so-called flex tariff meaning new PV installations are treated equal, lessening the burden of calculating a business case for smaller installations.
Price negotiations	The administrative processes related to negotiating prices with local DSO's for most installations are deemed to be a complex task for non-professional negotiators and households.	Pricing rules or methods for calculating real prices for smaller installations could be imposed on local DSO's if a socioeconomic benefit can be identified.

Variable prices are not forwarded to the consumers	The price fluctuations are to a very limited degree reflected in consumer prices today, which further decrease the economic feasibility of systems taking advantage of increased flexibility such as distributed electricity production combined with internal storage. The economic incentive to invest in flexible systems are limited by the current non-dynamic tariffs and taxes on energy which make up the bulk of the consumer prices. The expected out-phasing of the PSO and electricity taxes are expected to further decrease the incentive to invest in own production.	However, even if the limited support can be perceived as a barrier by some stakeholders today it does not mean that it is a barrier for a sound development. General price developments are expected to drive the incentive for further investments in distributed electricity production in the long run as prices on especially solar PV continue to fall.
Energy agreement 2018	The current energy agreement for the next four years, has a specific goal to decrease the number of onshore wind turbines to roughly half of today's numbers. In addition, the lack of support schemes and direct support for PV, will make the establishment of smaller PV systems less economically attractive. The general terms in the energy agreement also increases the cost effectiveness in developing RES with emphasis on larger production units through the technology neutral tendering scheme.	The goals of the energy agreement are assessed to decrease the investment in smaller distributed electricity production installations. However, even if the limited support can be perceived as a barrier by some stakeholders today it does not mean that it is a barrier for a sound development.
Legislation on connection for new production units (tilslutningsbekendtgørelsen)	Shift in the regulation regarding the connection of new RE units to the grid is shifting the economic burden from DSO to the production unit owner.	In principle DSOs are able to collect connection costs, and local reinforcements in the grid due to DES installations. It is however a general recommendation of the Industrial associations within energy that this rule should not apply to the smaller distributed electricity producers, but rather be reflected in the prices when buying the surplus production from smaller DES units. This can be perceived as a barrier by some stakeholders but does not

		necessarily mean that distributed electricity production installations face discriminatory or disproportionate procedures

Source: Sweco, Danish Energy agreement (Danish Ministry of Energy, Utilities and Climate, 2018)

5.7 Iceland specific barriers

The more general perceived barriers apply also for Iceland, such as lack of knowledge, transaction costs and significant upfront cost. Iceland do not have specific regulation to promote small-scale decentralised production, which can be regarded by market stakeholders as a barrier. However, Iceland has good natural resources for renewable large-scale generation (especially geothermal), and hence less needs to expand their distributed electricity production.

6 Future growth outlook

We describe a potential future development of distributed renewable electricity production and self-consumption in the Nordics by means of an outlook with a rather large outcome space. The lower end of the outcome space uses a trend projection from the past four years of available historic data (2013-2017) as a base. Furthermore, it assumes that the cost reductions for new technologies continue, electricity prices increase only slightly and that current policy measures are similar or gradually phased out as technology cost drops. The upper end of the outcome space assumes that the cost reductions for new production technologies continue at a fast pace, that the electricity price increases substantially as a consequence of increasing CO2-prices and that the technical potential is gradually reached and/or that policy targets are set to reach a certain volume.

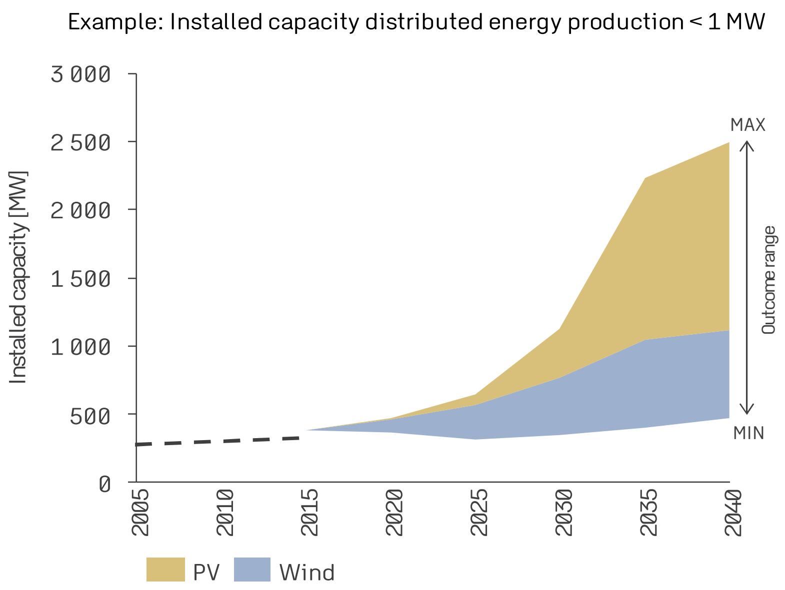
The outlook shows an outcome space for potential development of the distributed electricity production potentially used for self-consumption in the Nordics growing from currently about 5 TWh (2017) to 10-24 TWh in the upper end of the outcome space, the majority of this potential- 19 TWh – being solar PV.

6.1 Outlook methodology

We describe a potential future development of the distributed renewable energy in the Nordics by means of an outlook with a rather large outcome space. The outlook is developed based on historical data, current markets trends, implicit technology cost development assumptions, implicit electricity price development assumptions as well as expectations of policies either being in place or potentially put into place in the Nordic countries.

The outlook describes the potential outcome space for each country expressed in both MW and GWh. The outcome space presents a range of potential developments where the expected output is within the min-max range given by the graph. The outlooks project the installed capacity and energy production in installations below 1 MW but also the units used for self-consumption.

Figure 20: Example of outlook graph



6.1.1 The lower end of the outcome space

The lower end of the outcome space uses a trend projection from the past four years of available historic data (2013-2017) as a base. Furthermore, it assumes that the cost reductions for new technologies continue, electricity prices increase only slightly and that current policy measures are similar or gradually phased out as technology cost drops.

6.1.2 The upper end of the outcome space

The upper end of the outcome space assumes that the cost reductions for new production technologies continue at a fast pace, that the electricity price increases substantially as a consequence of increasing CO2-prices and that the technical potential is gradually reached and/or that policy targets are set to reach a certain volume.

6.2 Important parameters that define the outcome space

In this section we describe parameters that most likely will impact our outlook outcome space as such and the speed of deployment. These parameters and their principle effects are described even though neither the parameters nor their effects are explicitly quantified in the outlook, which would require a much more extensive analysis than possible within the frame of this project.

6.2.1 Technical potential

The estimated technological potentials from previous studies are used as limiting factors of growth per technology and country and thus as the upper limit of the outcome space, see Table 9. Worthwhile to mention that technical potential is not a figure fixed and set in stone for all future, but rather a moving target, depending on both technology development and the analysis method used, especially for less mature technologies. The technical potential numbers have to be viewed and weighed in that respect. The economic potential is estimated for all power sources to be at least 50% of the technical potential, except for PV.

Table 9: Estimated technical potential for power sources in the Nordics based on previous studies

Power source	Year	Country	Technical potential [MW]
Bio	2017	Sweden	87
Bio	2020	Denmark	650
Hydro	-	Finland	340
Hydro	-	Norway	3 248
Hydro	-	Sweden	188
PV	2030	Denmark	4 481
PV	2030	Finland	3 571
PV	2030	Iceland	200
PV	2030	Norway	5 500
PV	2030	Sweden	7 588

Source: European Commission (2017), NVE (2004), IAEA (1998), Svebio (2017), Björklund & Öhman (2015), Danish Energy Agency (2019j)

The technical potential for solar PV is estimated by the European Commission. The number includes an estimation of residential consumers and the available roof area in the given countries. Of the available roof area is 40% calculated as technically available for PV installations. For PV, we assume the economic potential of roof-mounted PV as share of the technical potential to increase further. Furthermore, we assume the technical potential to increase due to solar PV integrated in the facade of new buildings. Hence, we simplify and use 100% of the technical potential for roof mounted solar PV as a proxy for economic potential from both roof- and facade-mounted solar PV. We are aware of that many observers in the market deem that the Commissions figures underestimate the real technical potential for solar PV.

6.2.2 Regulatory issues

The EU's water directive means among other things that the environmental permits for hydropower needs to be updated. This will most likely affect the number of small-scale hydropower plants in the business as usual outlook. In the higher level of the outlook the regulation is assumed to be adjusted in order to maintain the current levels of hydropower production.

6.2.3 Speed of technology cost development

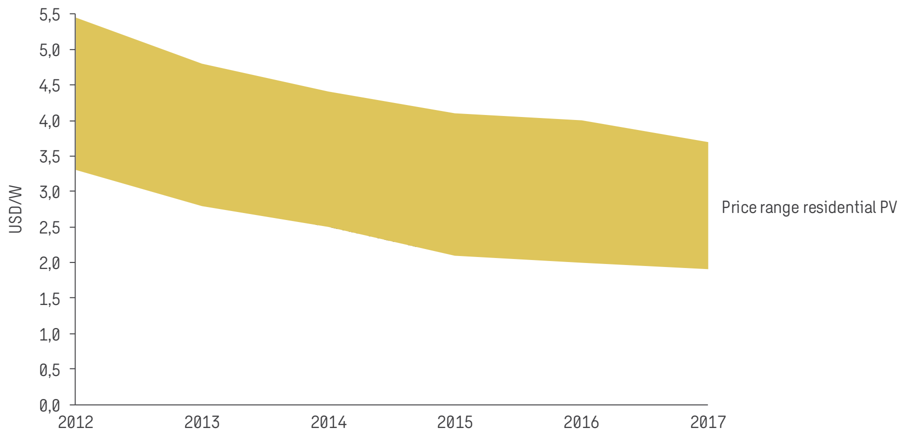
Since production cost as well as operation and maintenance costs are low for many distributed renewable electricity generation technologies, the investment cost development is often essential for increased competitiveness and market penetration.

For solar PV, the module followed by the inverter are the cost driving components in residential PV systems. In Sweden and Finland, the module is estimated to cover about 60% of the total system cost. (IEA - PVPS, 2018a). As the cost development for residential PV has been declining the past five years, see Figure 21, we have reason to believe that the cost development will continue to drop. System prices for residential PV systems reveal huge discrepancies from one country to another and the cost development will hence differ between the countries. (IEA - PVPS, 2018a). However, the difference between the Nordic countries is expected to be limited.

The European Commission assumes in their study on household prosumers (European Commission, 2017) that households need 6,2% rate of return of the investment in order to install solar PV. As technology costs decreases the number of households fulfilling that criteria will increase and the payback time of household investments will decrease.

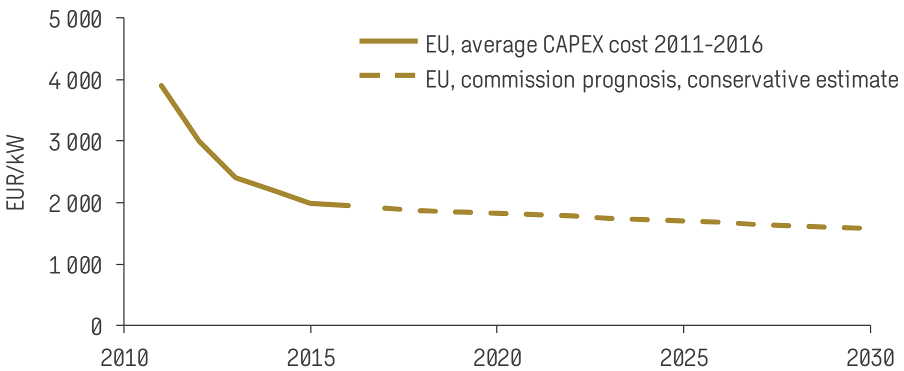
How much the solar PV prices will drop is hard to estimate, some analysts believe that the larges cost decrease was between 2010-2013 and that the price curve now will be more stable, with a slight decrease, see Figure 22. The EU commission uses a conservative estimate in their calculations which shows that the CAPEX cost for solar PV is expected to decrease from about 2000 EUR/kW to about 1500 EUR/kW in 2030. This would increase the market uptake for residential PV in all the Nordic countries in the outlook.

Figure 21: Technology cost development, small scale PV systems in IEA reporting countries



Source: (IEA - PVPS, 2018a)

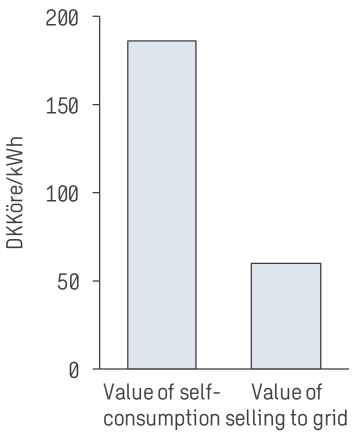
Figure 22: Solar PV CAPEX costs in EU member states



Source: (European Commission, 2017)

The technology costs for batteries and storage will impact the amount of possible self-consumption for households. The Danish TSO, Energinet.dk, investigated the share of self-consumption with three different combinations of residential PV with battery solutions (Energinet, 2016). The study showed that the amount of self-consumption increases with larger batteries. Especially the variations within the hour decreased as larger batteries was used. The largest difference however was observed when a system with a small battery was compared to a system without a battery. To install a small battery in a system without storage increased the profitability of the system significantly. The economic benefit in upgrading the battery to a larger storage capacity was however limited. The results showed that the share of self-consumption in the household increased from 25% to 40% when the small battery was installed. The smallest battery in the study was 3 kWh, batteries with lower capacities was not included in the study since the installation costs was considered to be too large compared to the earnings. Increased self-consumption affects the profitability since the net value of using the electricity for self-consumption is higher than selling electricity to the grid, see Figure 23.

Figure 23: Net value of PV generated electricity for household self-consumers in Denmark 2016



Source: (Energinet, 2016)

The energinet outlook estimates that the installed capacity of household PV systems with batteries could increase to about 1000 MW in Denmark in 2040. This can be compared to the PV systems without batteries that are expected to grow to about 1600 MW in 2040. The growth of battery systems is currently limited due to high technology costs and large investments. In case the technology costs for storage significantly drops further, this could potentially impact their deployment.

On the other hand, for small-scale wind power its technological status and its cost efficiency are seen as limiting factors affecting the distributed small-scale wind power growth rates. The small-scale wind power technology is less efficient compared with large-scale state of the art technology and has during the past years been characterized by technical failures and a limited number of suppliers. The business as usual outlook assumes a gradual phase out of small-scale wind power plants, with the lower level of the business as usual outlook being marked with a 23-year lifetime expectation of existing wind power plants and the higher using a 35-year lifetime expectation. All distributed wind power plants installed before 1990 that are still operational are expected to have a technical life time of 35 years.

6.2.4 Electricity price development

Any investment decision in new production capacity, whether central or distributed is at least to a larger degree depending on the expected electricity price over the lifetime of the investment.

The future electricity price is on the other hand depending on the development of electricity demand, the production mix, fuel and CO2 prices and transmission capacity between connected markets. However, increased coal prices and increased cost for emission allowances within the EU-ETS as targeted by EU policy makers make long term higher electricity prices likely in the Nordics and Continental Europe, which is an implicit assumption in the outlook. Obviously, an accelerated development towards higher electricity prices could accelerate the desire for own, distributed electricity production and self-consumption.

6.2.5 Policy support

Policy support matters, at least in the short-term to accelerate desired developments. We do not assume specific policy instruments, but rather that a specific volume target supported by suitable support measures might accelerate the deployment, while the absence of it would not break the current deployment trend.

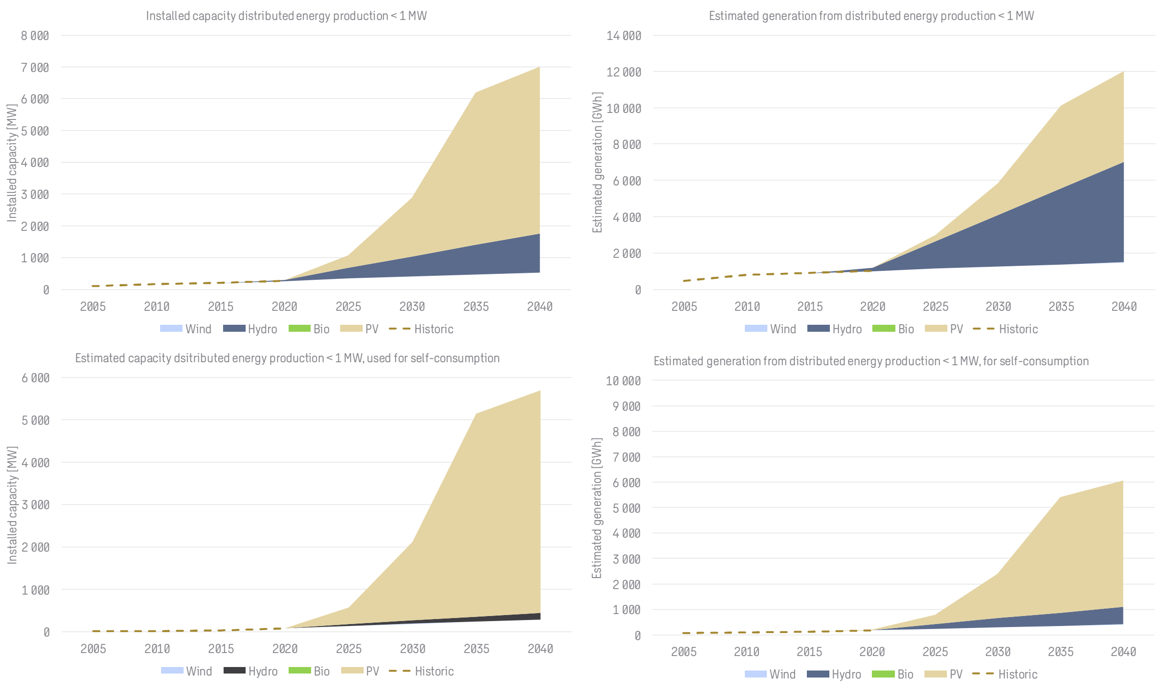
6.3 Norway

In the lower end of the outcome space, electricity generation from distributed electricity production (< 1MW) is increasing to about 1 500-4 400 GWh, see Figure 24, in the upper end of the outlook outcome space, the estimated electricity generation from distributed electricity production (< 1MW) could increase to about 12 000 GWh.

The installation of PV following the historical trend from the past four years, reaching 275 MW in 2040, marks the lower end. Over this long period of time and for fast-developing technologies, this kind of trend extrapolation always tends to underestimate real-life development. On the higher end, the technical potential of 5500 MW is the limiting factor for the growth in PV installations. This means that the electricity production from PV (<1MW) in Norway could potentially reach 5225 GWh.

In the lower end, small-scale hydropower in Norway has doubled since 2005, with the EU water directive expected to impact the future growth opportunities. The lower end of the outcome space sketches a decrease in the installations rate and the lower level describes an outlook where the installation level is constant. The historic trend points at an increase to about 275 MW in 2040, but considering potential impacts of the Water Directive, we set the lower end to be approximately 250 MW in 2040. The upper end potential for hydropower in Norway is estimated by the NVE and represents the technical potential in power plants below 999 kW. About 50% of the estimated potential in Norway is in plants with an investment cost below 3 NOK/kWh and the other 50% of the estimated potential have a build-out cost of 3-5 NOK/kWh. In the added policy outlook, the build-out potential below 3 NOK/kWh is used as the higher level for potential growth. The installed capacity in small-scale hydropower could hence potentially reach 1500 MW.

Figure 24: Outlook outcome space Norway



Source: Sweco

The growth rate in the small-scale Norwegian wind power has been low in the past ten years. The lower end of the outcome space expects constant installed wind power capacity or a minimal increase based on the historical growth. There are no political signals that the small-scale wind power should be actively developed further. Even if wind conditions in Norway are favourable in general and technical potential exists, we see only limited economic potential for small-scale wind power. Therefore, the installed wind power capacity in the upper end of the outcome space has potential to a very limited growth.

6.4 Sweden

In the *lower end of the outcome space*, electricity generation from distributed electricity production (< 1MW) is increasing to about 2 000-4 900 GWh, see Figure 25. In the upper end of the outcome space, electricity generation from distributed electricity production (< 1MW) reaches about 12 000 GWh.

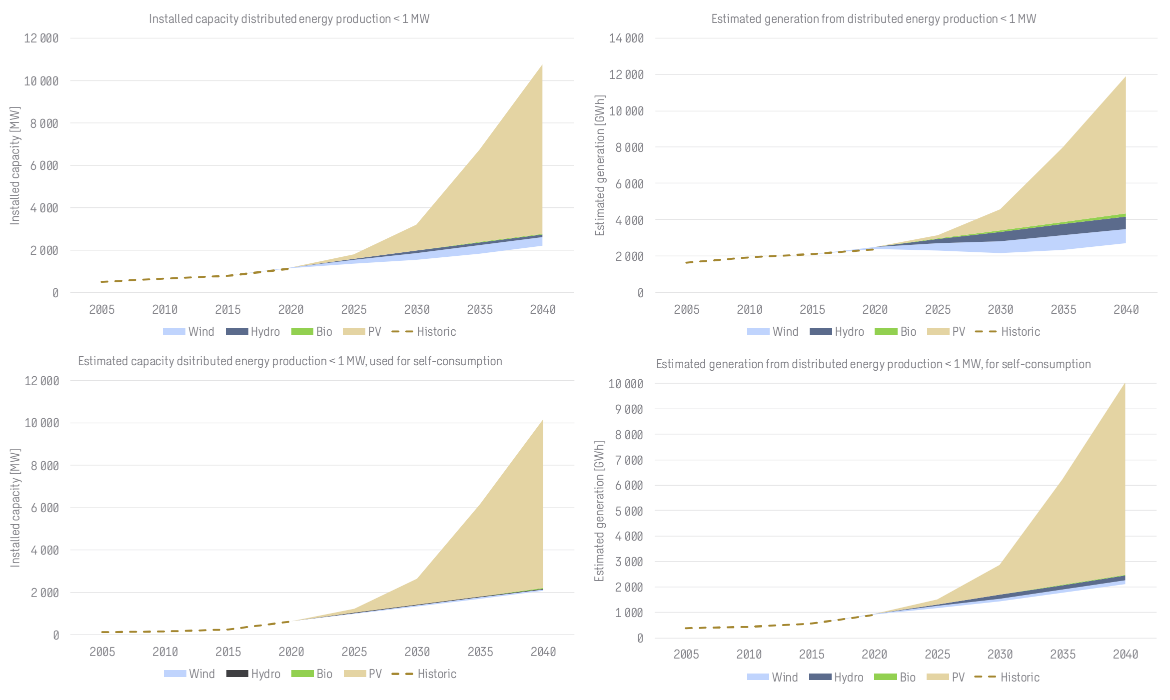
In the lower end of the outcome space, the installation of solar PV follows the historical trend of the past four years, reaching 2028 MW in 2040.The technical potential of 7000 MW is still set to be the limiting factor for PV growth and the electricity production from PV (<1MW) in Sweden could potentially reach 6650 GWh.

There is no statistical reliable data for the small-scale hydropower in Sweden. The small-scale hydropower association in Sweden assumes that there has been a slight decrease in the number of small-scale production units due to regulation and the age of the existing plants. The EU water directive is expected to affect the future growth negatively. The lower end of the outcome space shows 235 MW installed capacity.

The technical potential for hydropower in Sweden marking the upper outcome space is estimated by representatives in the small-scale hydropower association to be about 80% higher than the current installation levels. The upper end of the outcome space expects that half of that unused potential is used for new installations up to 2040. The total installed capacity would hence increase to about 300 MW.

The number of installed small-scale wind power plants in Sweden that could be regarded as distributed energy sources are decreasing in favour of larger scale turbines. The growth rates in small-scale wind power has only been 2-3 MW/year during the past five years. This means that the installation rates the coming years are expected to be lower than the total decommissions rates resulting in a net-decrease of small-scale turbine capacity. The Lower end of the outcome space shows a development where the number of installed turbines is negligible, and the life time expectancy of the existing turbines ranges from 22-35 years. Even in the upper end of the outcome space the levels of installed small-scale wind power in Sweden are not expected to increase. Even higher electricity prices or technology development are deemed unlikely to stimulate future growth in the installed capacity since the large-scale wind power is assumed to be much more cost-efficient and hence preferred and potential volumes would be low.

Figure 25: Outlook outcome space Sweden



Source: Sweco

The lower end of the outcome space sketches the number of small-scale bio energy plants to be constant or increase with the same rates as the historical growth. This means that the installed capacity would increase from 16 MW to 27 MW in 2040. The Swedish bio energy association estimates that the potential for small-scale turbines in existing thermal power plants is about 84 MW. If these new turbines are made available on the market the higher level of the Upper end of the outcome space expects the installed capacity to increase by about 84%.

6.5 Finland

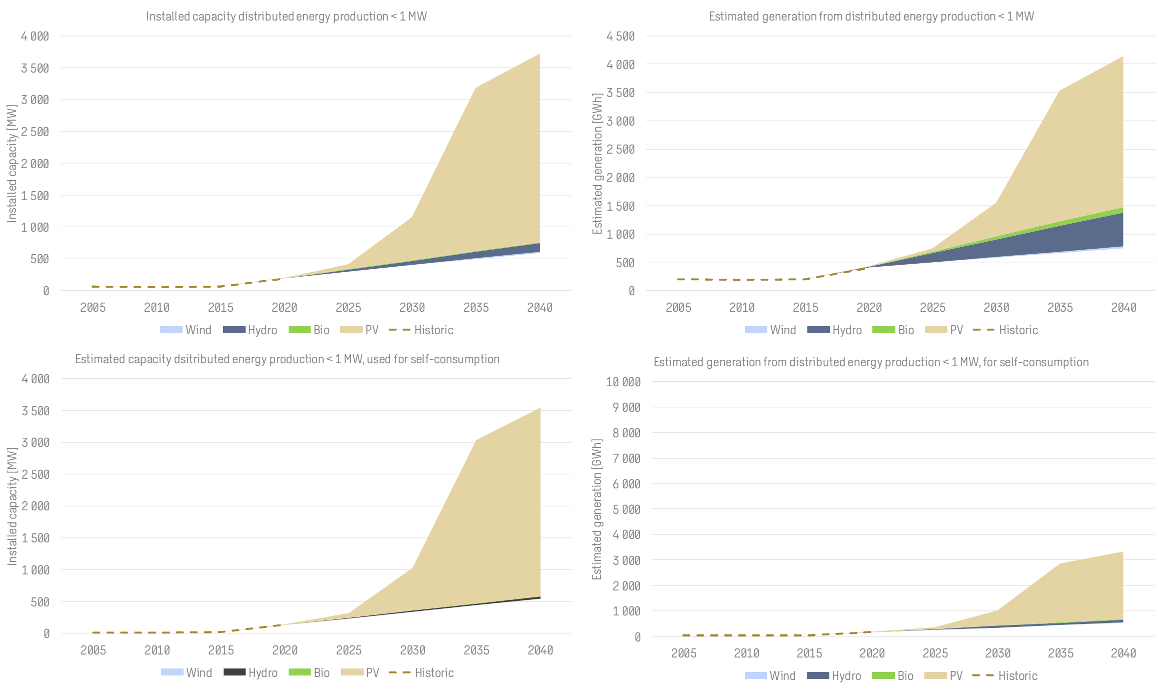
In the *lower end of the outcome space*, electricity generation from distributed electricity production (< 1MW) increases to about 800-1 900 GWh, see Figure 26. In the upper end of the outcome space, electricity generation from distributed energy sources (< 1MW) increases to about 4 100 GWh.

The installation of PV follows the historical trend from the past four years. This means that the installations of PV could reach 540 MW in 2040, marking the low end. The technical potential of 3500 MW is used as the limiting factor for the upper end of the outcome space growth in PV installations. This means that the electricity production from PV (<1MW) in Finland could potentially reach 3150 GWh.

There is no statistical reliable data for the small-scale hydropower in Finland. The EU water directive is expected to limit the future growth potential. The lower end of the outcome space points at a decrease in the number of installations and describes an outlook where the installation level is slightly decreasing from today's level. The technical potential for expansion of small-scale hydropower in Finland is estimated to be 340 MW.

The number of installed small-scale wind power plants in Finland are decreasing in favour of larger scale turbines, similar to the trends in other Nordic countries. During the past four years the installed capacity in small-scale wind power in Finland has been decreasing. The lower end of the outcome space shows the number of installed turbines being negligible, with an assumed technical lifetime of the existing turbines between 22-35 years. Even in the upper end of the outcome space the levels of installed small-scale wind power in Finland are expected to remain constant.

Figure 26: Outlook outcome space Finland



Source: Sweco

The lower end of the outcome space shows the number of small-scale bio energy plants to remain more or less constant, while the upper end of the outcome space shows a development where the installed capacity in small-scale electricity from bioenergy is doubled.

6.6 Denmark

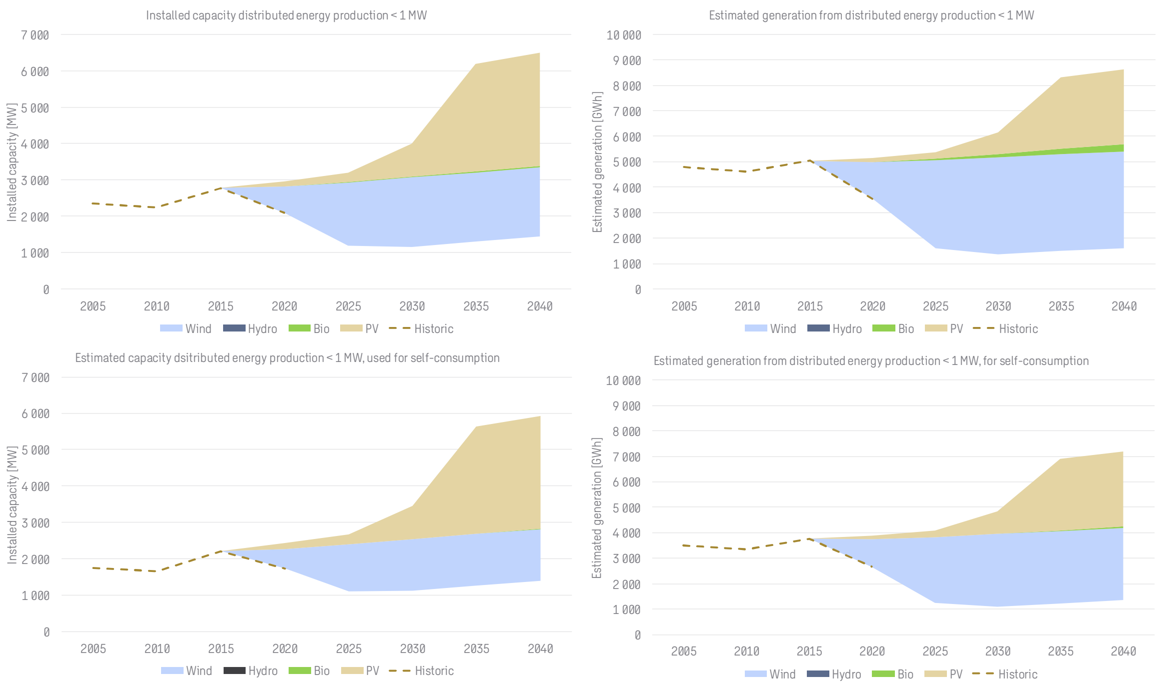
In the lower end of the outcome space, electricity generation from distributed electricity production (< 1MW) is decreasing to about 1 700-2 600 GWh, mainly driven by an expected phase-out of existing smaller wind turbines, see Figure 27. The timing of the phase-out and thus the decrease depends on lifetime assumptions for these turbines. In the upper end of the outcome space, the estimated electricity generation from distributed electricity production (< 1MW) is expected to be about 8 500 GWh.

In the lower end of the outcome space in Denmark, the installation of PV follows the historical trend from the past four years, resulting in an installed capacity of 1490 MW in 2040. For the upper end of the outcome space the technical potential of 4500 MW is set as the limiting factor growth for PV installations. With these assumptions, the electricity production from PV (<1MW) in Denmark could potentially reach 4275 GWh.

The small-scale hydropower in Demark is limited due to technical and geographical/resource factors. Both the lower and upper end of the outcome space show a development where the number of installed turbines is constant.

The number of installed small-scale wind power plants in Denmark are decreasing. The growth rates in small-scale wind power has only been 0.5-5 MW/year during the past five years. This means that the installation rates have been lower than the total decommission rates and that there is a reduction of small-scale turbine capacity below 1 MW. The lower end of the outcome space shows an outlook where the number of installed turbines is negligible, and the life time expectancy of the existing turbines are between 22-35 years, which would be in line with Danish Energy Agreements aims of cutting the number of onshore wind turbines with 50%. The upper end of the outcome space points at the levels of installed small-scale wind power in Denmark to decrease, but at a slower rate, as a consequence of longer lifetime, trying to keep the turbines running as long as possible. The upper outcome level of the outlook shows a development where the installation level is close to the installed capacity in 2017.

Figure 27: Outlook outcome space Denmark



Source: Sweco

The lower end of the outcome space expects the number of small-scale bio energy plants to be constant or increase with a limited rate since the support schemes for biogas are with current policy more in favour of bio gas upgrading to the distribution grid instead of electricity production.

The use of biogas in Denmark is equally split between electricity production and upgrading the gas to be fed into the natural gas grid. The technical potential for small-scale biogas electricity production could hence be doubled if a larger share was to be used for electricity production. The upper end of the outcome space shows a development where the installed capacity in small-scale electricity production is increased to 90 MW.

6.7 Iceland

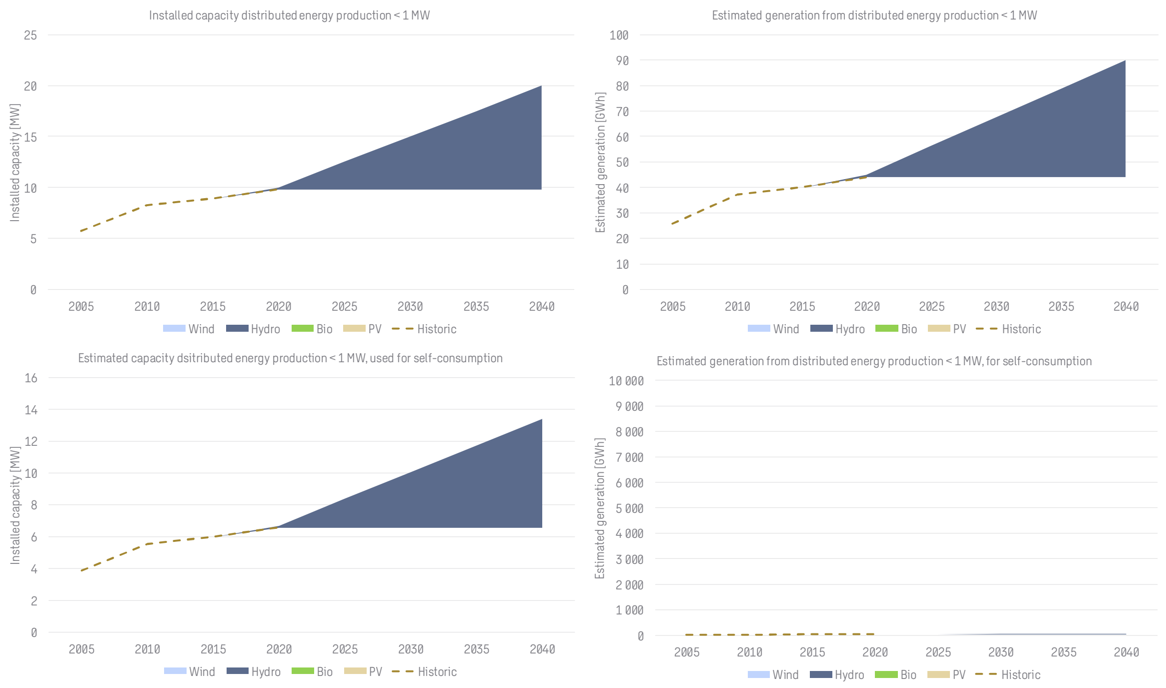
In the lower end of the outcome space, electricity generation from distributed electricity production (< 1MW) is expected to increase to about 45-65 GWh, see Figure 28. In the upper end of the outcome space, the estimated electricity generation from distributed electricity production (< 1MW) is expected to increase to about 60-80 GWh.

In Iceland, the technical and economic potential for PV installations appears very limited. When the European commission calculated the payback time for PV installation in Iceland the average time in year 2030 was 64.9 years (European Commission, 2017). The development of PV in Iceland is hence set to zero. Once again there is limited economic or technical potential for PV installations in Iceland (European Commission, 2017). One possibility could be small-scale off-grid solutions, but these are not included in this study. The development of PV in Iceland is hence set to zero.

The installed capacity in small-scale hydropower is expected to be constant or possibly a few MW larger in the Lower end of the outcome space. In the *upper end of the outcome space*, the installed capacity in small-scale hydropower is set to double and reach 20 MW in 2040.

There are only a few small-scale wind power projects in Iceland and the political will and public interested is a limiting factor in the lower end of the outcome space. In this scenario, there are no expectations that the distributed wind power capacity would grow. The distributed wind power capacity is not expected to grow in the upper end of the outcome space due to envisaged low public interest.

Figure 28: Scenario outcome space Iceland



Source: Sweco

The option of small-scale geothermal electricity production in Iceland is not included in the above scenarios, since it is currently does not appear to be economically viable.

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8 Appendix

8.1 Installed capacity in production units below < 1MW in the Nordics 2005-2017, [MW]

Technology	Country	Type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Grid-connected distributed PV capacity < 1MW	Denmark	MW	2,4	2,6	2,7	2,8	4	6,4	15,9	406,7	556,8	595,8	645,8	665,8	690
Grid-connected distributed PV capacity < 1MW	Finland	MW	0	0	0	0	0	0	0	0	0	6	10	27,1	69,8
Grid-connected distributed PV capacity < 1MW	Iceland	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
Grid-connected distributed PV capacity < 1MW	Norway	MW	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,3	1,7	3,2	13,6	31
Grid-connected distributed PV capacity < 1MW	Sweden	MW	0,25	0,56	1,68	3,08	3,54	5,15	8,42	14,82	32,15	64,07	109,11	181,16	293,92
Distributed hydro power capacity < 1 MW	Denmark	MW	3,702	3,702	3,702	3,702	3,702	3,702	3,702	3,727	3,727	3,727	3,749	3,749	3,749
Distributed hydro power capacity < 1 MW	Finland	MW	34,0	34,0	34,0	34,0	34,0	34,0	34,1	34,1	34,1	34,1	34,1	34,2	36,2
Distributed hydro power capacity < 1 MW	Iceland	MW	5,8	6,5	8,2	8,2	8,2	8,2	8,2	8,8	8,8	8,9	8,9	9,8	9,8
Distributed hydro power capacity < 1 MW	Norway	MW	108,6	122,8	133,8	148,8	164,5	173,9	179,4	185,3	188,5	192,1	197,6	200,7	201,6
Distributed hydro power capacity < 1 MW	Sweden	MW	235,0	235,0	235,0	235,0	235,0	235,0	235,0	235,0	235,0	235,0	235,0	235,0	235,0
Distributed wind power capacity < 1 MW	Denmark	MW	2323,5	2320,1	2312,8	2277,1	2250,1	2208,0	2173,6	2162,4	2148,4	2113,7	2082,3	2034,7	1967,1
Distributed wind power capacity < 1 MW	Finland	MW	23	22	21	20	20	19	20	21	21	22	19	16	18
Distributed wind power capacity < 1 MW	Iceland	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wind power capacity < 1 MW	Norway	MW	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,6	0,6	0,6	0,6	1,3
Distributed wind power capacity < 1 MW	Sweden	MW	267,7	284,0	327,9	362,0	384,5	399,7	410,3	419,4	424,2	423,6	422,8	418,7	415,1
Distributed bio power capacity < 1 MW	Denmark	MW	21,2	22,4	22,4	24,6	24,8	26,5	28,3	31,5	34,3	36,4	41,5	42,5	44,9
Distributed bio power capacity < 1 MW	Finland	MW	1,0											15,3	16,3
Distributed bio power capacity < 1 MW	Iceland	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed bio power capacity < 1 MW	Norway	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed bio power capacity < 1 MW	Sweden	MW	5,1	5,2	6,1	6,8	9,0	9,4	10,7	12,0	14,4	14,4	14,9	15,0	16,0
Distributed wave power capacity < 1 MW	Denmark	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power capacity < 1 MW	Finland	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power capacity < 1 MW	Iceland	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power capacity < 1 MW	Norway	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power capacity < 1 MW	Sweden	MW	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,9	0,9

8.2 Produced energy in production units below < 1MW in the Nordics 2005-2017, [GWh]

Technology	Country	Type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Grid-connected distributed PV < 1MW	Denmark	GWh	2,3	2,5	2,6	2,7	3,8	6,1	15,1	386,4	529,0	566,0	613,5	632,5	655,5
Grid-connected distributed PV < 1MW	Finland	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,4	9,0	24,4	62,8
Grid-connected distributed PV < 1MW	Iceland	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Grid-connected distributed PV < 1MW	Norway	GWh	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,2	1,4	2,6	10,9	24,8
Grid-connected distributed PV < 1MW	Sweden	GWh	0,2	0,5	1,6	2,9	3,4	4,9	8,0	14,1	30,5	60,9	103,7	172,1	279,2
Distributed hydro power < 1 MW	Denmark	GWh	16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,8	16,8	16,8	16,9	16,9	16,9
Distributed hydro power < 1 MW	Finland	GWh	153,0	153,0	153,0	153,0	153,0	153,0	153,5	153,5	153,5	153,5	153,5	153,9	162,9
Distributed hydro power < 1 MW	Iceland	GWh	25,9	29,0	37,1	37,1	37,1	37,1	37,1	39,8	39,8	40,0	40,0	44,0	44,0
Distributed hydro power < 1 MW	Norway	GWh	488,7	552,8	602,2	669,5	740,4	782,7	807,4	833,8	848,2	864,5	889,3	903,2	907,1
Distributed hydro power < 1 MW	Sweden	GWh	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5	1057,5
Distributed wind power < 1 MW	Denmark	GWh	4647,0	4640,2	4625,6	4554,2	4500,2	4415,9	4347,1	4324,8	4296,8	4227,4	4164,6	4069,4	3934,2
Distributed wind power < 1 MW	Finland	GWh	46,0	44,0	42,0	40,0	40,0	38,0	40,0	42,0	42,0	44,0	38,0	32,0	36,0
Distributed wind power < 1 MW	Iceland	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Distributed wind power < 1 MW	Norway	GWh	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,8	1,8	1,8	1,8	3,5
Distributed wind power < 1 MW	Sweden	GWh	535,4	567,9	655,7	724,0	769,0	799,4	820,5	838,9	848,3	847,1	845,7	837,5	830,1
Distributed bio power < 1 MW	Denmark	GWh	127,1	134,7	134,7	147,4	148,8	159,0	169,6	189,3	205,6	218,6	249,0	254,8	269,1
Distributed bio power < 1 MW	Finland	GWh	6,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	91,8	97,8
Distributed bio power < 1 MW	Iceland	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed bio power < 1 MW	Norway	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed bio power < 1 MW	Sweden	GWh	30,5	31,4	36,7	40,6	54,0	56,3	64,4	72,0	86,4	86,4	89,2	89,8	95,7
Distributed wave power < 1 MW	Denmark	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power < 1 MW	Finland	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power < 1 MW	Iceland	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power < 1 MW	Norway	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Distributed wave power < 1 MW	Sweden	GWh	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

8.3 Installed capacity in production units estimated for self-consumption in the Nordics 2005-2017, [MW]

Technology	Country	Type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PV estimated for self-consumption, capacity	Denmark	MW	2,4	2,6	2,7	2,8	4	6,4	15,9	406,7	556,8	595,8	645,8	665,8	690
PV estimated for self-consumption, capacity	Finland	MW	0	0	0	0	0	0	0	0	0	6	10	27,1	69,8
PV estimated for self-consumption, capacity	Iceland	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
PV estimated for self-consumption, capacity	Norway	MW	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,3	1,7	3,2	13,6	31
PV estimated for self-consumption, capacity	Sweden	MW	0,25	0,56	1,68	3,08	3,54	5,15	8,42	14,82	32,15	64,07	109,11	181,16	293,92
Hydropower estimated for self-consumption, capacity	Denmark	MW	0,1851	0,1851	0,1851	0,1851	0,1851	0,1851	0,1851	0,18635	0,18635	0,18635	0,18745	0,18745	0,18745
Hydropower estimated for self-consumption, capacity	Finland	MW	6,8	6,8	6,8	6,8	6,8	6,8	6,82	6,82	6,82	6,82	6,82	6,84	7,24
Hydropower estimated for self-consumption, capacity	Iceland	MW	3,85585	4,32485	5,52281	5,52281	5,52281	5,52281	5,52281	5,92548	5,92548	5,95228	5,95228	6,54858	6,54858
Hydropower estimated for self-consumption, capacity	Norway	MW	13,44127	15,20291	16,56239	18,41257	20,36282	21,52528	22,20499	22,93098	23,32875	23,77528	24,45684	24,83989	24,94843
Hydropower estimated for self-consumption, capacity	Sweden	MW	61,1	61,1	61,1	61,1	61,1	61,1	61,1	61,1	61,1	61,1	61,1	61,1	61,1
Wind power estimated for self-consumption, capacity	Denmark	MW	1742,615	1740,072	1734,61	1707,84	1687,565	1655,965	1630,167	1621,785	1611,309	1585,269	1561,729	1526,008	1475,309
Wind power estimated for self-consumption, capacity	Finland	MW	1,38	1,32	1,26	1,2	1,2	1,14	1,2	1,26	1,26	1,32	1,14	0,96	1,08
Wind power estimated for self-consumption, capacity	Iceland	MW	0	0	0	0	0	0	0,03	0,03	0,03	0,03	0,03	0,03	0,03
Wind power estimated for self-consumption, capacity	Norway	MW	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,625	0,625	0,625	0,625	1,25
Wind power estimated for self-consumption, capacity	Sweden	MW	48,18276	51,11226	59,01426	65,16432	69,20982	71,94402	73,845	75,49938	76,34826	76,24044	76,10904	75,37248	74,71098
Bio power estimated for self-consumption, capacity	Denmark	MW	2,32947	2,46862	2,46862	2,70182	2,72712	2,91412	3,10992	3,46962	3,76948	4,00774	4,56511	4,67104	4,93405
Bio power estimated for self-consumption, capacity	Finland	MW	0,17	0	0	0	0	0	0	0	0	0	0	2,601	2,771
Bio power estimated for self-consumption, capacity	Iceland	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
Bio power estimated for self-consumption, capacity	Norway	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
Bio power estimated for self-consumption, capacity	Sweden	MW	0,9671	0,99503	1,16356	1,28478	1,71038	1,78353	2,04079	2,27905	2,73448	2,73448	2,82492	2,84297	3,03183
Wave power estimated for self-consumption, capacity	Denmark	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption, capacity	Finland	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption, capacity	Iceland	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption, capacity	Norway	MW	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption, capacity	Sweden	MW	0	0	0	0	0	0	0	0	0	0	0	0	0

8.4 Produced energy in in production units estimated for self-consumption in the Nordics 2005-2017, [GWh]

Technology	Country	Type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PV estimated for self-consumption	Denmark	GWh	2,28	2,47	2,565	2,66	3,8	6,08	15,105	386,365	528,96	566,01	613,51	632,51	655,5
PV estimated for self-consumption	Finland	GWh	0	0	0	0	0	0	0	0	0	5,4	9	24,39	62,82
PV estimated for self-consumption	Iceland	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0
PV estimated for self-consumption	Norway	GWh	0,08	0,08	0,08	0,08	0,08	0,16	0,16	0,16	0,24	1,36	2,56	10,88	24,8
PV estimated for self-consumption	Sweden	GWh	0,2375	0,532	1,596	2,926	3,363	4,8925	7,999	14,079	30,5425	60,8665	103,6545	172,102	279,224
Hydropower estimated for self-consumption	Denmark	GWh	0,83295	0,83295	0,83295	0,83295	0,83295	0,83295	0,83295	0,838575	0,838575	0,838575	0,843525	0,843525	0,843525
Hydropower estimated for self-consumption	Finland	GWh	30,6	30,6	30,6	30,6	30,6	30,6	30,69	30,69	30,69	30,69	30,69	30,78	32,58
Hydropower estimated for self-consumption	Iceland	GWh	17,35133	19,46183	24,85265	24,85265	24,85265	24,85265	24,85265	26,66466	26,66466	26,78526	26,78526	29,46861	29,46861
Hydropower estimated for self-consumption	Norway	GWh	60,48574	68,41309	74,53075	82,85658	91,6327	96,86378	99,92244	103,1894	104,9794	106,9888	110,0558	111,7795	112,2679
Hydropower estimated for self-consumption	Sweden	GWh	274,95	274,95	274,95	274,95	274,95	274,95	274,95	274,95	274,95	274,95	274,95	274,95	274,95
Wind power estimated for self-consumption	Denmark	GWh	3485,229	3480,144	3469,22	3415,679	3375,13	3311,93	3260,333	3243,569	3222,617	3170,538	3123,458	3052,016	2950,619
Wind power estimated for self-consumption	Finland	GWh	2,76	2,64	2,52	2,4	2,4	2,28	2,4	2,52	2,52	2,64	2,28	1,92	2,16
Wind power estimated for self-consumption	Iceland	GWh	0	0	0	0	0	0	0,06	0,06	0,06	0,06	0,06	0,06	0,06
Wind power estimated for self-consumption	Norway	GWh	1,12	1,12	1,12	1,12	1,12	1,12	1,12	1,12	1,75	1,75	1,75	1,75	3,5
Wind power estimated for self-consumption	Sweden	GWh	96,36552	102,2245	118,0285	130,3286	138,4196	143,888	147,69	150,9988	152,6965	152,4809	152,2181	150,745	149,422
Bio power estimated for self-consumption	Denmark	GWh	13,97682	14,81172	14,81172	16,21092	16,36272	17,48472	18,65952	20,81772	22,61688	24,04644	27,39066	28,02624	29,6043
Bio power estimated for self-consumption	Finland	GWh	1,02	0	0	0	0	0	0	0	0	0	0	15,606	16,626
Bio power estimated for self-consumption	Iceland	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Bio power estimated for self-consumption	Norway	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Bio power estimated for self-consumption	Sweden	GWh	5,8026	5,97018	6,98136	7,70868	10,26228	10,70118	12,24474	13,6743	16,40688	16,40688	16,94952	17,05782	18,19098
Wave power estimated for self-consumption	Denmark	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption	Finland	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption	Iceland	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption	Norway	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave power estimated for self-consumption	Sweden	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0