Distributed energy production and self-consumption in the Nordics

A REPORT TO NORDIC ENERGY RESEARCH (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

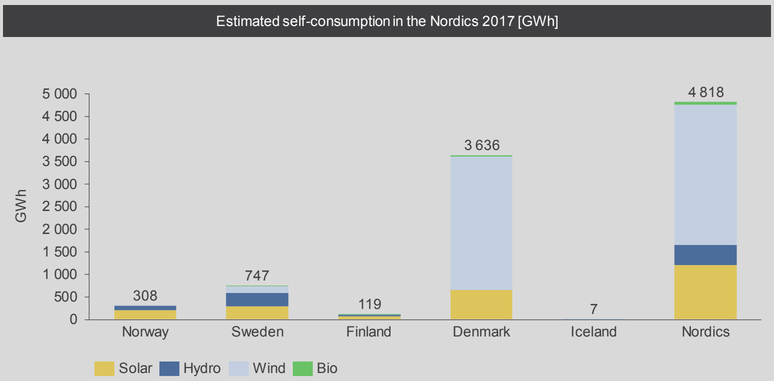
Executive Summary

In this study, we interpret *distributed energy production and self-consumption* in line with art. 21 and 22 in REDII as being defined as "distributed electricity production with regards to installed capacity (<1 MW), even if no self-consumption is linked to them" and *on-grid electricity production and consumption of renewable electricity.* We follow the REDII definition for *renewable self-consumers* are 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." Furthermore, we interpret *sound development of distributed energy production and self-consumption* that it should not face discriminatory or disproportionate procedures and that such producers should have the same rights and obligations as other producers.

Our statistical overview shows that it is mainly the photovoltaic installations that have been increasing during 2005-2017, while distributed hydropower has remained constant and distributed wind power has been decreasing. In general, the statistical data concerning the small-scale production units is rather weak in many of the Nordic countries. There is often a lack of data for both small-scale on and off-grid units. According to our analysis, the total amount of installed capacity for distributed energy production in the Nordics was about 3030 MW in 2005 and about 4050 MW in 2017. Micro-scale ageing wind power in Denmark and Sweden stands for about three quarter of the installed capacity which is decreasing in line with a natural technical lifetime phase-out. The biggest increase in installed capacity is in solar PV, which is increasing in all the Nordic countries except Iceland.

In energy terms, we estimate that about 5 TWh electricity that potentially could be used for self-consumption were produced in the Nordic countries in 2017, the majority of it in Denmark, followed by Sweden and Norway.

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



Source: Sweco estimates, Oslo Economics estimates

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

If we look at 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 regulations and 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). That said, self-production of electricity is quite strongly supported in all countries relative to consumption based on centralized production. As mentioned above Iceland do not seem to have in place specific regulation and incentives for DES.

Overall an important incentive to invest in self-production in the Nordics is the opportunity to save energy costs, grid tariffs, taxes, VAT and in some cases earning electricity certificates in hours of self-consumption. Furthermore, 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 energy 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 energy production 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.

Challenges for the future power system include intermittency and difficulties to forecast, securing available power at any time, voltage and frequency stability. The level of these challenges differs from a largely hydro to a largely fossil-based system, especially over time when many fossil-fuelled central thermal power plants phase out and more intermittent decentralised or distributed renewables phase in. Assuming a high share of reservoirs, a largely hydro-based power system like the Nordic system will have smaller challenges in the transition towards a power system with a high share of renewables, whether these are distributed or not.However, even a largely hydro-based system will require more flexibility than currently as a result of its transformation. This flexibility can be provided both from production, grid, energy storage and demand response.

Flexibility in all forms will become extremely important and should be sought at all voltage levels, even though its required amount and the suitability of its location would be dependent on the mix of DER sources. Energy storage in general, as one of the four major flexibility means grid, flexible production, energy storage and demand response will play an essential role in the future power system, being used to manage temporary production peaks and dips in the power system, for frequency control, but also for seasonal storage. Whereas storage should be provided at different voltage levels and locations, the most economical solutions might often be to solve the challenges in the power systems where they occur or at least close by, rather than transferring them further into the power system and solving them elsewhere. Therefore, local energy storage is an important solution.

Of the local storage options, batteries are very interesting solutions, both for power and energy supply. Batteries can contribute to load shifting, changing consumption profiles, limiting price variations by either storing locally produced electricity or electricity from the grid. They can locally contribute to reducing the need for grid investments and its potential to contribute with several system services, such as voltage and frequency control.

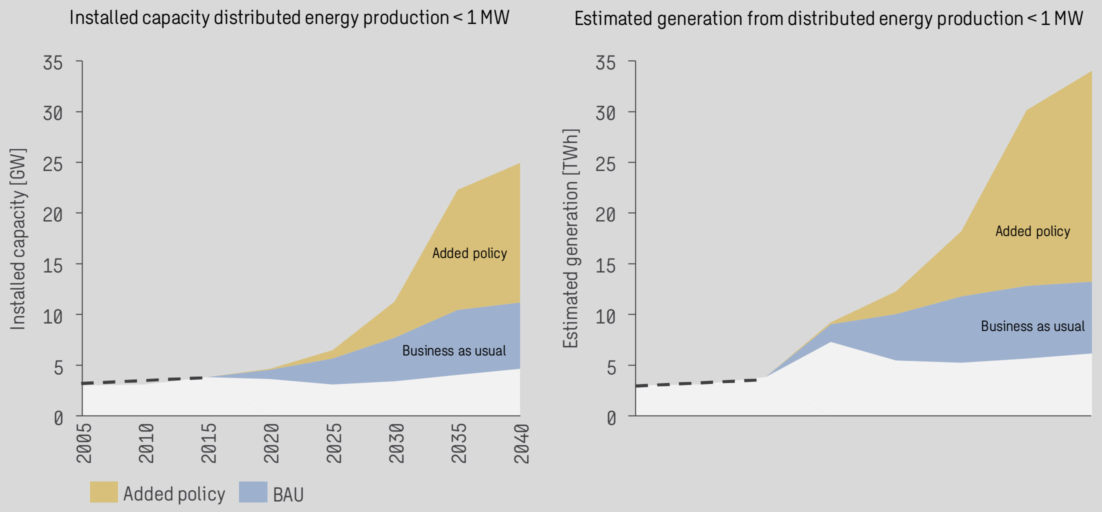
There are several general barriers for development of distributed electricity production/self-consumption which are the same across the Nordics (as well as other countries), including limited knowledge, transaction costs and installation costs. Generally valid drivers are environmental concerns, marketing value and potential cost saving aspects. Regulatory barriers and drivers differ between countries. However, this study's mapping shows some general aspects regarding regulatory barriers and drivers. All Nordic countries except Iceland aim to incentivize distributed energy resources and have therefore introduced policy instruments supporting this (i.e. policy drivers).

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 makes it harder for potential producers (households, companies) to overlook the system and potential supports 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 the barriers related to transaction costs and installation costs. The third policy barrier identified – uncertainty regarding future policy outlook – increase risk and therefore actors (households, companies etc) willingness to invest.

We describe a potential future development of the distributed renewable energy in the Nordics by two different scenarios, a 'Business as usual-scenario' and an 'Added Policy-scenario'. In the BAU scenario current policies are continuously adjusted to provide about the same, but not more profitability for distributed energy production and self-consumption in the longer term than now, until grid parity is reached. The Added policy scenario is based on political willingness to set a volume target and thus more oriented at the economic and technical potential for residential consumers to adapt the renewable technologies. Basically, in this scenario policies are designed to either reduce the cost side or increase the income so that the volume target is reached.

The scenarios show a potential development of the distributed electricity production in the Nordics growing to 6-13 TWh in the BAU scenario and 13-34 TWh in the Added policy scenario, see Figure 23. This can be compared to the estimated 2017 level of about 5 TWh. The full potential for PV in the Added policy scenario is 19 TWh. In the BAU scenario the energy produced from PV is estimated to 4-10 TWh in the Nordics.

Figure 2: Installed capacity and estimated generation in the two policy scenarios "Business as usual" and "Added Policy"



Source: Sweco

Sammanfattning

(Sammanfattning på Svenska)

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 MW[1] 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 energy 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) energy production to date often has led to greater fluctuations in energy 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, e.g. BAU or an "added policy support scenario", where key factors that constitute the core of those scenarios should be highlighted

[1] IRENA 2018 Statistics; value includes Denmark, Norway, Sweden and Finland

[2] Distributed production may potentially increase or decrease the overall need for investments in the grid. However, since distributed energy 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 energy production

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

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 energy production and self-consumption in line with art. 21 and 22 in REDII as being:

- Distributed energy 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 propose to 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), we agreed that sound development should be 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.

2 Literature overview

2.1 Literature overview: Self-consumer and distributed energy 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;
- Ecofys (2016): Network Integration of Photovoltaic Systems

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. 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 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

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 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. 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; Feed-in premiums, 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 the need for applying for building permits when installing a PV system on a building, was removed 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 energy 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 (2018) 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 working 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 actors who install PV 0-70 kW and actors with large scale installations above 300 kW.

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

The identified challenges are related to the grid 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
- IEA-PVPS (2017a): National Survey Report of PV Power Applications in Sweden 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,
- 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 the renewable energy production, investment subsidy of 25% and tax credits. The report also mentions when the report was issued, e.g. hourly-based-net metering for individuals, BIPV support measures and support schemes for energy storage.

[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.

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 on behalf of 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.

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 self-production.

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

[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.

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 find specific and realistic solutions for developing the electricity market and maintain security of supply. In the report, the working group gives recommendations on four main 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”. This will be achieved through giving the consumer better opportunities to participate in the electricity market, increasing the security of supply, and cutting costs.

The report considers different forms of distributed production of electricity and their potential, current state and barriers for implementing them. The report describes energy communities, both within housing companies and across property boundaries, as well as aggregators and electricity storage players.

Overview of current framework conditions, regulations and tax scheme

On a national level the report describes the following regulations/support-schemes; Distribution grid tariffs, Proportional electricity tax, Taxation of electricity storage, Regulation of network 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 report considers that bi-directional transmission of electricity might complicate management of distribution grids. If this proves to be the case, measures would have to be initiated in order to eliminate the negative effects. The report expects that increased self-consumption could have a positive effect on the grid, caused by a decrease in demand of electricity at peak hours.

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. 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. With regards to building restrictions, 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 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.

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 network is used to a lesser extent to supply the underlying distribution network when the solar PV cells produce the most. In some cases, the transmission network 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 network 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 on 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

Our statistical overview shows that it is mainly the photovoltaic installations that have been increasing during 2005-2017, while distributed hydropower has remained constant and distributed wind power has been decreasing. In general, the statistical data concerning the small-scale production units is rather weak in many of the Nordic countries. There is often a lack of data for both small-scale on and off-grid units. According to our analysis, the total amount of installed capacity for distributed energy production in the Nordics was about 3030 MW in 2005 and about 4050 MW in 2017. Micro-scale ageing wind power in Denmark and Sweden stands for about three quarter of the installed capacity which is decreasing in line with a natural technical lifetime phase-out.

The biggest increase in installed capacity is in solar PV, which is increasing in all the Nordic countries except Iceland.

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):

- Prosumer production (by households and businesses producing mainly for their own consumption)
- Other production

By "prosumer production", we mean all electricity produced by the prosumer, both for its own use and for sale (via the electricity grid).

Note, that not all the energy produced in the small-scale production units below 1 MW is generated with the purpose of nor used for self-consumption. This report has analysed the market in all the Nordic countries and estimates 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, see 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.

Figure 4. Self-consumption will always be lower.

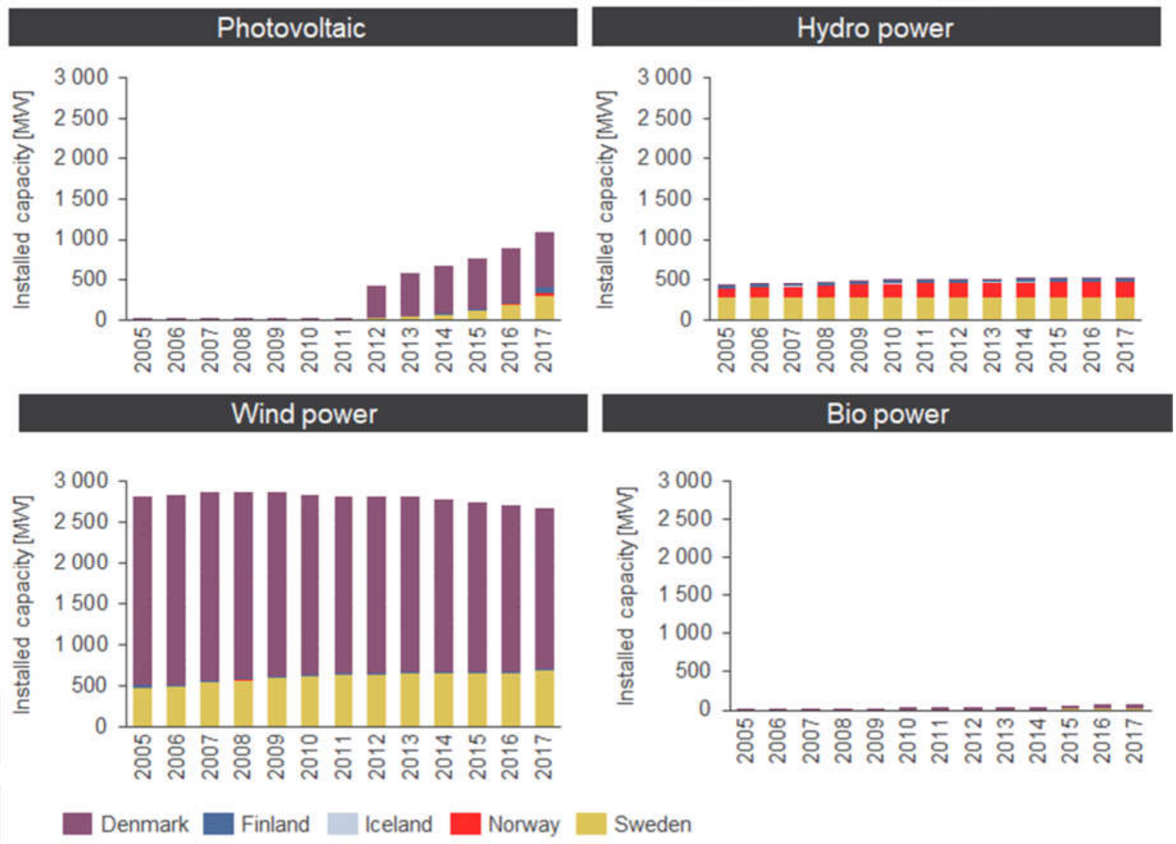
3.2 Statistical overview Nordics

The installed capacity of distributed renewable energy production in the Nordics was about 4000 MW in 2017, see Figure 3. This is an increase compared to the installed capacity in 2005. 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 registers of the small-scale production units and hence the development is hard to estimate.

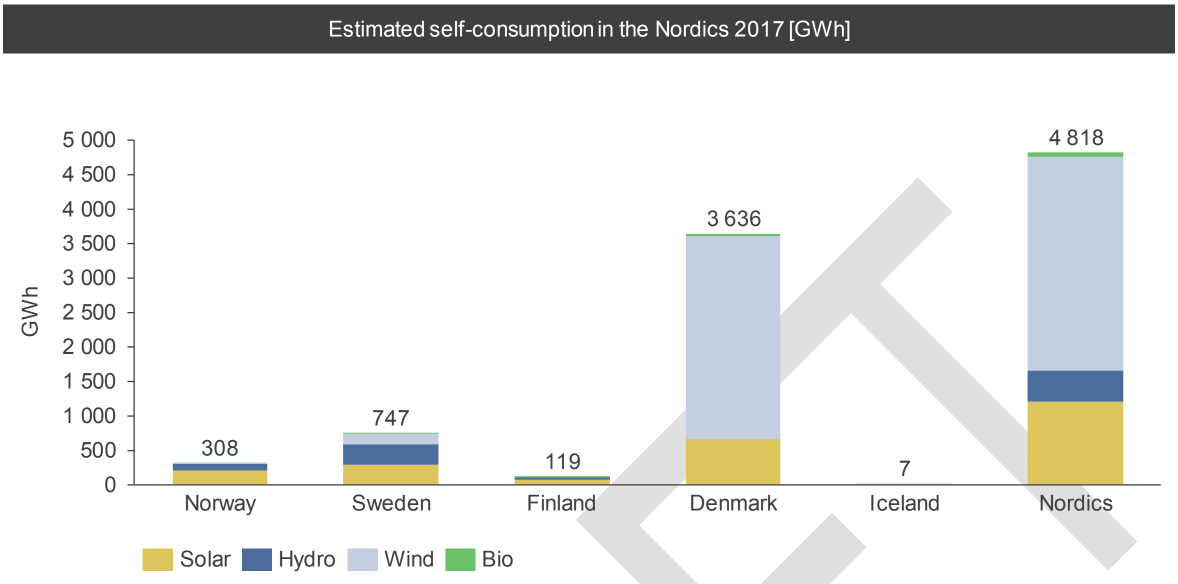
Figure 3: Summary distributed energy units in the Nordics 2005-2017 with installations below 1 MW



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 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.

Figure 4: Estimated distributed electricity production for potential self-consumption in the Nordics 2017



Source: Sweco estimates, Oslo Economics

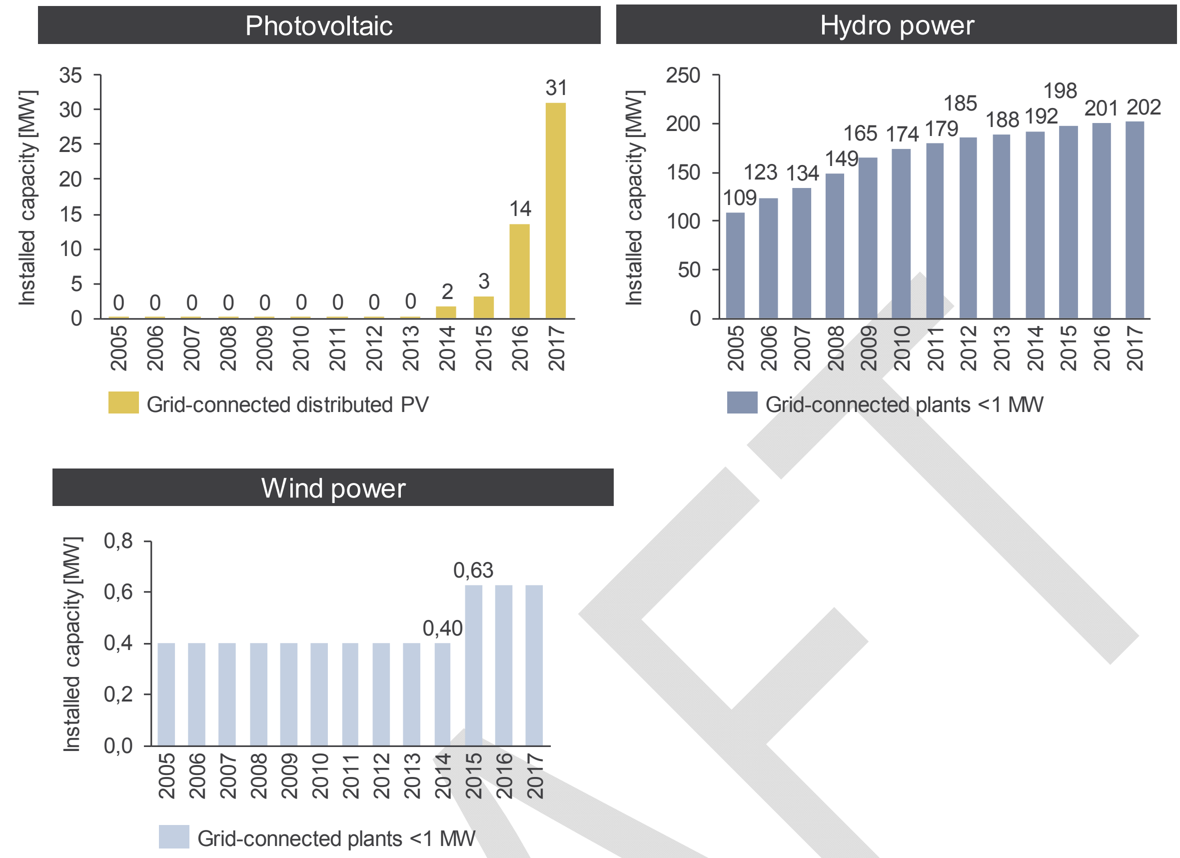
3.3 Statistical overview – Norway

The distributed energy production in Norway is mainly solar-, but also hydropower. The amount of installed PV in Norway increased during 2016 and 2017, reaching 31 MW, see Figure 5. 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 in Norway in 2017 consists of:

- 31 MW of solar PV power (~200 GWh)
- 24 MW of hydropower (~108 GWh)
- 0.2 MW of wind power (~0.6 GWh)
- Total: 55.2 MW of prosumer power (~308 GWh)

Figure 5: Summary installed capacity for distributed production in Norway 2005-2017



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 energy 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 950 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).

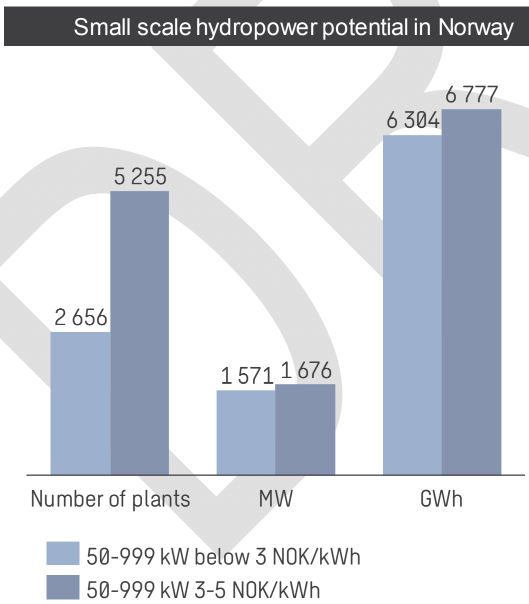
Small-scale hydroelectric power plants in Norway are classified into three categories: “small power plants” have an installed effect between 1 and 10 MW; “mini power plants” have an installed effect between 100 kW and 1 MW; and “micro power plants” are power plants with an installed effect of less than 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 energy 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 prosumers 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 ore 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 6. 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 6: 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 installed distributed energy production in Sweden was in 2017 40% small-scale wind power, 30% PV and 30% small-scale hydropower. The total amount of installed distributed energy production was about 1000 MW.

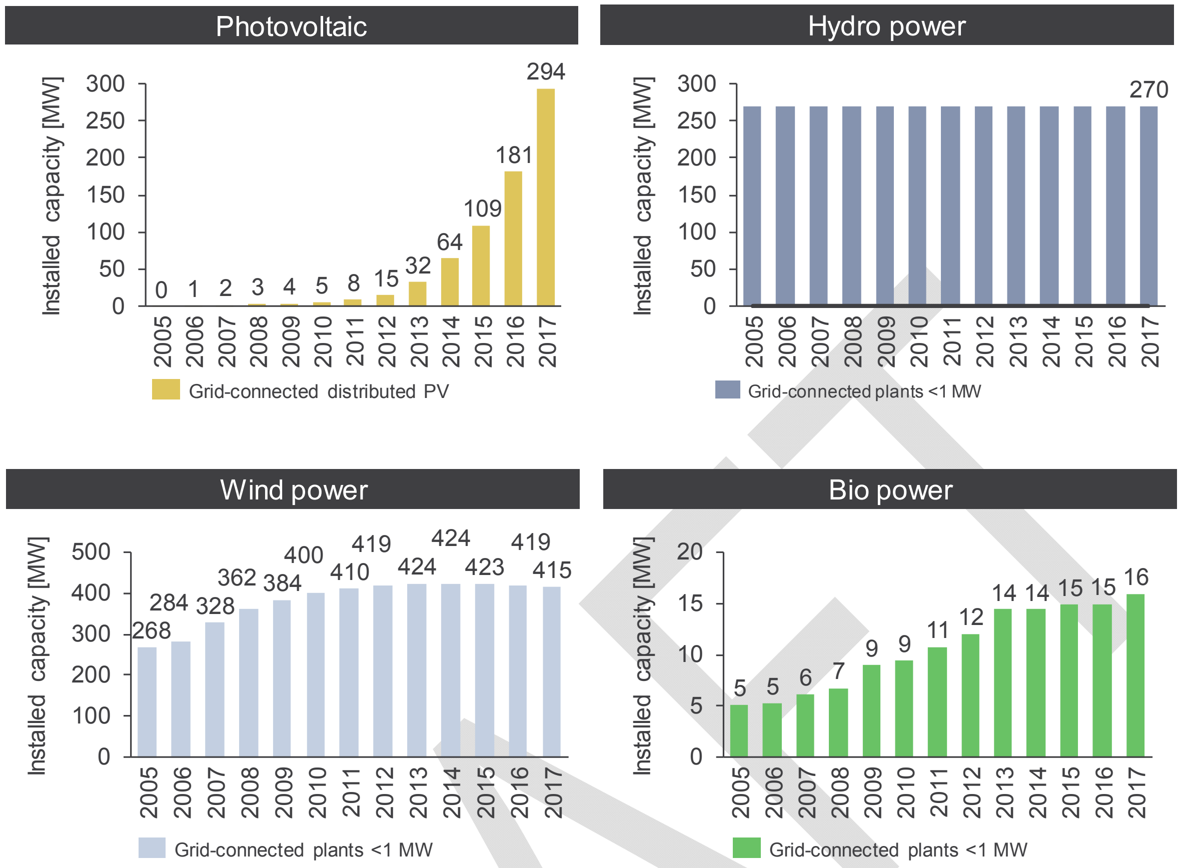
The installation of PV has increased during the past 5 years and is now 294 MW. There is no statistical data on the small-scale hydropower in Sweden. Interviews with the small-scale hydropower association gave us information that the number of small-scale hydropower plants has decreased since the 1950's 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 privet owners.

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

- 294 MW of solar PV power (279 GWh)
- 70 MW of hydropower (300 GWh)
- 74 MW of wind power (150 GWh)
- 3 MW of bio power (18 GWh)
- Total: 441 MW of prosumer power (747 GWh)

Figure 7: Summary installed capacity for distributed production in Sweden 2005-2017



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

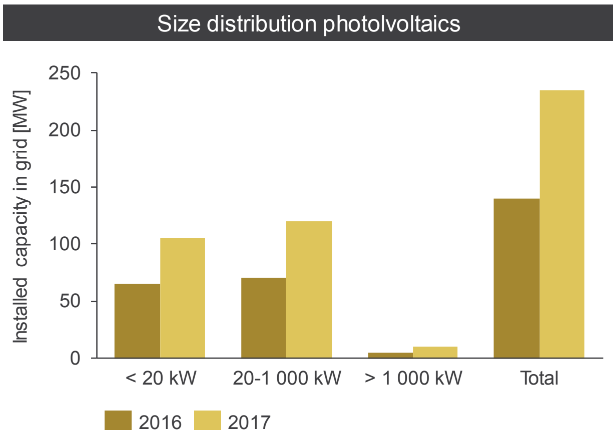
3.4.1 Solar PV

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 capacity in installed off-grid PV was 33 MW year 2017, which is about 10% of the total national PV installations, see Figure 8 and Table 1.

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 and thus the electricity production 279 GWh in the self-consumption installations.

Figure 8: Size distribution of photovoltaics in Sweden



Source: Swedish Energy Agency (2018b)

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)

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 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 installed hydropower plants shows that 235 MW of the installed hydropower capacity is in units below 1 MW. This corresponds to 1060 GWh.

There is a register of a selection of small-scale hydropower plants in Sweden, created by a private person (vattenkraft, 2019). This register is not a complete register of the Swedish small-scale hydropower but gives an overview of existing plants and area of usage. In the register of small-scale installation are 20% estimated to be used for self-consumption i.e. farms or other businesses. The estimation om 20% self-consumption in the plants below 1 MW means that the total installed capacity for this is 70 MW and the energy production for self-consumption 300 GWh.

3.4.3 Wind power

In 2016 was 12.3 % of the electricity in Sweden produced by wind power. The total installed 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 9. For wind power, 74 MW of the installed wind power capacity below 1 MW, in total 670 MW, was registered on private owners. The approximated annual electricity consumption in these are approximated in the register to 1550 GWh. The increase in small-scale wind power turbines is not as extensive.

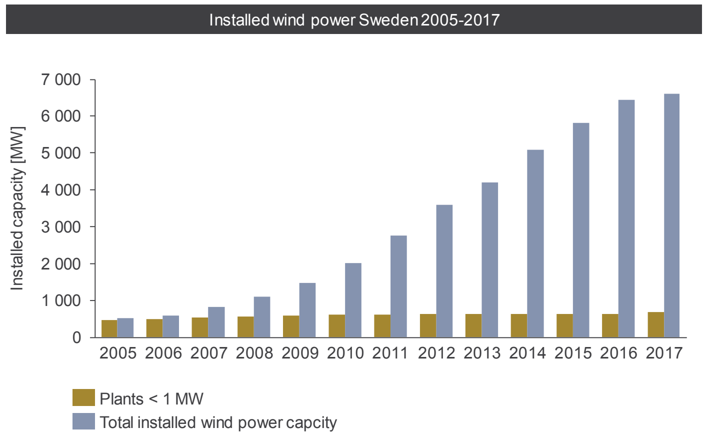
Year 2003, i.e. at the time the electricity certificate scheme was introduced, there were approximately 400 MW installed in wind power turbines with capacity below 1 MW. Only a few installations were turbines above 1 MW[7]. Since the electricity certificate scheme was introduced the installed wind power capacity in small plants (below 1 MW) has increased with approximately 240 MW. In 2017 the installed capacity in small wind power plants (below 1 MW) was 690 MW. In total 366 wind power turbines with installed capacity has been given electricity certificates since 2003. 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 74 MW of the installed wind power capacity below 1 MW, in total 670 MW, was registered on private owners. The approximated annual electricity consumption in these are approximated in the register to 1550 GWh.

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

Figure 9: 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 energy 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

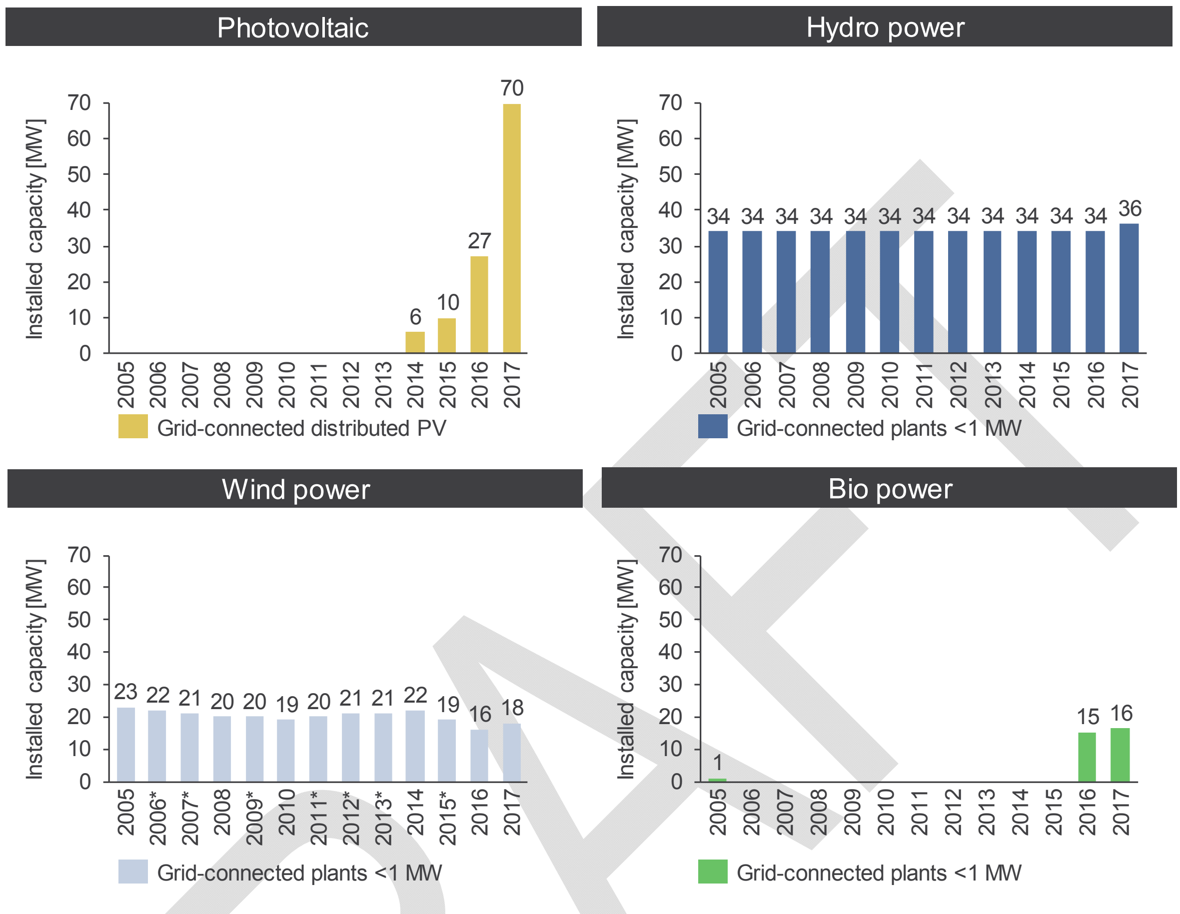
In 2017 about 120 MW small-scale energy production units below 1 MW were connected to the grid. The distributed energy source with largest share of the installed capacity was PV. Since 2015 has PV increased from 10 MW to 70 MW in Finland. The small-scale hydropower is about 36 MW and the small-scale wind 18 MW. In Finland most of the small-scale electricity is used for off-grid solution for i.e. summer cottages.

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

- 70 MW of solar PV power (66.5 GWh)
- 7.2 MW of hydropower (32.4 GWh)
- 1 MW of wind power (2 GWh)

- 3 MW of bio power (18 GWh)
- Total: 81.2 MW of prosumer power (118.9 GWh)

Figure 10: Summary installed capacity for distributed production in Finland 2005-2017



*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. Most of the systems are built for self-consumption of PV electricity since there is no economic potential for utility scale PV systems yet.

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 have 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 hydropower 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.

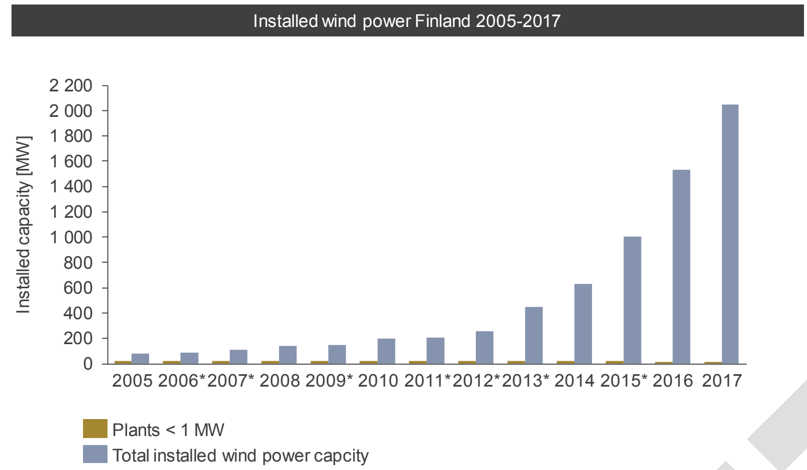
Since 2005 the installed wind power capacity in Finland has increased to about 2000 MW. The amount of installed small-scale turbines has though been decreasing since 2005, see Figure 11. In the register of wind power projects in Finland about 5% of the projects in 2005 was owned by privet owners or associations. 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 energy production of 2 GWh annually.

In 2005, the Finnish Wind 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 12. 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 regulation. 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.

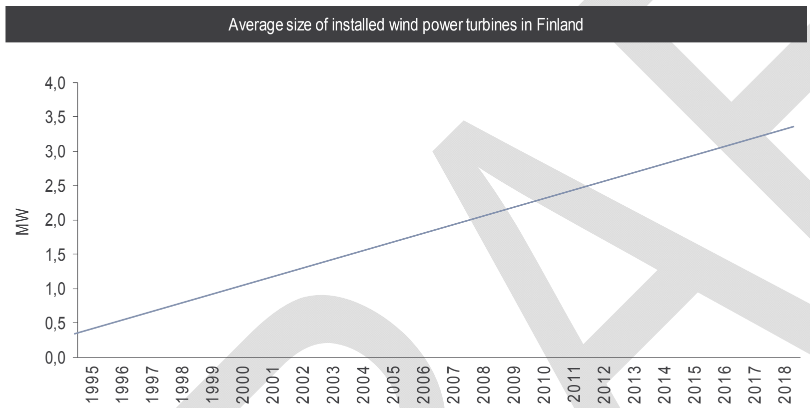
In the register of wind power projects in Finland about 5% of the projects in 2005 was owned by privet owners or associations. This amount is expected to be the same in 2017 but of the projects initiated during 2005-2017 almost all projects are industrial and large scale. The amount of 1 MW used for 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 energy production of 2 GWh annually.

Figure 11: Total wind power capacity in Finland 2005-2017



Source: Finnish Wind Power Association (2019)

Figure 12: 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 and biomass is not used in an extensive level. 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).

The amount of bio power used for self -consumption is assumed to be the same as in the Swedish electricity certificate registry, 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.

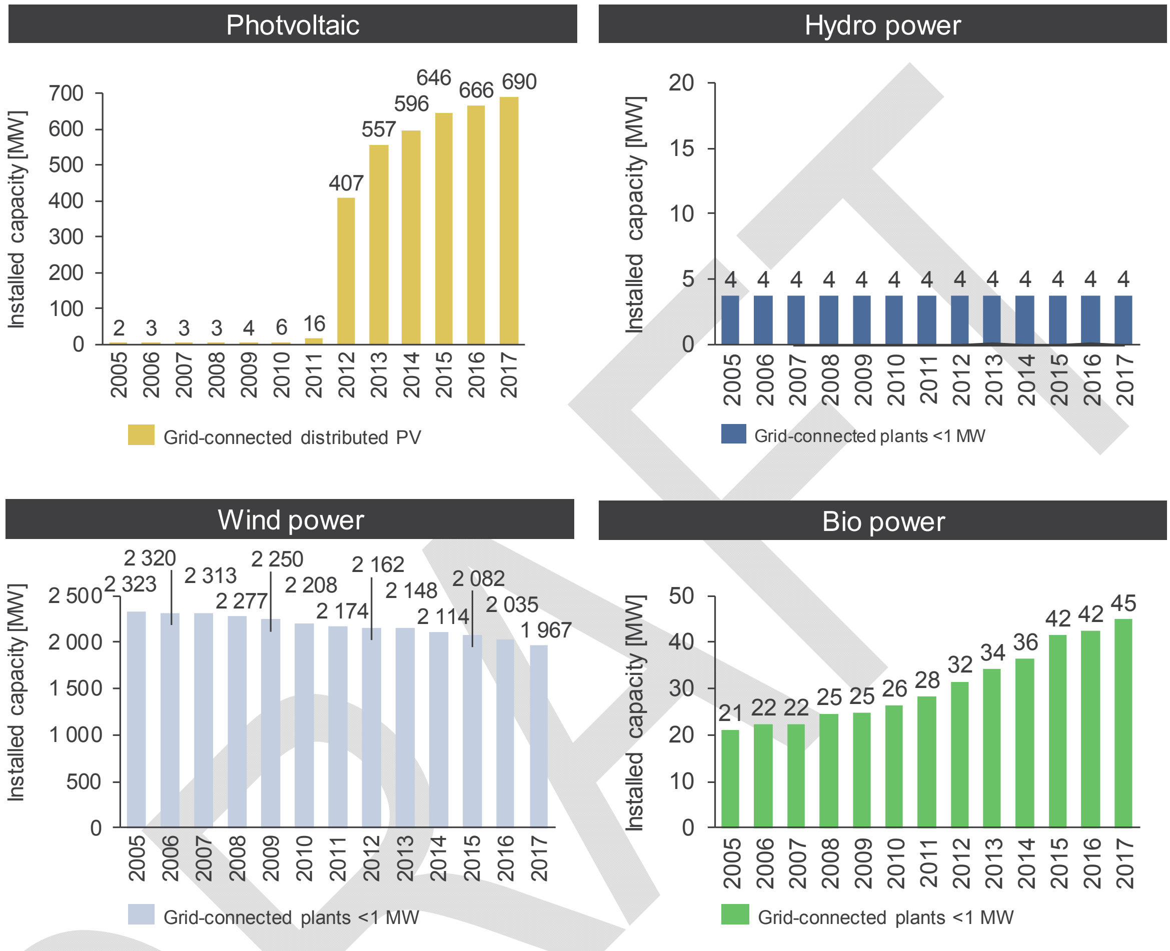
The PV installations increased enormously in 2011-2012 and the installed capacity rose from 16 to 407 MW. The installed capacity in small-scale wind power is on the other hand decreasing due to replacement of small turbines with more efficient larger ones.

We estimate that total prosumer production 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 (2950.5 GWh)
- 5 MW of bio power (30 GWh)
- Total: 2170 MW of prosumer power (674 GWh)

Figure 13: Summary installed capacity for distributed production in Denmark 2005-2017



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

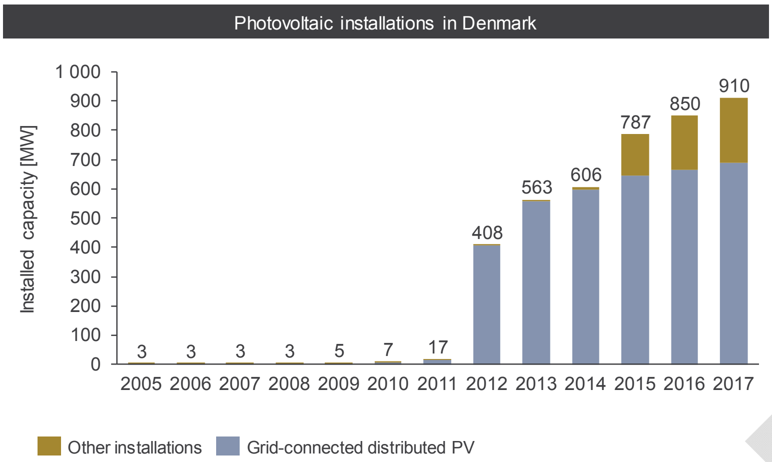
3.6.1 Photovoltaic

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 14. The most common installed PV systems are below 20 kW, see Figure 15.

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.

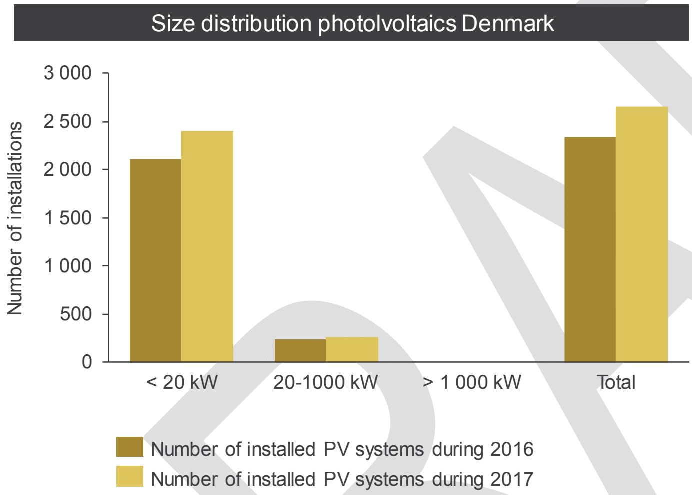
Based on our knowledge of solar PV power production in Denmark, approximately the installed capacity named ‘grid-connected decentralized’ in the PVPS report could almost exclusively be classified as prosumer production (100% of 690 MW). The electricity production of photovoltaics in Denmark is 900-1000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

Figure 14: Installed PV systems in Denmark 2016-2017



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

Figure 15: Size distribution of installed PV systems in Denmark during 2016 and 2017



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

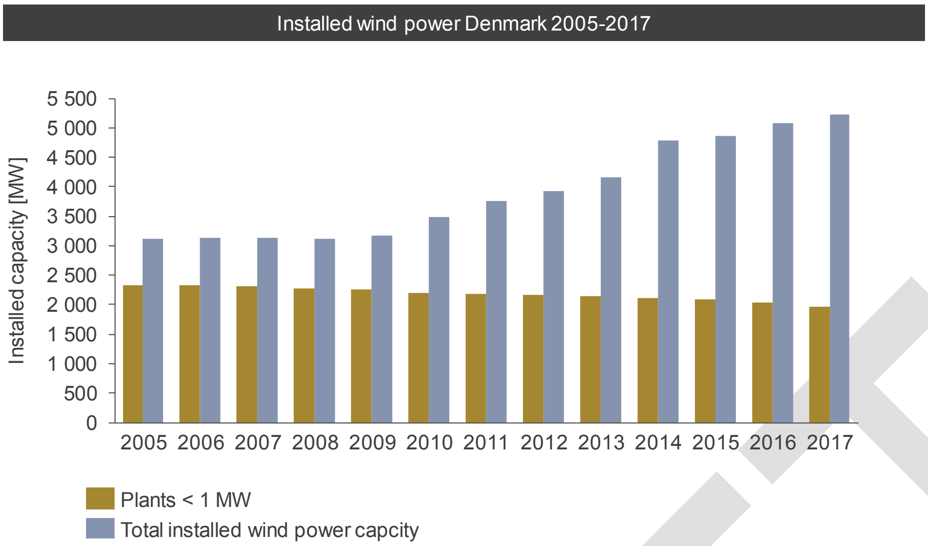
3.6.2 Wind power

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 16.

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 17.

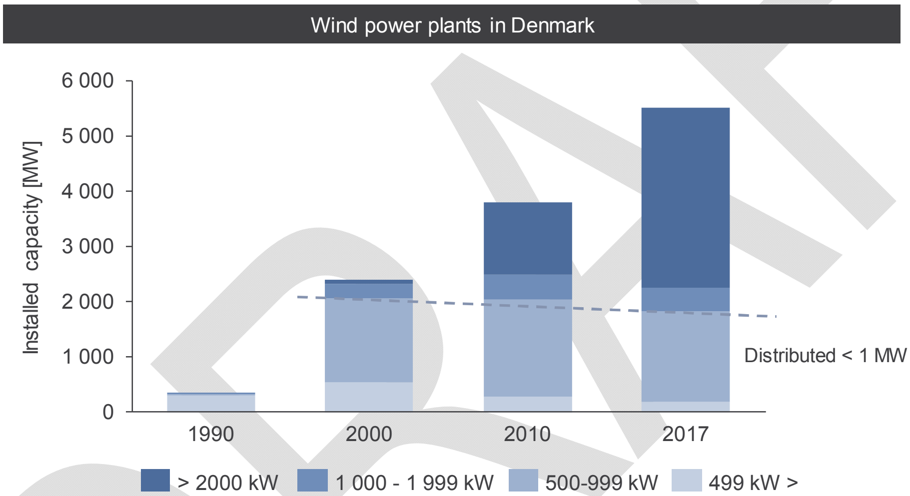
The Danish wind power Association estimated that about three quarters of the installed wind power in Denmark was privately owned by individuals or cooperatives in 2013 (Danmarks Vindmølleforening, 2019; Climate Policy Info Hub, 2019). This share is also applied estimating the share of production used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

Figure 16: Total installed wind capacity in Denmark 2005-2017



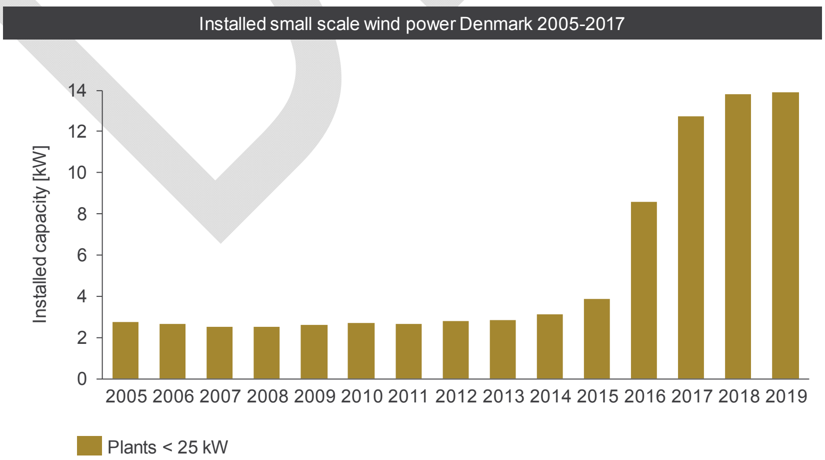
Source: Sweco, Danish Energy Agency (2019f)

Figure 17: Size distribution of wind Power plants in Denmark



Source: Danish Energy Agency (2019f)

Figure 18: Small-scale wind power in Denmark (<25 kW)



Source: Sweco, 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 energy 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 i.e. 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, 6000h, the energy produced for self-consumption is 30 GWh if the installed capacity for self-consumption is 6 MW.

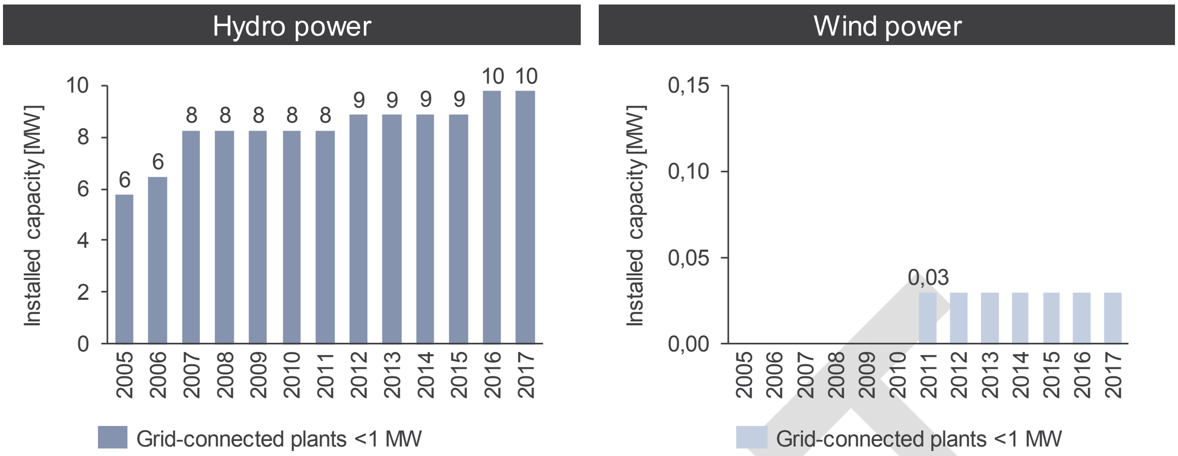
3.7 Statistical overview – Iceland

On 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 on Iceland are in units below 1 MW. Only a few wind power projects in small-scale wind has been installed on Iceland. None of the installed geothermal power plants is considered to be small-scale.

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

- 6.7 MW of hydropower (36 GWh)
- 0.03 MW of wind power (0.75 GWh)
- Total: 7 MW of prosumer power (44 GWh)

Figure 19: Summary installed capacity for distributed production in Iceland 2005-2017



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

3.7.1 Photovoltaic

The use of photovoltaic power on Iceland is limited due to limited solar irradiance. There are however some small-scale off-grid solutions installed. 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 on 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 on 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 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 on 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 on Iceland are known to be used for private electricity consumption.

3.7.4 Geothermal power

There are six geothermal plants on 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.

4 Overview of current framework conditions, regulations and tax schemes

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

If we look at 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 regulations and 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). That said, self-production of electricity is quite strongly supported in all countries relative to consumption based on centralized production. As mentioned above Iceland do not seem to have in place specific regulation and incentives for DES.

Overall an important incentive to invest in self-production in the Nordics is the opportunity to save energy costs, grid tariffs, taxes, VAT and in some cases earning electricity certificates in hours of self-consumption. Furthermore, 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 energy 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 energy production 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[8] (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 energy production and self-consumptions are:

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

The Energy Performance in Buildings directive 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 self-generation in buildings (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).

[8] 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 self-production and -consumption: The properties of electricity production which are used to differentiate self-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 self-production and -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: Self-production of electricity can substantially reduce the total energy consumption from the grid. Depending on the grid-tariff structure, and the regulation of self-production, 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 self-production of electricity, 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. Self-production 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 for self-production and 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 self-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 self-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. For instance, 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 self-production or -consumption in Iceland[9], 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 (measured as 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 or the local DSO.	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/ <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)	Exempt from electricity-tax (~0.028 EUR/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) Depr. of installed capacity 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 feed-in (if same connection point, <100 A, max 18000 SEK/y) Investment support for energy storage, 60% of investment	Up to 45% tax credit for the work cost of PV installations	No public investment support.
Support businesses	Examples of support of several MNOK	60 öre/kWh feed-in (if same connection point, <100 A, max 18000 SEK/y). Investment support renewable energy for farmers, 40% of investments Inv. support for energy storage, 60% of investment	Up to 25% investment subsidy of PV	No public investment support for smaller units.

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

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. GOs practically inaccessible	GOs practically inaccessible	Technology-neutral national tendering scheme where larger units can apply.
Other relevant regulation	Easy licensing/ authorization + building regulation	ROT – 30% support of installation cost (for example appr. 9% of total cost for solar PV panel installation).	Municipal efforts	Tax deduction for craft 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 self-production and -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-produced electricity free of charge. During hours of self-consumption, the prosumer can avoid cost for electricity and the variable electricity network 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) 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) which produce 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, i.e. 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), a large part of the grid-tariff cost savings of the prosumers is currently paid by other consumers. 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 power tariffs (cost/W) replace energy tariffs (cost/Wh), the financial incentives for self-production and -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[10] 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 government enterprise responsible for promotion of environmentally friendly production and consumption of energy. 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).

Investment support for businesses

Enova does not have a standardized support scheme for distributed energy 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.

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

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 self-production and 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).

Price of excess electricity

During hours of self-usage, the cost for both electricity and the variable electricity network cost can be avoided. The electricity cost is usually spot-price plus balancing cost, electricity certificate and supplier margin. The variable electricity network 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

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 network 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 network 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[11] (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

[11] 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.

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 and is similar to a "feed-in tariff", however it is 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 energy 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 self-production of power (Swedish Energy Agency, 2016).

Investment support for businesses

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

Investment support can be received in general for renewable energy 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 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 installation cost of solar PV panels. The 30% tax deduction on installation costs corresponds to approximately 9% of total solar PV investment cost. ROT cannot be combined with investment support (Swedish Energy Agency, 2018b).

In August 2018 an exemption was introduced which simplifies the deployment of 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 (Swedish Energy Agency, 2018b).

4.2.4 Regulation in Finland

Definition of self-production and -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 (Ministry of Economic Affairs and Employment of Finland, 2018).

Market access

Prosumers can sell excess electricity through the grid (LUT, 2017). According to the Finnish 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 trading-companies/electricity suppliers 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. 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 electricity is purchased from.

Grid production tariffs

Grid production tariffs are set by the DSOs according to local conditions and vary significantly. 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

In 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), even though a monthly fee for self-generators might apply depending on DSO company. Thus, self-production and -consumption can reduce the total grid bill for the individual prosumer. 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 the PV system. 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 energy 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 energy 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 practical for micro-generation (LUT, 2017).

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 self-production and -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 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 energy 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 network cost can be avoided (including the PSO tariff). The variable electricity network 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 energy production tariff. DSO's are obliged to exempt smaller (decentralised) RES producing units included under certain offtake agreements[12]. These agreements cover most of the installed distributed energy systems (RES). Decentralized production units exempted from the production fee includes 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 energy production. The calculation of the energy charges is based on the total consumption with the gross energy 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 energy 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 energy 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).

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

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 network. 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 energy 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.

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).

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

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

5 Effects of distributed electricity production/self-consumption in different power systems and the importance of local storage

Challenges for the future power system include intermittency and difficulties to forecast, securing available power at any time, voltage and frequency stability. The level of these challenges differs from a largely hydro to a largely fossil-based system, especially over time when many fossil-fuelled central thermal power plants phase out and more intermittent decentralised or distributed renewables phase in. Assuming a high share of reservoirs, a largely hydro-based power system like the Nordic system will have smaller challenges in the transition towards a power system with a high share of renewables, whether these are distributed or not.

However, even a largely hydro-based system will require more flexibility as a result of its transformation. This flexibility can be provided both from production, grid, energy storage and demand response.

Flexibility in all forms will become extremely important and should be sought at all voltage levels, even though its required amount and the suitability of its location would be dependent on the mix of DER sources. Energy storage in general, as one of the four major flexibility means grid, flexible production, energy storage and demand response will play an essential role in the future power system, being used to manage temporary production peaks and dips in the power system, for frequency control, but also for seasonal storage. Whereas storage should be provided at different voltage levels and locations, the most economical solutions might often be to solve the challenges in the power systems where they occur or at least close by, rather than transferring them further into the power system and solving them elsewhere. Therefore, local energy storage is an important solution.

Of the local storage options, batteries are very interesting solutions, both for power and energy supply. Batteries can contribute to load shifting, changing consumption profiles, limiting price variations by either storing locally produced electricity or electricity from the grid. They can locally contribute to reducing the need for grid investments and its potential to contribute with several system services, such as voltage and frequency control.

5.1 Challenges

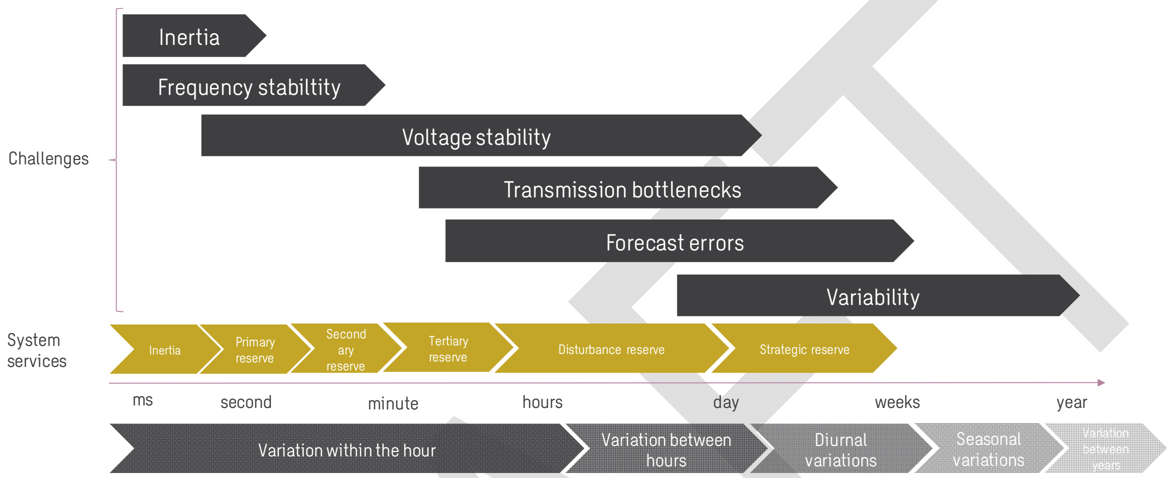
A power system based solely on renewable power production will differ considerably from the power system we have today. Large-scale centralized thermal power plants will be replaced by wind and solar PV power plants, which may be of a smaller scale and at the same time more distributed than today's power plants. The thermal power plants' production can be planned and controlled in a completely different way, a production based on wind and photovoltaic solar power is variable by definition. At the same time, the large power plants - hydropower and thermal power plants - also contribute with so-called mechanical inertia that makes the power system resistant to fast changes in frequency.

Both the physical transmission network and many of the regulations governing the electricity market are - directly or indirectly - adapted to the production mix that exists today, and both grids and regulations will need to be adapted to a future production mix with completely different properties than today's. The adaptations that must be implemented can be summarized in a number of challenges that must be resolved. Below we will briefly describe the most important challenges, and later in the chapter we will describe possible solutions to these challenges with focus on storage. The challenges that will be discussed relate to physical processes and administrative processes at several different time scales - everything from processes at millisecond level to seasonal variations.

Intermittency and difficulties to forecast: Production from wind and photovoltaic solar power is weather dependent, which means that it is not plannable in the same way as thermal power or hydropower with reservoirs. This leads to higher requirements for reserve power than today.

Available power at any time: Under favourable weather conditions, inexpensive solar PV and wind power will outcompete more expensive alternatives in the power market, in which currently the thermal power plants function as base power. The profitability of these power plants can be undermined short-term, which can lead to them disappearing from the market, which can lead to a shortage of power. In the longer-term, fossil-fuelled thermal power plants will be phased out of the market, adding to the challenges described above.

Figure 20: Challenges in a power system with high share of RES-E



Source: Sweco

Voltage Stability. In order for large amounts of power to be transported over long distance across a country, the reactive power balance is required to be handled locally in order to maintain the voltage levels in the transmission network. Reactive power cannot be transmitted over long distances, which means that power plants are needed to provide reactive power across the transmission network to maintain voltage levels at sufficiently high levels throughout the network. As an example, it is nuclear power that accounts for a significant part of the reactive power in southern Sweden. When the nuclear power plants in southern Sweden phase out and are partly replaced by wind turbines located in northern Sweden, new solutions are needed to maintain the voltage levels in the transmission network's southern parts. This can be done using power electronics.

Frequency stability and inertia. Today, in the Nordic power system, a large amount of hydropower is used to regulate the system at all time horizons. To be able to contribute to frequency regulation (automatic primary and secondary regulation) it is required that the hydropower plants rotate and are connected to produce power. In situations with low loads and a large proportion of wind and sun, hydropower will have to be regulated to a minimum so that wind and solar PV power need not be spilled. This in turn means that there are fewer hydropower units that can contribute to frequency regulation. The new power plants are not as easy to control and are not cannot be ramped up on demand. The weather dependence of the new power plants also means that the variations in the power balance can be expected to be even greater than today. Thermal power plants and hydropower plants consist of rotary synchronous generators that are directly connected to the transmission network. The rotating mass in these plants adds significant inertia to the system. This inertia is of great importance to the stability of the system, as it can be used to very quickly handle rapid frequency variations in the transmission network.

5.1.1 Challlenges and effects in different power systems

The challenges from an increasing share of intermittent renewables summarized in Figure 20 above exist regardless of the production mix in the power system, but their effects will vary, especially long-term, when fossil-based flexible thermal power will be forced out and flexible hydro power will remain in the power system, the latter dampening potentially negative effects.

With an increased production from intermittent renewables the variability of the residual demand increases. As a result – provided there are no other sources of flexibility - other production sources will have to ramp up and down faster on different timeframes. At the same time, supply of flexibility from centralised power plants is becoming more and more challenging. Intermittent renewables, with close to zero operational costs, replace generation from conventional power plants. This transformation of the generation structure pushes power prices down during periods of oversupply, typically during summer in systems with a share of solar PV and during periods with high wind for systems with a high share of wind power.

In a largely fossil-based system, central power plants with high variable costs may leave the market as a consequence. In the long run, a number of controllable plants may leave the market, in particular peaking plants that traditionally have provided a large part of the flexibility in the system. This lacking flexibility will then have to be provided by other sources. One therefore often seeks to finance flexible central capacity with capacity payments, allowing financing additional investments and at the same time preventing price peaks. This, however. could add distortions to the market and potentially lead to overcapacity while reducing prices volatility and incentives for storage and demand response. The loss of large central thermal power plants will also lead to a much mechanical inertia in the system, increasing the risk for fast frequency deviation, which has to be counteracted by other means.

Assuming a high share of reservoirs, a largely hydro-based power system like the Nordic system will have smaller challenges in the transition towards a power system with a high share of renewables, whether these are distributed or not. This is both due to the fact that less fossil-fuelled thermal production has to be phased out over time to reach CO2-emission targets and at the same time hydro reservoirs will allow regulation and ramping up and down to accommodate the production profile for intermittent renewables. This will also dampen the price decreasing effects of large amounts of renewable surplus in the power system somewhat unless the market integration with markets with a high share of fossil-fuelled generation becomes very high. In a largely hydro-based system, the loss of mechanical inertia might be somewhat lower than in a largely fossil-based power system, thus somewhat reducing the risk for frequency deviations or need for other frequency stabilising measures.

From a storage point of view, large reservoirs function as seasonal or shorter term storage, decreasing the need for flexibility sources. However, the use of hydropower to balance intermittent renewables or fluctuating demand still requires a well built-out grid. In a largely fossil-based systems, these large-scale storages do not exist and their function has to be provided by other flexibility means.

Regardless of power system, the trend from more centralised to more decentralised power production will also require a substantial grid capacity on all levels. On a local level (i.e. distribution), rising shares of DER connected to distribution grids lead to a transformation of local distribution grids from passive to active systems that function in both directions due to reversed power flows. DSOs have to handle a series of operational issues (voltage problems, reverse power flows, congestions and potentially increased losses) arising from the shift towards a decentralised power supply and a shift from a passive operation of distribution networks to a more active operation.

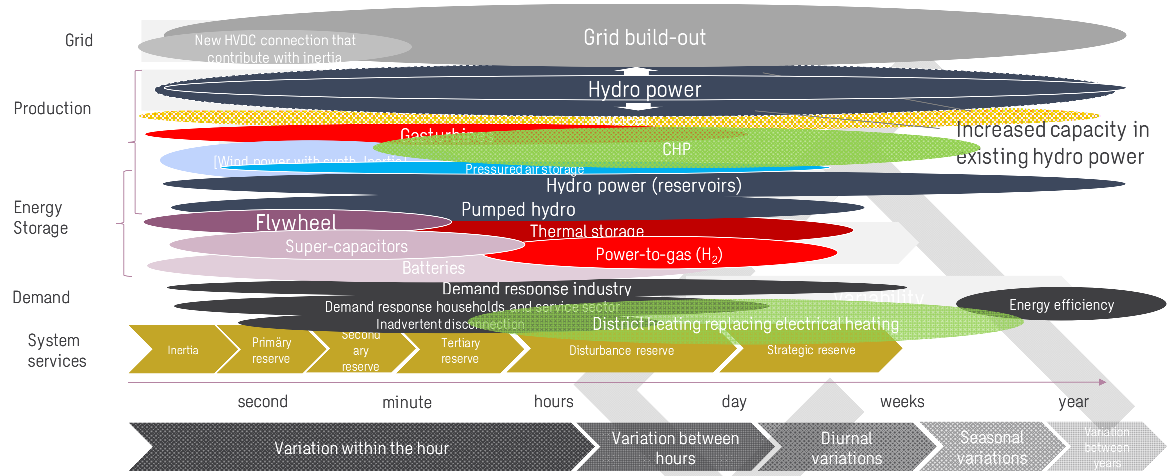
5.2 Solutions

Many different measures are needed to make a power system with 100% mostly intermittent renewables work, both in grid, production, energy storage, demand as well as market and business models. The challenges described above will require a range of flexibility options. In what follows, we will discuss a number of different flexibility options and describe how contributing to solving the problems described above.

At the overall level, the resources available to increase the flexibility of the power system can be divided into flexible production, demand flexibility and storage, even if the boundaries between these flexibility resources are not always entirely clear. A hydropower plant can e.g. be considered a flexible production resource, but also as a production plant with an associated giant stock in the form of a power plant pond. In addition, grid expansion that enables export/import can also contribute to managing the system's need for flexibility. A summary of the various measures is given in Figure 21.

Flexiblity from production. Traditionally, the power system's need for flexibility has been handled with the help of production facilities with good ability to rapidly increase or decrease production according to the power system's needs. The conditions for quickly regulating electricity production differ between different production sources, both technically and economically. In many countries that do not have other flexible resources such as hydropower, gas turbines constitute an important flexibility resource, not least for emergency reasons.

Figure 21: Flexibility options for a power system with a high share of RES-E



Source: Sweco

Gas turbines then often constitute the most important reserves for managing the loss of production facilities and other disturbances. In the Nordic power system, hydropower has primarily been responsible for the need for up and down regulation in a comparatively simple and cost-effective manner. But as the weather-dependent renewable electricity production increases, additional flexibility resources will be needed. Demand flexibility is another resource that so far has not been used to any great extent, but which is considered to have great potential. However, technically, the system benefit does not differ, as up or down regulation of input/output can contribute from what changes in demand / demand can bring about. E.g. fast regulation (MW/min) and short warning times are in many cases not more difficult to handle for demand than for production. However, normally production is a more sustainable resource that can be utilized for a long time, unlike demand response, which can only be used for a limited time.

Flexibility from the grid. From a system perspective, a build-out of both the transmission grid, distribution grid and local grid level will be required in order to both allow connection of new renewable electricity production but also to enable a connection with other countries for a higher market integration and risk diversification.

Flexibility from energy storage. Furthermore, storage options with different storage time horizons and faster resources for primary regulation are useful, as outlined in Figure 22.

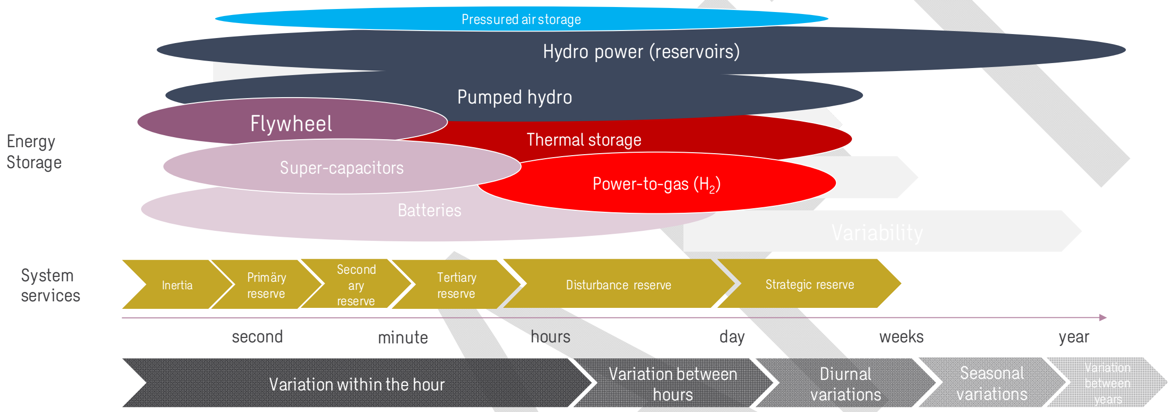
Flexibility from the demand side. In addition to the above measures, more flexibility from demand will be required. This can include long-term measures such as energy-efficiency improvements, demand response from industrial consumers and households, but also converting load from e.g. electrical heating to district heating, thereby offloading the power system off its high peaks during cold periods.

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

Energy storage in general – as one of the four main flexibility options - is, together with a well-planned electricity grid and developed regulations concerning its application, of great strategic importance in order to achieve high-aiming renewable energy and climate targets. As electricity dependence in society gradually increases with increasing electrification, accessibility to electricity is an essential function that must always be functional and stable. Even short interruptions in the supply can cause high costs for end users, especially industrial end-users. This means that in the future, the need for flexibility in all parts of the power system including the end-user side will increase and therefore also the importance of local storage.

Energy storage plays an essential role to manage supply from intermittent renewable sources in a distributed electricity production/self-consumption, but also self-consumption in a scenario with a high share of EVs to be charged. It can help smoothening the power flow, to manage temporary production peaks and dips in the power system, but also for seasonal storage where solar PV power produced during the summer is stored for consumption during the winter months. It can assist in load shifting from higher-price to lower-price hours or serve as a backup when the primary source of energy fails (reserve power). Energy storage will also be essential to satisfy the energy demand from EV charging infrastructures on a local level. If placed right, energy storage can help avoiding grid investments. Some forms of energy storage can be also used for frequency control. Figure 22 summarizes how and which energy storage technologies can help solving the various challenges for specific time horizons.

Figure 22: Different energy storage solutions in the power system



Source: Sweco

Energy storage technology can also be classified according to its size and location in the power system, whether that is close to production, consumption or transport, differentiating between large-scale (GW), medium-sized (MW) or smaller local systems (kW).

- Small, local end-user storage systems (kW-size):
    - batteries (lead acid, Li-ion) for both power and energy supply
    - super-capacitors, flywheels for power
- Grid storage systems (MW-size):
    - batteries such as lead acid, Li-ion, NaS and Flow batteries for energy supply
    - lead acid and Li-ion batteries, for both power and energy supply
    - Power-to-gas (hydrogen), pressurized air storage, pumped hydro, (small-scale, 10 to over 100 MW, hours to days)
    - super-capacitors, Superconducting Magnetic Energy Storage (SMES), flywheels for power
- Large energy storage (GW-size):
    - pumped hydro
    - thermal storage (e.g. Power-to-heat)
    - pressurized air storage
    - chemical storage (e.g. Power-to-gas (hydrogen, large scale >100MW), up to weeks and months

Earlier Sweco studies show that flexibility should be sought at all system voltage levels and that amount and location would be dependent on the mix of DER sources. The increased penetration levels of distributed energy resources expected in future systems not only necessitates the incorporation of flexibility from production and demand as well as energy storage connected to the distribution and local grid level. In addition, physical and/or institutional extensions of market areas and changes in market regulation are needed to open access to flexible distributed resources in both time and geography.

However, the most economical solutions to overcome the challenges might often be to solve them where they occur or at least close by, rather than transferring them further into the power system and solving them elsewhere. That means, e.g. that distributed intermittent renewable production should preferably only be transferred to the grid to the degree it can be handled within the system, otherwise some form of storage or consumption close to it are recommended. For distributed electricity production, this could mean a combination of aggregated local consumption or storage, whereas this local storage could be provided in different forms, e.g. batteries at home or via a two-way set-up with the vehicle. It is also important to understand the potential of different types of energy storage for the future. This is to avoid large investments in the expansion of electricity distribution grid in order to solve today's transfer problems, when the problems at a later stage could instead have been solved considerably cheaper using energy storage. Likewise, following the philosophy of solving the issue where it occurs, in a more centralized system, energy storage would be preferable close to larger intermittent renewable production such as larger wind parks.

Of the local storage options, batteries are very interesting solutions, both for power and energy supply. For local storage in a distributed energy production and self-consumption setting, it is reasonable to assume batteries with a capacity of a few kW and kWh as typical, in some cases perhaps up to MW and MWh. Batteries can contribute to load shifting, changing consumption profiles, limiting price variations by either storing locally produced electricity or electricity from the grid. They can locally contribute *to reducing the need for grid investments* and its potential to contribute with several system services, such as *voltage and frequency control*. Batteries in the home can be interesting in that both "cut peaks" when the power requirement is greatest and thus enable downsizing of fuses, which can lead to decreased grid capacity tariffs. In Germany, where solar PV has been growing significantly both on a larger scale and more centralized and distributed, the surplus electricity produced from solar PV power plants has triggered incentive schemes purchase of batteries. The cost of batteries has been falling significantly and continues to fall, while battery technology is continuously evolving and getting better and more efficient with parameters such as storage capacity, volume and lifetime improving.

Local energy storage is likely to be used differently depending on season. Looking at the scenarios for the Nordic countries we outline in this report, most of the growth for distributed energy production and self-consumption is expected from solar PV systems. The higher the distributed solar PV systems production capacity, the more important local storage will be for its owner in order to avoid low prices in high surplus hours and for the local grid owner to avoid the export of a high surplus to the local and/or distribution grid and with potential bottleneck implications. The function of this storage will however vary over the year. During summer, energy storage connected to solar PV will first and foremost reduce the load on the grid. A battery system together with a solar PV system will normally imply that the battery is initially used to store solar PV production during the daytime when it exceeds demand for self-consumption. When the battery is fully charged power could be delivered to the grid. When the battery is discharged and during the later hours of the day, power requirements will mainly be covered by the grid and potentially own production, but not the battery. The battery can now be used for charging from the grid to exploit the price difference between night and day. During winter, when there is little or no solar PV production the entire battery capacity can be used to exploit price differences between night and day.

Batteries at end-consumers or prosumers can reduce the power requirement and in combination with distributed power generation the potential to make traditional customers self-sufficient, potentially to the extent to enable them to disconnect from the grid. The major drawback of batteries is their loss of energy for a load cycle in the order of 20%, which may limit their application in markets with low volatility in power prices.

EVs are likely good options for local storage, if and when technology allows. In the future, batteries in electric cars can get additional functionality by allowing them to be used for stationary local storage when the car is not in use but parked, which is the majority of the time form most cars. According to Northvolt, EVs would constitute over 80% of total battery demand by 2025-30 and thus provide a substantial storage volume to be double-used locally in a distributed energy-production and self-consumption setting. In many Nordic countries, EVs are expected to grow rather fast due to political will and target setting as well a largely fossil-free power system that can provide the electricity for those EVs with a low CO_2-content. According to an analysis by NVE (NVE, 2019a), the battery capacity associated with electric cars in Norway could be up to 100 GWh in 2030, constituting an energy and power reserve that can be used to reduce the consumption peak in during winter season by 10-50%.

For the grid owner, local energy storage can be used to defer grid investments or connecting new consumers or producers. Capacity challenges or voltage problems in the local or distribution grid may be handled by installing batteries rather than grid reinforcement to handle the two-way flow of power. According to a recent study by NVE (NVE, 2018a), this may be particularly relevant in cases where costly cables are required to increase grid capacity locally or to replace existing capacity. According to the study, the smaller the requested capacity increase and the less frequent the potential capacity problem, the greater the likelihood that batteries may compete with traditional grid reinforcement. NVE also expects developments in modern communication and management technology to lead to more end-user flexibility becoming a real alternative to network enhancements. From a grid owner point of view, batteries can further assist with input and output of active or reactive power to ensure satisfactory quality of delivery, optimize the operation of the grid and thus improve security of supply.

Another recent study in Sweden (Mälarenergi et al, 2017) points at possibilities for reduced peak loads and lower main fuse ratings in contracts will provide great potential for freeing up capacity in the supply network. This "freed up" capacity can then be used for e.g. connecting new residential areas, the deferral or avoidance of grid expansion, or it could also be used to connect new electricity production, thereby e.g. creating opportunities for the establishment of distributed electricity production.

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

There are several general barriers for development of distributed electricity production/self-consumption which are the same across the Nordics (as well as other countries), including limited knowledge, transaction costs and installation costs. Generally valid drivers are environmental concerns, marketing value and potential cost saving aspects.

Regulatory barriers and drivers differ between countries. However, this study's mapping shows some general aspects regarding regulatory barriers and drivers. All Nordic countries except Iceland aim to incentivize distributed energy resources and have therefore introduced policy instruments supporting this (i.e. policy drivers).

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 makes it harder for potential producers (households, companies) to overlook the system and potential supports 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 the barriers related to transaction costs and installation costs. The third policy barrier identified – uncertainty regarding future policy outlook – increase risk and therefore actors (households, companies etc) willingness to invest.

6.1 Background: Natural economic conditions for distributed electricity production in different countries

When analysing drivers and policy barriers in the Nordic countries, it is important to have a basic understanding of the main drivers for the development of distributed power production globally, and to what extent those are present in the Nordics. Important drivers globally have been strong technological and commercial development which have increased the profitability of distributed electricity production relative to alternative sources, as well as political objectives and desires to reduce the dependence and use of fossil energy fuels in many countries. In the Nordic region, both the expected profitability and the perceived environmental impact of installing distributed electricity production are lower than in many other countries, due to a relatively high renewable share and low electricity prices compared to other countries.

In addition, 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. The natural economic conditions for PV are poorer in the Nordics than in many other countries.

Growth in distributed electricity production (and 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 energy 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).

In general, the benefits of distributed (PV) electricity production are smaller in the Nordic countries, than in several other, warm and sunny regions. This can be explained by the facts that:

- Insolation are poor in winter (few hours of sunlight a day)
- Energy demand is high in the winter (cold), and relatively low in the summer (limited need for cooling)
- Energy prices are relatively low
- Grid quality is relatively high
- Energy production largely renewable already

These fundamental framework conditions are likely to as least as relevant to the development than the specific policy measures regulating distributed (PV) electricity production. This is important to bear in mind, when we analyse the specific barriers and drivers for distributed electricity production in the Nordic countries. Additionally, there is the factor that all decisions are not fully rational from an economic point of view. Part of the reason for this can be explained though limited knowledge and significant transactions costs, see Table 4.

The Nordic has more of a history of bio- and hydropower (including small-scale) compared to other countries and were also early adopters of the wind power technology and hence have a number of small-scale hydropower. These other technologies are more stagnating/decreasing but their barriers and drivers will also be considered.

6.2 General findings barriers and drivers in the Nordics

There can be several barriers to households and businesses who consider 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 consumer. However, there can also be several drivers which can lead households and businesses to start distributed electricity production, despite the presence of the barriers. For instance, and as described in Chapter 4, consumption of self-produced electricity can reduce prosumers' energy-, grid- and tax bill.

The individual household and business make their investment decision based on the sum of barriers (disadvantages) and drivers (advantages) of starting distributed electricity production. Therefore, rather than considering each single barrier to distributed electricity production, we will make a broad analysis of the sum of barriers and drivers for potential prosumers in each of the Nordic countries.

In the analysis, the barriers and drivers are split in the following categories:[13]

Barriers

- Knowledge
- Transaction cost (administration)
- Installation cost
- Regulation which may hinder distributed production

Drivers

- Preferences of households and businesses
- Commercial and technological development
- Electricity and grid prices
- Regulation which may promote distributed production

[13] Inspired by categories used by CICERO in their report "Power from the people - Driving forces and hindrances" (2018)

The barriers and drivers may differ between segments of potential prosumers. For instance, regulation on self-production and consumption may be stricter for apartment buildings than for individual houses (detached and attached houses). When relevant, we will describe differences in barriers and drivers between segments. We also describe planned future changes in barriers and drivers and discuss which changes in barriers and drivers which may be necessary to increase distributed electricity production in the different segments.

The main barriers and main drivers are summarized in Table 4. The barriers include limited knowledge, transaction costs and installation costs as well as the drivers environmental concern/marketing value and potential cost saving aspects are similar in all the Nordic countries (as well as in other countries) whilst regulatory barriers and drivers varies between countries.

Table 4: Main drivers and main barriers for all Nordic countries

Key barriers	Key drivers
Knowledge • Limited knowledge regarding DES and its opportunities	**Preferences of households and businesses** • Environmental concern • Marketing/social value
Transaction cost (administration) • Time consuming process • 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** • High electricity and grid prices that promote distributed production
Regulation which may hinder distr. prod • Differs between countries, outlined in more detail below	**Regulation which may promote dist. prod.** Differs between countries, but in general, the following regulation promotes distributed energy production in the Nordics: • Grid tariffs based on energy use • 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 (i.e. feed-in-tariffs)

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

In the public debate several policy barriers for distributed energy production in the Nordics are usually brought up. One of the major barriers which is often highlighted in the Nordics is the complexity of the different policy instruments, where there are many exemptions and incentives for distributed resources, but different definitions apply in different cases, it is hard to get an overview of all support systems and time-consuming to apply for all different supports and there are different ways to apply for these supports. Additionally, the regulation has been developed continuously and the lack of long-term policy outlook regarding support for distributed energy resources is therefore also considered a barrier. The next sections provide an overview of main policy and market barriers for each country. It should however be noted that it is the combination of different regulatory aspects which in general forms barriers, i.e. not only each policy instrument/lack of policy.

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 Chapter 7Future growth scenarios.

6.3 Norway specific barriers and drivers

The 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 to unintended consequences[14].

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 hindrances", 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.

Based on our knowledge of the biggest 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 by introducing further "positive" regulatory measures (support schemes) which either increases revenues or decreases costs associated with distributed production (if politically desirable).

Apart from the more general barriers described above and in Chapter 6.2, there are some Norwegian specific regulatory-related barriers which has been identified, see Table 5.

Table 5: Policy and market barriers in Norway

Policy and market barriers in Norway	Impact	Assessment/Potential mitigation
Electricity network capacity tariffs	It is possible that an important driver for self-production today, namely grid cost savings, may be reduced if the grid tariffs are changed so that consumers are charged for maximum capacity rather than total energy used (as proposed by the Norwegian	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.

[14] 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.

	energy regulator, see chapter on regulation).	
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 prosumer-scheme will reduce the regulatory barriers for the distribution and consumption of self-produced electricity within an apartment building. Barriers related to the coordination between neighbours will remain but may be reduced with technical and commercial development.

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

6.4 Sweden specific barriers and drivers

Apart from the more general barriers (see Chapter 6.2) there are some Sweden specific regulatory related barriers which has been identified, see Table 6.

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

Table 6: Policy and market barriers in Sweden

Policy and market barriers in Sweden	Impact	Assessment/Potential mitigation
Complexity of the regulatory regime	High 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 would be preferable. 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 barrier.

Unclear savings (especially for smaller producers)	The feed-in (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 feed-in 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 and desirable that the policy can be more stable going forward.
Trend towards electricity network capacity tariffs	Lower variable electricity network tariff	The Swedish solar commission propose that maximum 50% of the electricity network 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 network	Stakeholders owning multiple building, also the ones in close proximity of each other, cannot use their self-generated electricity in other buildings if they want tax exemption	The Swedish solar commission propose that tax exemption should apply also when electricity is moved between building. The rule regarding that tax exemption is not allowed if distributed over concession network 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. Hence, Sweco and Oslo Economics assess that the current regulation is suitable.
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)

6.5 Finland specific barriers and drivers

Apart from the more general barriers (see Chapter 6.2) there are some Finland specific regulatory related barriers which has been identified, see Table 7.

Table 7: Policy and market barriers in Finland

Policy and market barriers in Finland	Impact	Assessment/Potential mitigation
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 the process could be made less ambiguous if municipalities would clearly imply which types of installations are exempt of the permitting process.
Permission is required from the distribution system operator for connecting a generation installation to the electricity network	There are some 80 different distribution system operators in Finland and consequently also significant number of network 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 network 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	Sales of surplus electricity is enabled; the producer is only obligated to sign an offtake agreement with the selected energy company.

	company electricity is purchased from, which limits the possibility to compete one's electricity supply contract.	
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.	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.
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 energy aid among other things 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.

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

6.6 Denmark specific barriers and drivers

Apart from the more general barriers (see Chapter 6.2) there are some Danish specific regulatory related barriers which has been identified, see Table 8.

Table 8: Policy and market barriers in Denmark

Policy and market barriers in Denmark	Impact	Assessment/Potential mitigation
Complexity of the regulatory regime	Due to the very complex regulatory set up, and frequent regulatory changes support systems has previously been perceived as non- transparent 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 very in transparent and complex.	The new regulatory regime includes no direct support for DES systems. This does increase transparency in the regulation but does little to promote the use of DES systems. With future installations all PV's are regulated under a so-called flextariff 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 very 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 DES systems with internal storage. The economic incentive to invest in flexible systems are further decreased 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.	General price developments are expected to drive the incentive for further investments in DES 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 in DES 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 is assessed to decrease the investment in smaller DES. However, there might still be incentive for DES production especially outside urban areas and in cases where new roofing are implemented as well as to shifts towards increased electricity usage from introduction of electric vehicles and heat pumps as these will help balance the usage and production from DES systems.
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 producers of DES installations, but rather be reflected in the prices when buying the surplus production from smaller DES units.

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

6.7 Iceland specific barriers and drivers

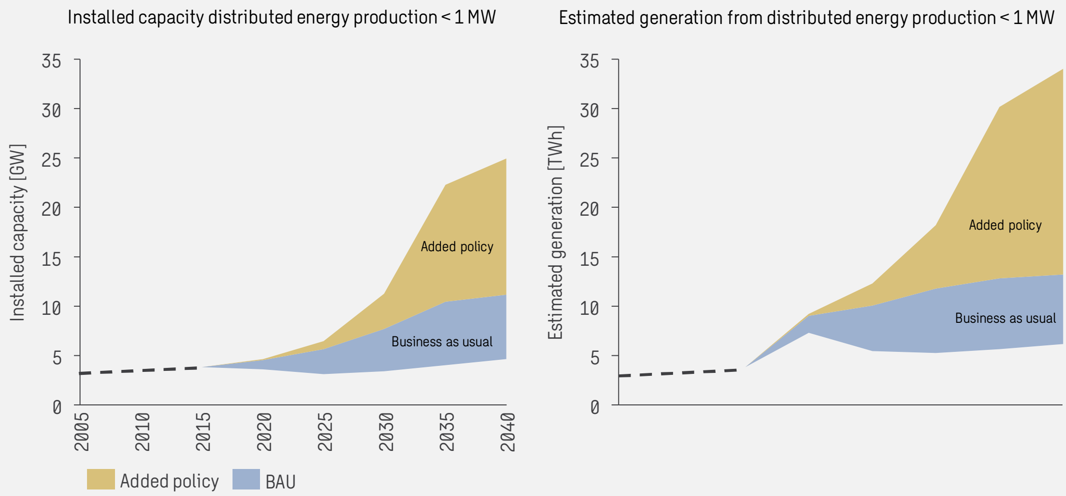
The more general barriers apply also for Iceland, such as lack of knowledge, transaction costs and significant upfront cost. Iceland do not have specific regulation to promote small-scale decentralised production, which can be regarded as a barrier. However, Iceland has good natural resources for renewable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

7 Future growth scenarios

We describe a potential future development of the distributed renewable energy in the Nordics by two different scenarios, a 'Business as usual-scenario' and an 'Added Policy-scenario'. In the *BAU scenario* current policies are continuously adjusted to provide about the same, but not more profitability for distributed energy production and self-consumption in the longer term than now, until grid parity is reached. The *Added policy* scenario is based on political willingness to set a volume target and thus more oriented at the economic and technical potential for residential consumers to adapt the renewable technologies. Basically, in this scenario policies are designed to either reduce the cost side or increase the income so that the volume target is reached.

The scenarios show a potential development of the distributed electricity production in the Nordics growing to 6-13 TWh in the *BAU scenario* and 13-34 TWh in the *Added policy* scenario, see Figure 23. This can be compared to the estimated 2017 level of about 5 TWh. The full potential for PV in the Added policy scenario is 19 TWh. In the BAU scenario the energy produced from PV is estimated to 4-10 TWh in the Nordics.

Figure 23: Installed capacity and estimated generation in the two policy scenarios "Business as usual" and "Added Policy"

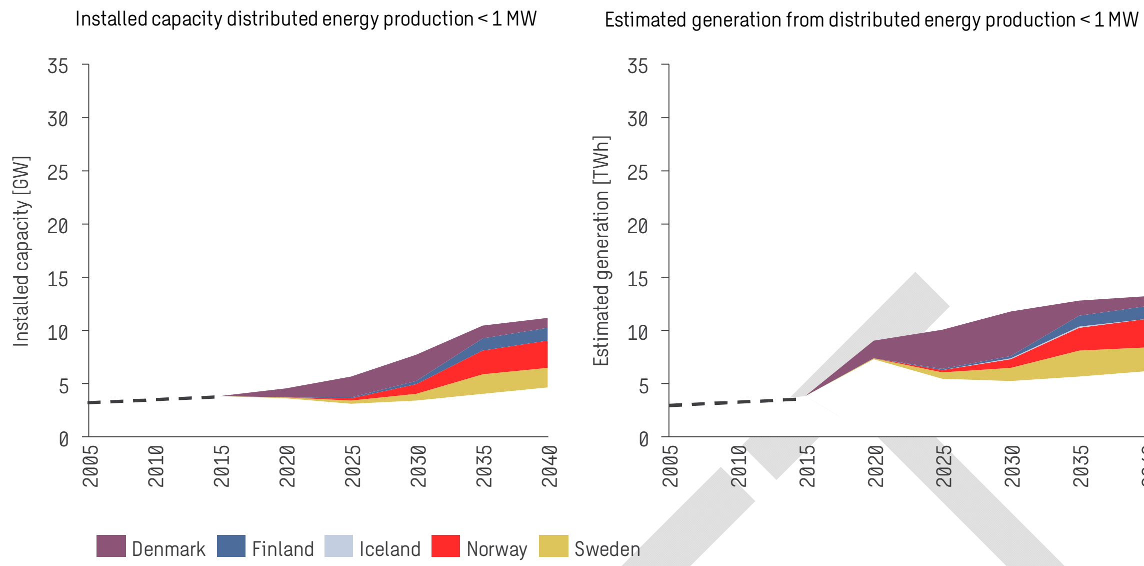


Source: Sweco

In 2017, the distributed energy production from installations below 1 MW in the Nordics was 8.5 TWh. Of this energy production was 55% estimated to be energy produced for self-consumption, see Table 9.

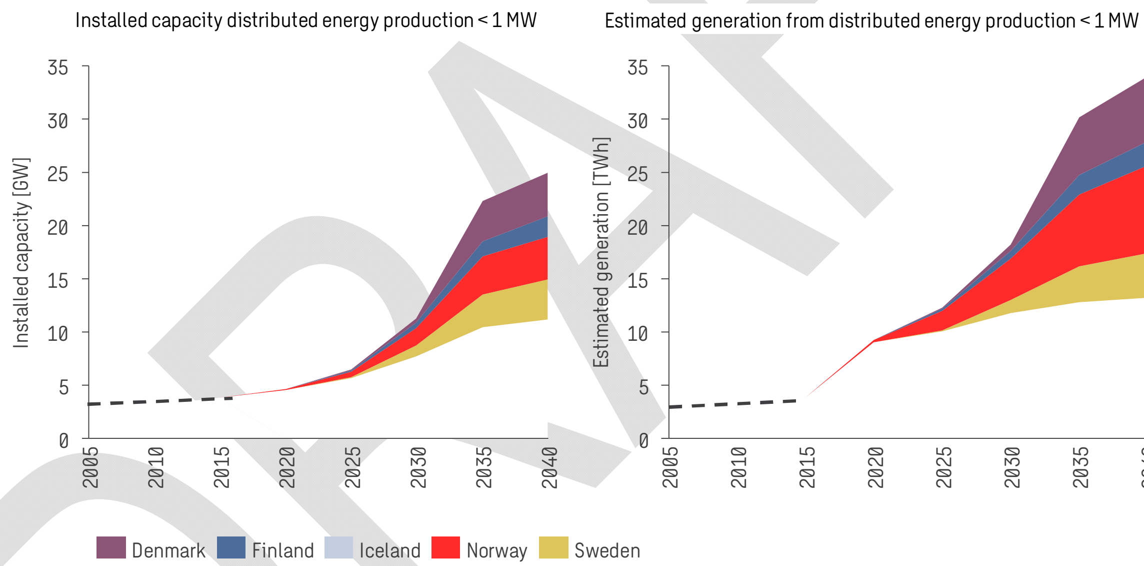
In the Nordic Business as usual scenario, the produced energy from distributed sources is maximum 13.2 TWh in 2040, see Figure 24. In this scenario, the use of PV is high, which increases the self-consumption share. The amount of energy produced for the purpose of self-consumption is estimated to 10.4 TWh, which is 78% of the distributed energy, see Table 9. In the added policy scenario, the energy production from distributed energy sources is estimated to maximum 34 TWh in 2040, see Figure 25. In this scenario, the share of small-scale hydropower has increased which lowers the share of energy produced for self-consumption. The amount of energy produced for the purpose of self-consumption is estimated to 23.9 TWh, which is 70% of the distributed energy, see Table 9.

Figure 24: Business as usual scenario Nordics



Source: Sweco

Figure 25: Added policy scenario Nordics



Source: Sweco

Table 9: The share of distributed energy used for self-consumption in the different scenarios

Source: Sweco	Source: Sweco	Source: Sweco	Source: Sweco
Source: Sweco	Source: Sweco	Source: Sweco	Source: Sweco
Source: Sweco	Source: Sweco	Source: Sweco	Source: Sweco
Source: Sweco	Source: Sweco	Source: Sweco	Source: Sweco
Source: Sweco	Source: Sweco	Source: Sweco	Source: Sweco

Source: Sweco

7.1 Scenario methodology

The scenarios are developed based on historical data, current markets trends, implicit technology cost development assumptions, implicit electricity price development assumptions as well as expectations of policy instruments either being in place or potentially put into place in the Nordic countries. The scenarios are expressed as a "*Business as usual (BAU)"* and as "*Added policy*" scenario. The outlined developments in the two scenarios are expressed as potential outcomes per scenario, with a *high* and a *low* for each of them.

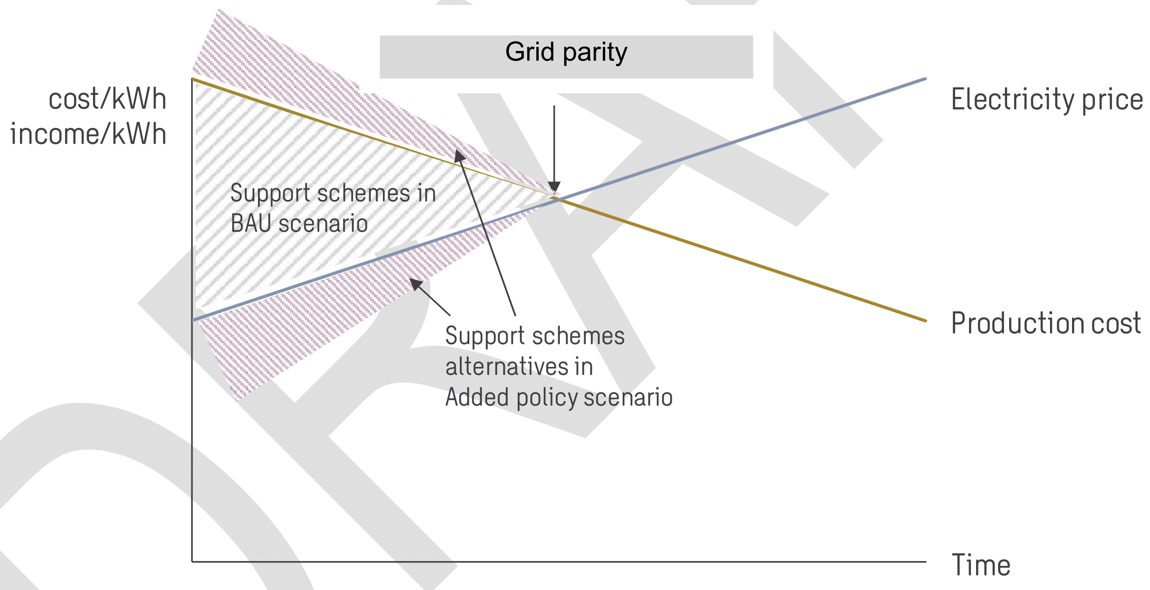
For immature technologies, assumptions about technology uptake are depending on the development and expected increase of electricity prices as a consequence of increased CO_2 prices and interconnection with the Continent and an expectation of a decrease in production costs, both implicit rather than explicit.

In the *BAU scenario* current policies are continuously adjusted to provide about the same, but not more profitability for distributed energy production and self-consumption in the longer term than now, until grid parity is reached. Beyond this point, take up rates will potentially increase strongly, only limited by technical potential, see Figure 26.

In the *Added policy* scenario volume targets for distributed energy production and self-consumption are assumed to be set by the Nordic countries. As a consequence, policies are assumed to be put in place to either increase the income side or reduce cost side.

For both scenarios, we define a lower and higher level to define an outcome space. Thereby, the higher level of the *BAU scenario* marks the lower level of the *Added policy* scenario.

Figure 26: Cost and income curves in BAU and Added Policy scenarios for immature technologies



Source: Sweco

7.1.1 BUSINESS AS USAL (BAU)

In the *BAU scenario* current policies are continuously adjusted to provide about the same, but not more profitability for distributed energy production and self-consumption in the longer term than now, until grid parity is reached. The lower level of the BAU scenario 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 and that current policy measures are similar or gradually phased out as technology cost drops.

The higher level of the business as usual scenario assumes that further cost reduction of small-scale electricity technology stimulates higher take up rates and accelerates investments.

Both small-scale wind power technology 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 scenario assumes a gradual phase out of small-scale wind power plants, with the lower level of the business as usual scenario 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.

The EU's water framework 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 scenario. In the higher level of the scenario the regulation is assumed to be adjusted in order to maintain the current levels of hydropower production.

7.1.2 ADDED POLICY SCENARIO

The *Added policy* scenario is based on political willingness to set a volume target and thus more oriented at the economic and technical potential for residential consumers to adapt the renewable technologies. For PV 100% of the estimated technical potential identified by the European commission 2017 can be set as a goal for the PV development and hence sets the higher level of the scenario.

The estimated technological potentials from previous studies are used as limiting factor of growth per technology and country, see Table 10. The economic potential is estimated for all power sources to be at least 50% of the technical potential, except for PV.

The technical potential for solar PV is estimated by the European commissions. 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 facede-mounted solar PV.

Table 10: 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)

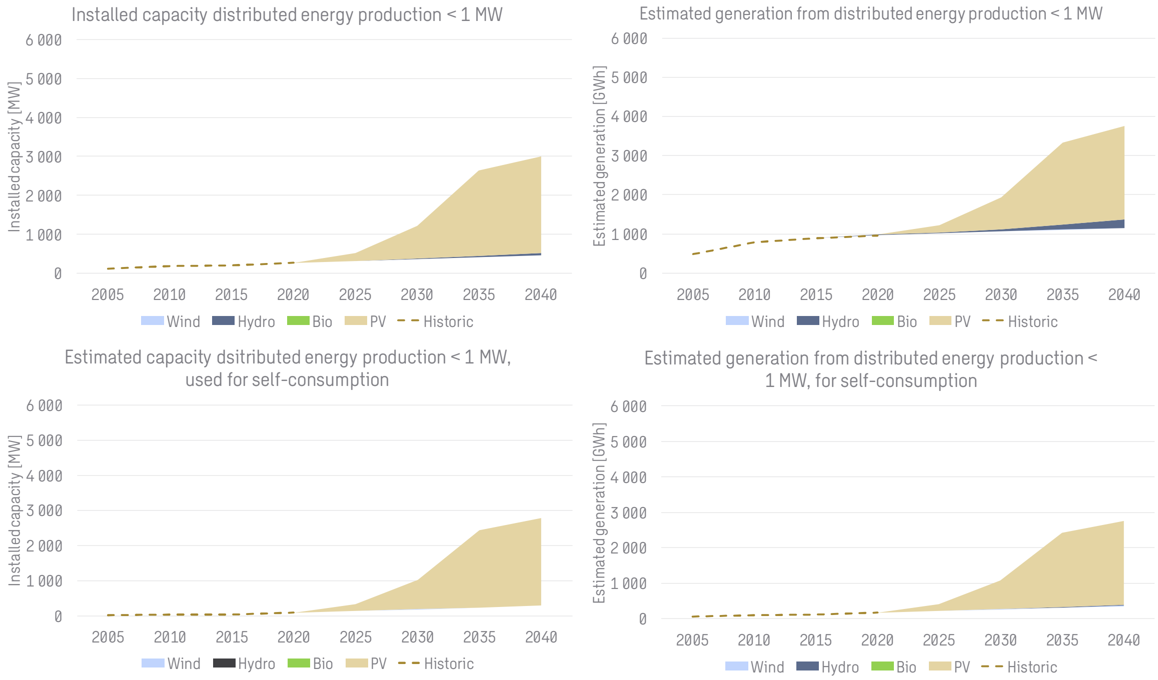
7.2 Norway

In the BAU scenario, electricity generation from distributed energy production (< 1MW) is increasing to about 1 500-4 400 GWh, see Figure 27. The installation of PV is following the historical trend from the past 4 years. This means that the installations of PV will reach 275 MW in 2040. Half the technical potential is 2750 MW which is the limiting factor on the BAU scenario.

Small-scale hydropower in Norway has doubled since 2005, with the EU water directive being expected to impact the future growth opportunities. The BAU scenario sketches a decrease in the installations rate and the lower level describes a scenario where the installation level is constant. The historic trend points at an increase to about 275 MW in 2040. The higher BAU level assumes that the number of installed small-scale hydro plants is affected by the end of the green certificates scheme and hence the installed capacity are set not to reach historic trend levels. The BAU scenario expects the installed capacity to be approximately 250 MW at the highest in 2040.

The growth rate in the small-scale Norwegian wind power has been low in the past ten years. The BAU scenario expects constant installed wind power capacity or a minimal increase based on the historical growth.

Figure 27: BAU scenario Norway



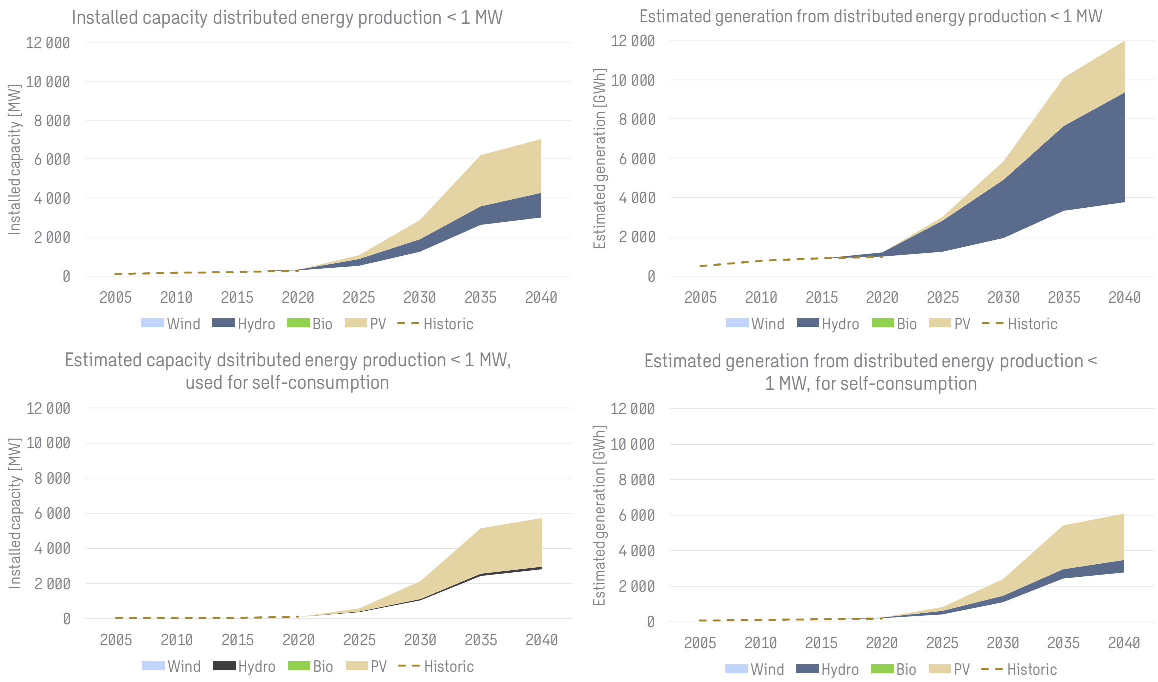
Source: Sweco

In the *Added policy scenario*, the estimated electricity generation from distributed energy production (< 1MW) could increase to about 4 200-12 000 GWh, see Figure 28. The technical potential of 5500 MW is the limiting factor for the Added policy scenario growth in PV installations. This means that the electricity production from PV (<1MW) in Norway could potentially reach 5225 GWh.

The 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 scenario, 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.

There are no political signals that the small-scale wind power should be actively developed further. Even if wind conditions are favourable in general and technical potential exists, we see only limited economic potential for small-scale wind power. The installed wind power capacity in the *Added policy scenario* has potential to a very limited growth.

Figure 28: Added policy scenario Norway



Source: Sweco

7.3 Sweden

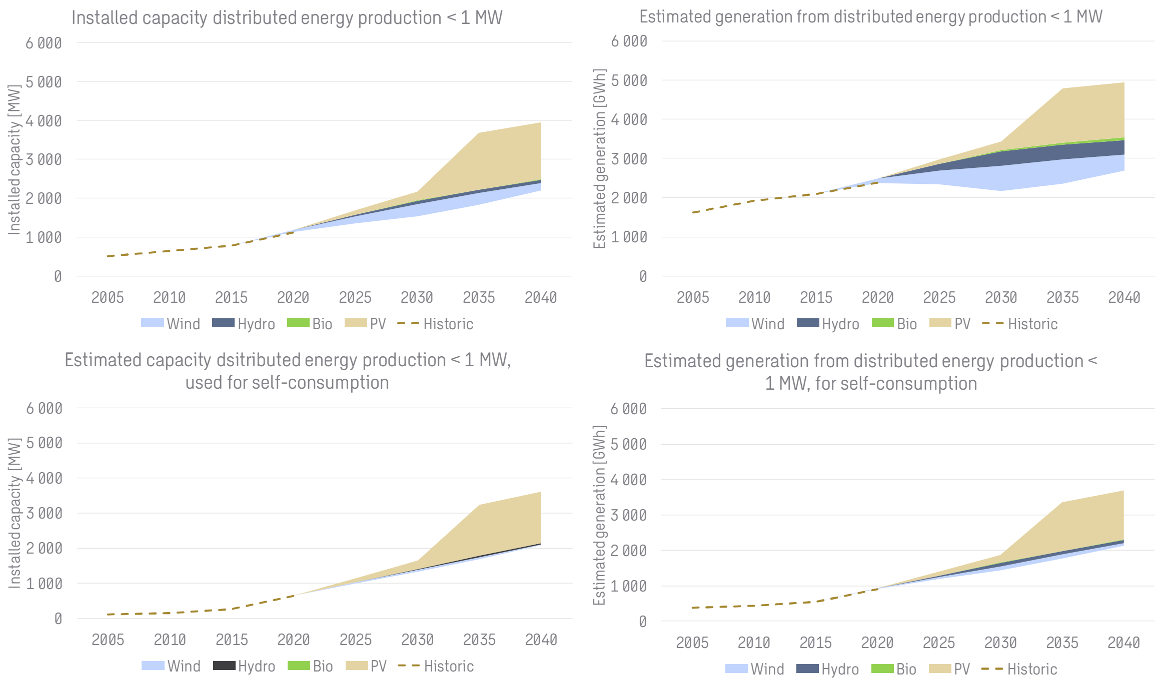
In the *BAU scenario*, electricity generation from distributed energy production (< 1MW) is increasing to about 1 800-4 900 GWh, see Figure 29. The installation of solar PV is following the historical trend of the past 4 years, reaching 2028 MW in 2040. Half the technical potential is 3500 MW which is the limiting factor on the BAU scenario.

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 BAU scenario shows a decrease in the number of installations rate and describes a scenario where the installation level is decreasing or is held constant at about 235 MW.

The number of installed small-scale wind power plants in Sweden that could be viewed 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 BAU scenario shows a scenario where the number of installed turbines is negligible, and the life time expectancy of the existing turbines ranges from 22-35 years.

The BAU scenario 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.

Figure 29: BAU scenario Sweden



Source: Sweco

In the *Added policy scenario*, electricity generation from distributed energy production (< 1MW) reaches about 5 000-9 000 GWh, see Figure 30.

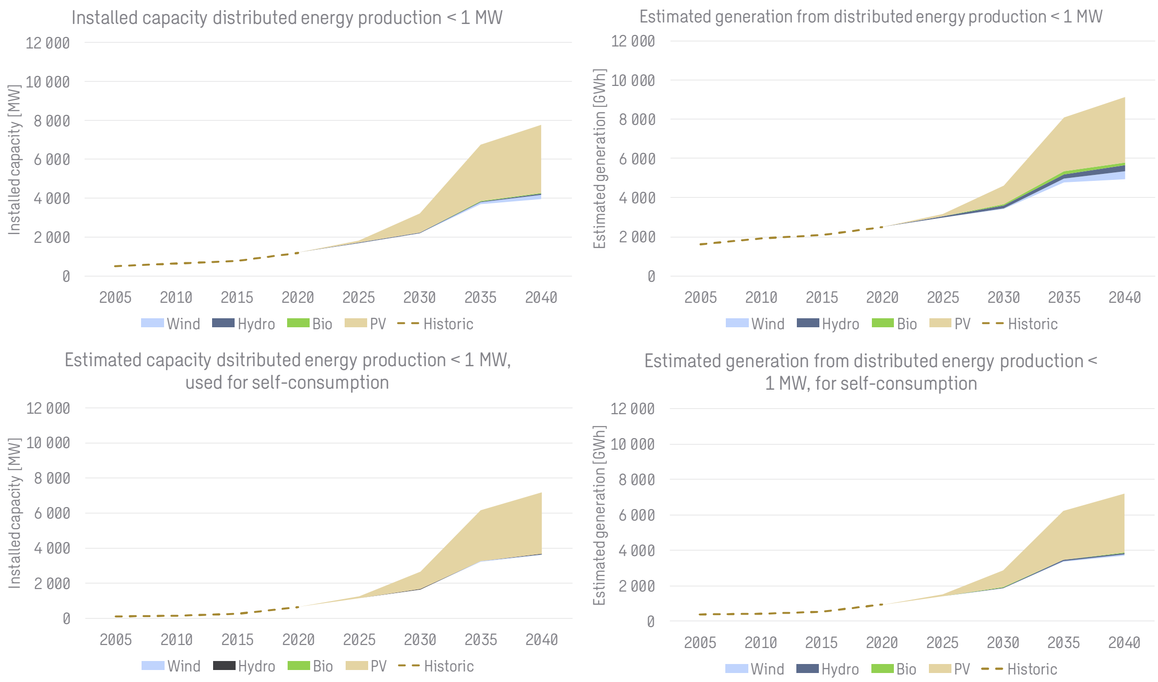
The technical potential of 7000 MW is still set to be the limiting factor for PV growth in the Added policy scenario. In our scenario, the electricity production from PV (<1MW) in Sweden could potentially reach 6650 GWh.

The technical potential for hydropower in Sweden is estimated by representatives in the small-scale hydropower association to be about 80% higher than the current installation levels. The *Added Policy scenario* 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.

Even in the *Added policy scenario* the levels of installed small-scale wind power in Sweden are held constant. The added policy is not assumed to be willing 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.

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 Added policy scenario expects the installed capacity to increase by about 84%.

Figure 30: Added policy scenario Sweden



Source: Sweco

7.4 Finland

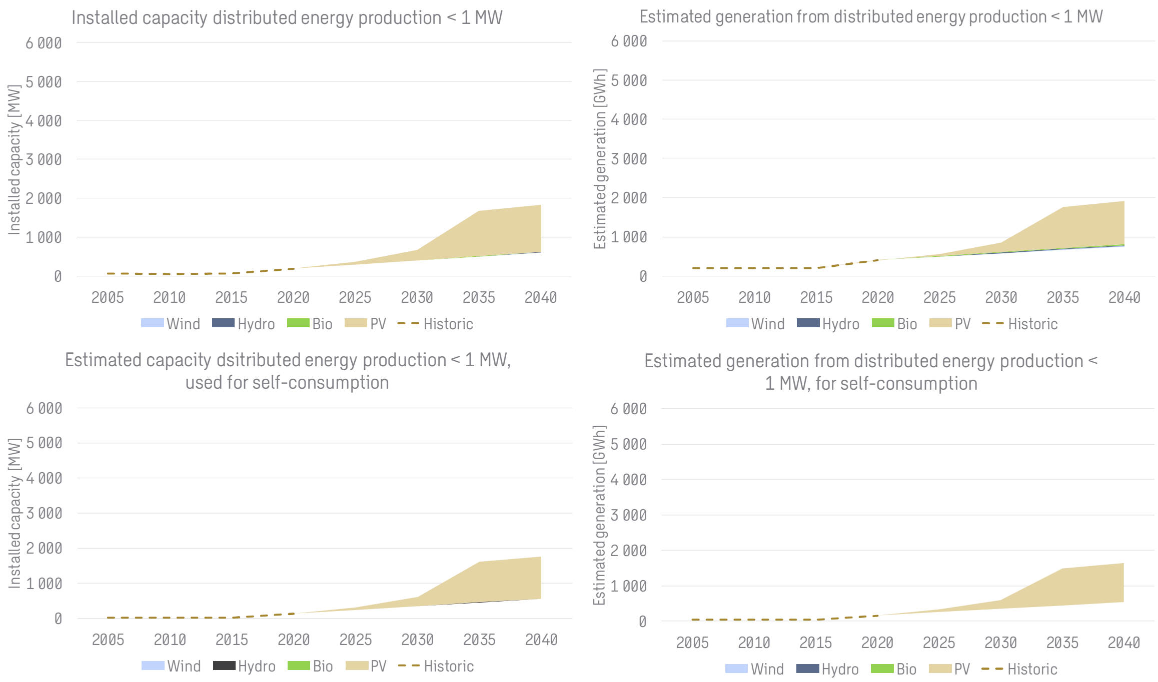
In the *BAU scenario*, electricity generation from distributed energy production (< 1MW) increases to about 800-1 900 GWh, see Figure 31. The installation of PV is following the historical trend from the past 4 years. This means that the installations of PV will reach 540 MW in 2040. Half the technical potential is 1750 MW which is the limiting factor on the BAU scenario.

There is no statistical reliable data for the small-scale hydropower in Finland. The EU water directive is expected to affect the future growth potential. The BAU scenario points at a decrease in the number of installations and describes a scenario where the installation level is decreasing (BAU low) or is held constant at about 36 MW (BAU high).

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 BAU scenario shows a scenario where the number of installed turbines is negligible, with an assumed technical lifetime of the existing turbines between 22-35 years.

The *BAU scenario* shows the number of small-scale bio energy plants to be constant or to increase with the same rates as the historical growth.

Figure 31: BAU scenario Finland



Source: Sweco

In the *Added policy scenario*, electricity generation from distributed energy sources (< 1MW) increases to about 2 000-4 100 GWh, see Figure 32.

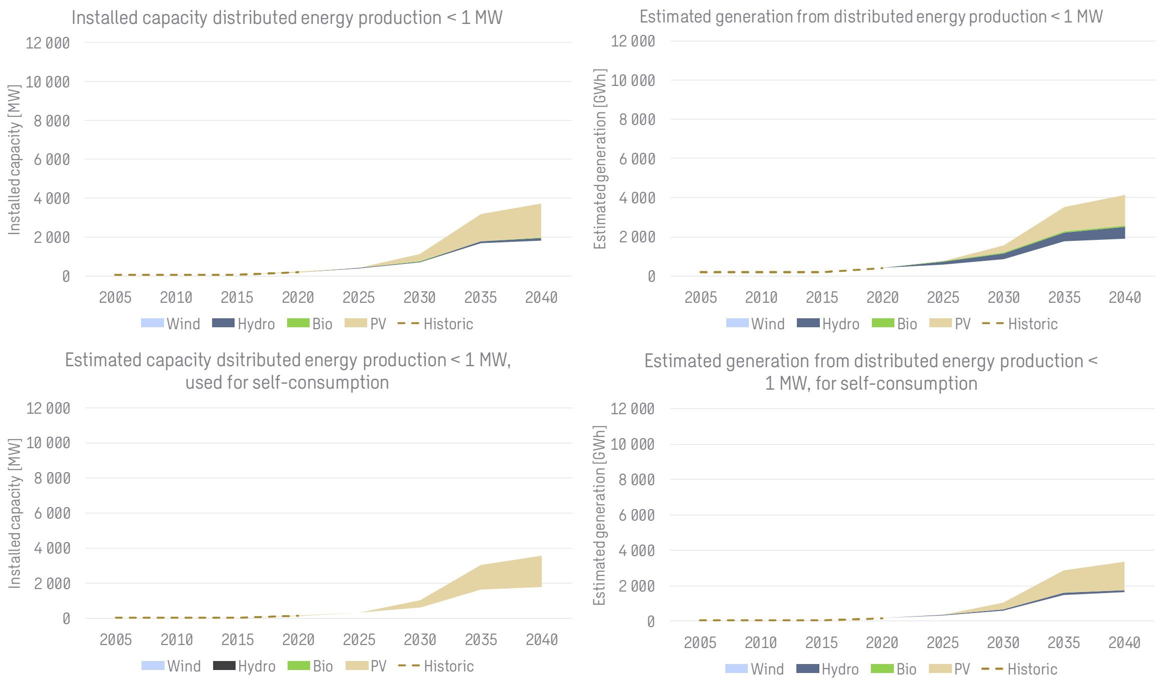
The technical potential of 3500 MW is used as the limiting factor for the Added policy scenario growth in PV installations. This means that the electricity production from PV (<1MW) in Finland could potentially reach 3150 GWh.

The technical potential for expansion of small-scale hydropower in Finland is estimated to be 340 MW. The Added Policy scenario expects that half of the unused potential is used for new installations in 2040. The total installed capacity would hence increase to about 170 MW in the *Added policy scenario*.

Even in the *Added policy scenario* the levels of installed small-scale wind power in Finland are held constant. The added policy is not assumed to be willing 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.

The *Added policy scenario* shows a development where the installed capacity in small-scale electricity from bioenergy is doubled.

Figure 32: Added policy scenario Finland



Source: Sweco

7.5 Denmark

In the *BAU scenario*, electricity generation from distributed energy 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 33. The timing of the decrease is depending on lifetime assumptions for these turbines.

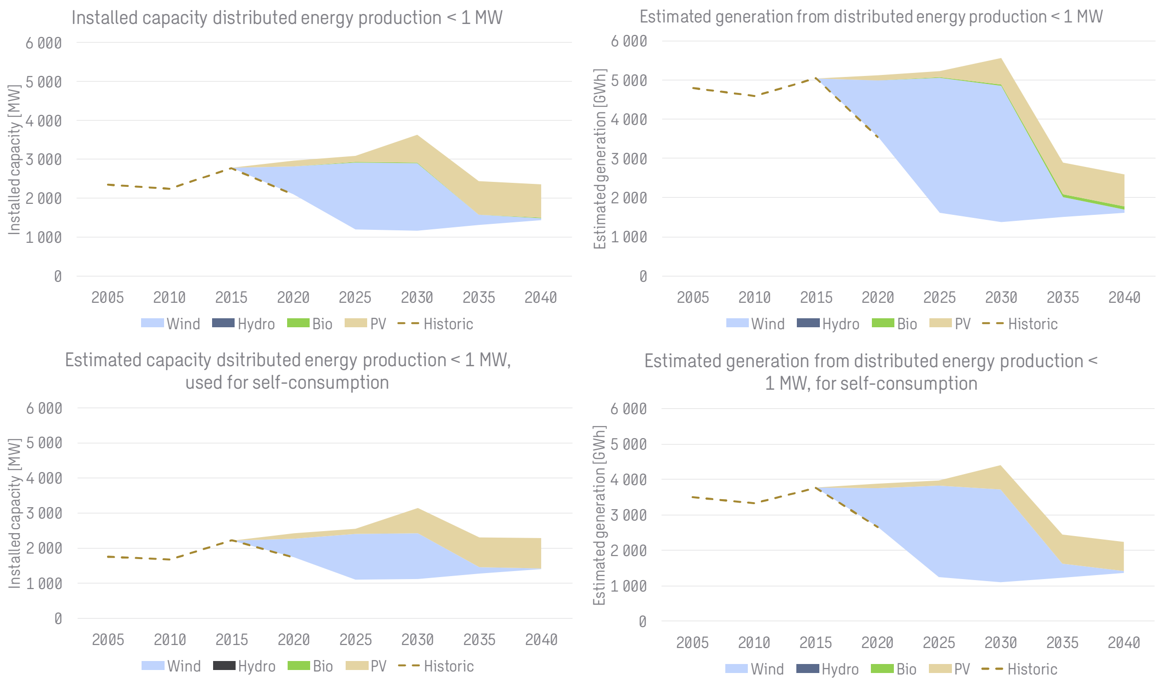
In the BAU scenario in Denmark, the installation of PV is following the historical trend from the past 4 years. This means that the installations of PV will reach 1490 MW in 2040. Half the technical potential is 2250 MW which is the limiting factor on the BAU scenario.

The small-scale hydropower in Demark is limited due to technical and geographical factors. The flat landscape is limiting the technical potential for hydropower expansion. The BAU scenario shows 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 decommissions rates and that there is a reduction of small-scale turbine capacity below 1 MW. The BAU scenario shows a scenario where the number of installed turbines is negligible, and the life time expectancy of the existing turbines are between 22-35 years.

The BAU scenario 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 network instead of electricity production.

Figure 33: BAU scenario Denmark



Source: Sweco

In the *Added policy scenario*, the estimated electricity generation from distributed energy production (< 1MW) is expected to be about 2 800-8 500 GWh, see Figure 34.

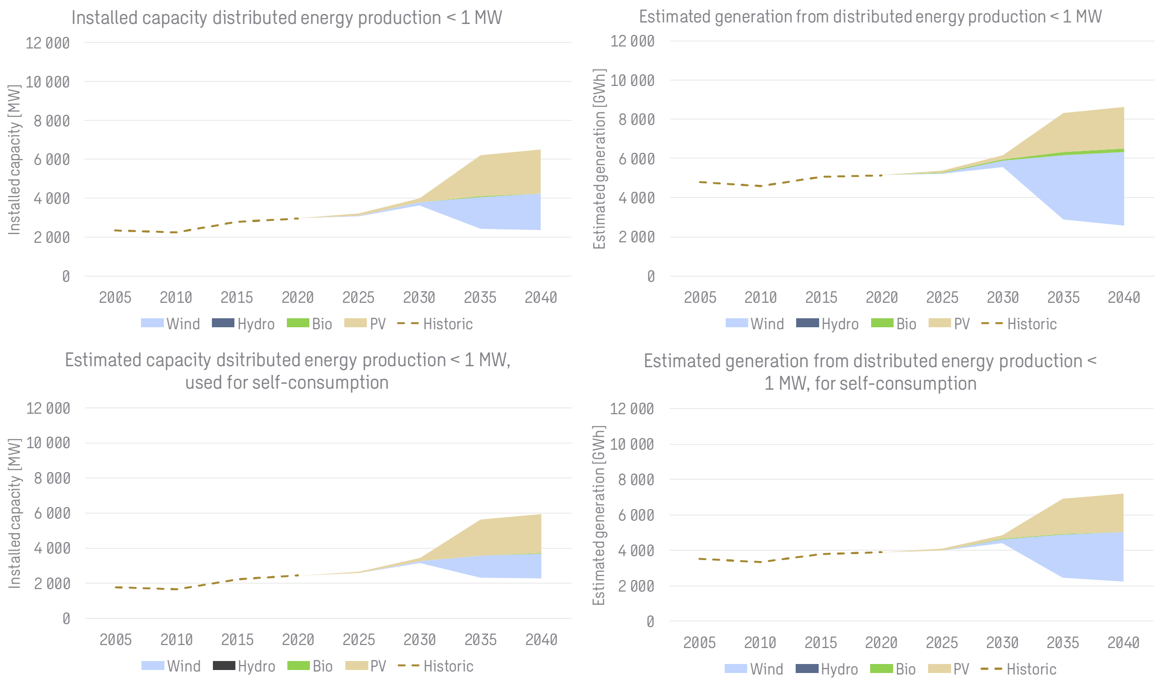
The technical potential of 4500 MW is set as the limiting factor for the *Added policy scenario* growth in PV installations. With these assumptions, the electricity production from PV (<1MW) in Denmark could potentially reach 4275 GWh.

Due to the technical and geographical limitations to install small-scale hydropower, the Added policy scenario shows a development where the installed hydropower is constant or shows a slight increase.

Even if the added policy would be used to support small-scale wind power, the *Added policy scenario* points at the levels of installed small-scale wind power in Denmark to decrease, but at a slower rate. The upper outcome level of the scenario shows a development where the installation level is close to the installed capacity in 2017.

The use of biogas in Denmark is equally split between electricity production and upgrading to the natural gas network. 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 *Added Policy scenario* shows a development where the installed capacity in small-scale electricity production is increased to 90 MW.

Figure 34: Added policy scenario Denmark



Source: Sweco

7.6 Iceland

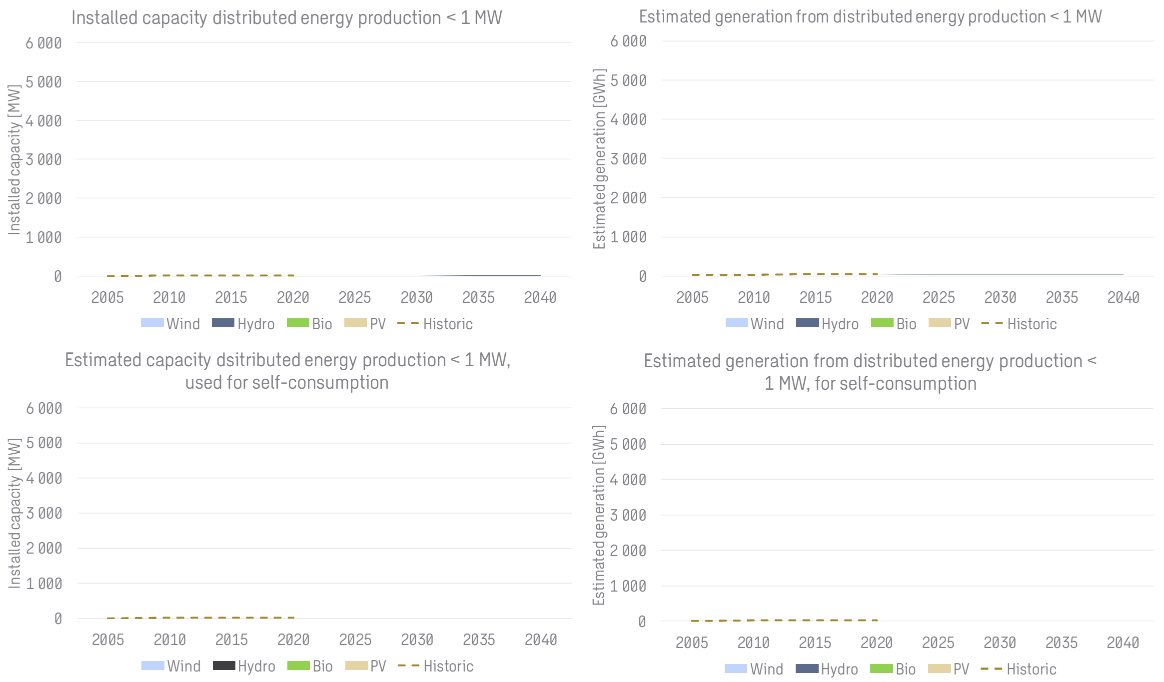
In the *BAU scenario*, electricity generation from distributed energy production (< 1MW) is expected to increase to about 45-65 GWh, see Figure 35.

In Iceland, the technical and economic potential for PV installations appears very limited. When the European commission calculated the payback time for PV installation on Iceland the average time in year 2030 was 64,9 years (European Commission, 2017). The development of PV on 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 BAU scenario.

There are only a few small-scale wind power projects on Iceland and the political will and public interested is a limiting factor in the BAU scenario. In this scenario, there are no expectations that the distributed wind power capacity would grow.

Figure 35: BAU scenario Iceland



Source: Sweco

In the *Added policy scenario*, the estimated electricity generation from distributed energy production (< 1MW) is expected to increase to about 60-80 GWh, see Figure 36.

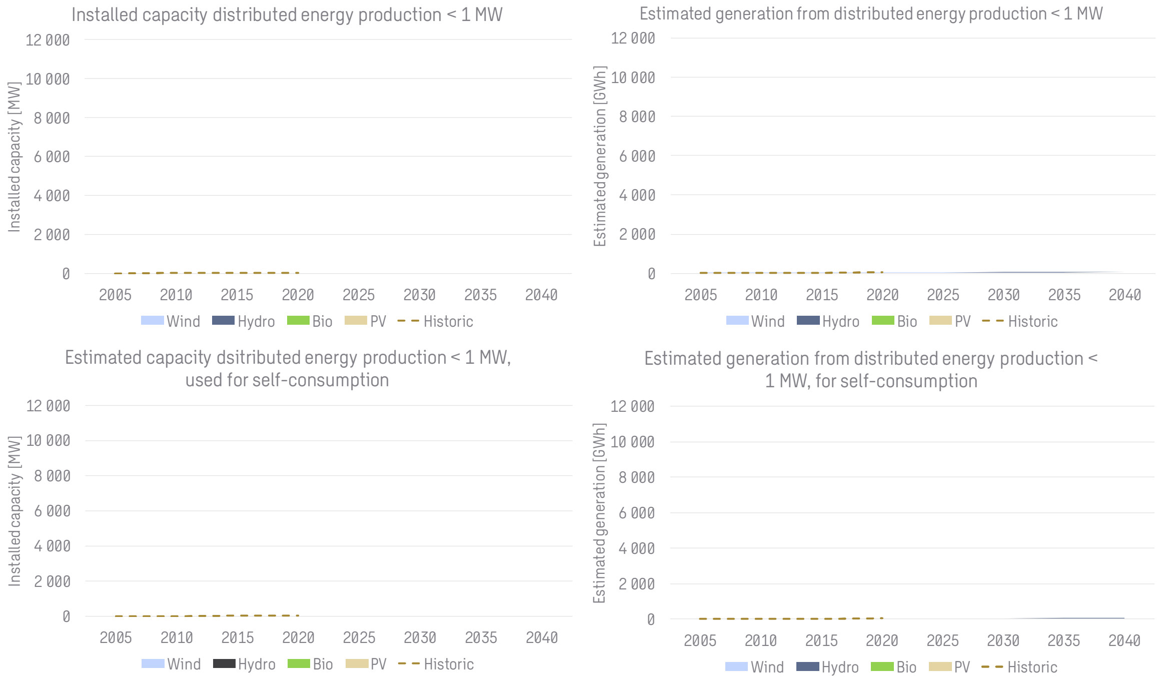
Once again there is no economic or technical potential for PV installations on Iceland. One possibility could be small-scale off-grid solutions, but these are not considered in this analysis. The development of PV on Iceland is hence set to zero (European Commission, 2017).

In the *Added policy scenario*, the installed capacity in small-scale hydropower is set to double and reach 20 MW in 2040.

The distributed wind power capacity is not expected to grow in the Added Policy scenario due to envisaged low public interest.

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

Figure 36: Added policy scenario Iceland



Source: Sweco

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Appendix