Case study report Norway

Findings from case studies of PV pilot Trøndelag, Smart Energi Hvaler, and ASKO Midt-Norge

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CONTENTS

PREFACE 5

1 NATIONAL CONTEXT FACTORS 6

1.1 COUNTRY PROFILE OF NORWAY 6

1.2 THE NORWEGIAN ENERGY SYSTEM 6

1.3 POLICY AND REGULATION OF THE ENERGY MARKET 7

1.4 MARKET STRUCTURE AND ENERGY CONSUMPTION 11

1.5 THE SMART GRIDS LANDSCAPE IN NORWAY 12

2 NORWEGIAN CASE STUDIES 14

PV Demonstration Trøndelag ....**Fejl! Bogmærke er ikke defineret.**

Smart Energi Hvaler ....**Fejl! Bogmærke er ikke defineret.**

ASKO midt-Norge ....**Fejl! Bogmærke er ikke defineret.**

2.1 CASE 1: PV DEMONSTRATION TRØNDELAG 16

2.1.1 Background and project characteristics.......................................16

2.1.2 Socio-technical configurations applied in the project 17

2.1.3 Discussion: Success and outcomes 19

2.2 CASE 2: SMART ENERGI HVALER 20

2.2.1 Background and project characteristics.......................................20

2.2.2 Socio-technical configurations applied in the project**Fejl! Bogmærke er ikke defineret.**

2.2.3 Discussion: Success and outcomes 25

2.3 CASE 3: ASKO MIDT-NORGE 20

2.3.1 Background and project characteristics.......................................26

2.3.2 Socio-technical configurations applied in the project 27

2.3.3 Discussion: Success and outcomes 31

3 LITERATURE 33

About ERA-Net Smart Grids Plus

ERA-Net Smart Grids Plus is an initiative of 21 European countries and regions. The vision for Smart Grids in Europe is to create an electric power system that integrates renewable energies and enables flexible consumer and production technologies. This can help to shape an electricity grid with a high security of supply, coupled with low greenhouse gas emissions, at an affordable price. Our aim is to support the development of the technologies, market designs and customer adoptions that are necessary to reach this goal. The initiative is providing a hub for the collaboration of European member-states. It supports the coordination of funding partners, enabling joint funding of RDD projects. Beyond that ERA-Net SG+ builds up a knowledge community, involving key demo projects and experts from all over Europe, to organise the learning between projects and programs from the local level up to the European level.

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Preface

This report is the outcome of work package 2 *Detailed case studies of the ERA-Net Smart Grids Plus project Markets, Actors and Technologies: A comparative study of smart grid solutions* (MATCH), which involves partners from Austria, Norway and Denmark.

The aim of MATCH is to explore how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. This is studied on basis of detailed national case studies carried out in each of the three participating countries. This report (MATCH deliverable D2.3) presents the main findings from the Norwegian case studies.

The national case studies establish the empirical foundation for the comparative analysis across cases and countries in work package 3 *Identifying determining factors for integrated and successful smart grid solutions* and for the later work package 5 *Recommendations for designers, planners and policy makers*. The deliverables from these work packages will be published on the website of MATCH (http://www.match-project.eu/), which also includes further information about the project and its other publications. The latter includes coming scientific papers that are going to explore differences and similarities between cases in further detail in relation to specific research questions.

The empirical work in relation to the national case studies was guided by an analytical framework developed in the MATCH work package 1 *Design of overall analytical framework for case studies*. This deliverable (D1) can be downloaded from the MATCH website. The framework combined different theoretical perspectives in order to establish a shared understanding of how we should approach the cases and what kind of data to collect. This ensured a certain degree of empirical homogeneity between the national case studies.

In order to support the comparative analysis, the national case study reports (D2.1-D2.3) follow the same outline. Thus, in the following, we will first present the national context of the Norwegian case studies (Chapter 1). This includes a brief introduction to the national profile of Norway in addition to a presentation of the Norwegian energy system, policies & regulation, market structure & energy consumption and, finally, the smart grid landscape. Then follows the main part of the report (Chapter 2), which presents the outcome of the Norwegian case studies. A brief description of the empirical work carried out introduces this chapter, and is followed by three sub-sections presenting the findings from the three national cases: Two solar PV demonstration projects in Trøndelag by the two energy companies in this region, TrønderEnergi and Nord Trøndelag Energi (section 2.1), Smart Energi Hvaler on the archipelago of Hvaler (section 2.2) and a large solar pilot driven by ASKO midt-Norge, which is an SME dealing with wholesale of groceries (section 2.3). Each of these case presentations is organised in three sub-sections: Background and project characteristics; socio-technical configurations; Discussion of successes and outcomes.

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Trondheim, 17th November 2017

1 National context factors

1.1 Country profile of Norway

The kingdom of Norway is situated on the Scandinavian Peninsula and has an area of 323,802 km^2 and a population of 5,258,317 as of January 2017. Apart from the mainland, the country also consists of the island of Jan Mayen and the archipelago of Svalbard, the inclusion of which makes the total area of the country 385,252 km^2. Norway shares a long border with Sweden, and borders Finland and Russia to the northeast and Denmark across the strait of Skagerrak to the south. Its coastline, meandering along bays and fjords, stretches for 28,953 km. If including the 239,057 registered islands, the total coastline is 100,915 km long, the second longest in the world after Canada (SNL 2017). Norway reigns over 1,979,179 km^2 of ocean divided into three areas including the mainland economic zone (878,575 km^2) and fishing zones near Jan Mayen (293,049 km^2) and Svalbard (803,993 km^2, see Kartverket, 2017).

Norway is sparsely populated, due to its large and geographically uneven territory. It is a very long and narrow country, and stretching 2562 km from 57° north at its southernmost point to 71° north, the country is host to the polar circle at 66°. As much of the country is mountainous, permafrost can be found all year in the higher areas, together with numerous glaciers. Because of its location far to the north and the length of the country, it experiences a wide variety in climate and daylight conditions. Due to the Gulf Stream however, which travels along the coast of Norway on its way to the arctic sea depositing warm weather along the way, Norway’s climate is warmer than it would have been thus far north. In the northernmost parts, it exhibits a maritime subarctic climate, but the southern regions have weather not that different from central Europe. The country has four distinct seasons, enjoying pleasant if somewhat short summers compared with southern latitudes. Daylight conditions is another aspect which is influenced by the northern placement, and even the southern regions experience only a few hours of daylight (~0900-1500) in winter and almost no darkness during night in the peak of summer. In the north, these conditions are more extreme, resulting in no daylight at all during winter solstice, but never ending days in mid-summer.

In spite of a steadily ageing population it is still increasing slightly. About half of the increase consists of immigration. Norway has about 2.3 million households with an average of 2.2 persons. The home is the primary object of investment for a majority of households, resulting in a very high home ownership. It is estimated that 4.2 million live in owned housing (SSB 2017a). The majority of housing arrangements consist of single-family detached dwellings (52.9%). The second most common living arrangement are multi-dwelling buildings (22.7%) followed by row houses (11.8), semi-detached (9.2), and other residences (3.4%).

Norway is a constitutional monarchy, and divides state power between parliament, cabinet and supreme court as defined in the constitution of 1814. Current head of state is King Harald V and the prime minister is Erna Solberg. Norway has administrative and political subdivisions on two levels, and consists of 426 municipalities across 19 counties. Although not a member of the European Union (membership was dismissed by referendums in 1972 and 1994) the nation remains in close collaboration with it as well as the United States. In lieu of a membership in the EU, Norway maintains ties through the EEA-agreement, which makes the country a member of the European Economic Area, requiring it to adopt EU law and regulation in a fashion more or less similar to that of the other EU members. In practice Norway has had its policies on financial affairs, foreign policy, social affairs, infrastructure, energy, and climate influenced by EU to a comparable degree to the rest of its nations. Through the EEA-agreement, Norway is mandated to let the European Free Trade Association (EFTA) Surveillance Authority, and in a last resort the EFTA-court, ensure that Norwegian authorities and other entities act in accordance with the agreement. Norway does not have veto powers over the EU, as the Storting, which is the Norwegian Parliament, may decide whether rules and regulation shall be accepted. This is called the reservation right, and has only been used once[1]. Apart from being a founding member of the UN, NATO, the European Council, the Organisation for Security and Co-operation in Europe, and the Nordic Council, the country is a member of the World Trade Organization, Organisation for Economic Co-operation and Development, and a part of the Schengen area. The country is part of the EU Emission Trading System and it has signed the Paris Agreement and reported an Intended Nationally Determined Contribution (INDC) with a commitment to reduce absolute greenhouse gas emissions by at least 40 % by 2030 compared to the 1990 level.

Norway has experienced a strong economic development during the last few decades. It bases its economy on oil, gas, mining, timber, seafood, and hydropower. The basic development of the Norwegian economy the last 100 years can be ascribed mainly to hydropower, but the rapid increase in this development the last 50 years is due to oil and gas production and adjacent sectors, which today contributes about a quarter of GDP. The GDP of Norway is thus quite sensitive to the fluctuations in oil prices, which have been prevalent in the last few years. GDP per capita is currently around $74,000, owing largely to the country's role as the world's third largest exporter of oil and gas (IEA 2011). Between 1990 and 2015, the disposable per capita income increased by 89 %, and by the end of the 2000s Norway had become the one member of the OECD countries with the highest per capita income (SSB 2016c). The oil and gas exports have been an important engine in this development. High employment rates, a positive development of real wage rates and private consumption, a relatively equal distribution of economic wealth, strong public finances combined with a well-developed welfare state, are all characteristics of this prosperous period. The period seems to have come to a temporary halt with the drop in the oil price that was experienced in 2015, which resulted in lower activity and layoffs in the oil sector, and with some effects in other sectors. Increasing international instability also add to the uncertainty regarding future development. Even so, the Government Pension Fund Global, consisting of offshore industry revenue and subsequent investment profits, has acted as a buffer to worldwide economic fluctuations. The ability of politicians to use it for covering budget deficits has effectively insulated the Norwegian economy from the latest crises. The value of the fund today stands at around € 800 billion.

In order to describe the context for smart energy technology in Norway, the following will give a short review of recent history. Norway is large in area relative to its population and a wide range of energy resources are available. A long coastline gives potentials for wind, wave and tidal energy, while the inland adds waterfall and biomass resources. Substantial offshore oil and gas resources complement the energy endowment. However, most of this is exported and not a part of the energy system or, in official terms, the carbon footprint. The energy sector in Norway is dominated by two main areas, hydropower and oil/gas.

1.2 The Norwegian energy system

Hydropower
The utilization of hydropower developed through the 20th century and with an increased focus after WW2. This laid the foundation for the power-intensive industry within metals, chemicals, fertilizers etc., brought industrial development to the nation, including rural communities, and created the foundation for the modern Norwegian energy system. Important institutional principles, such the concession system with the reversion principle (ownership of waterfall resources returns to the Norwegian state after the concession

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[1] The dispute was about letting foreign offshore helicopter transport companies operate on the Norwegian continental shelf, as well as granting responsibilities for supervision of such operations to international authorities. The Norwegian authorities dismissed the so-called Helicopter Offshore Regulations based on having no relevance for activity on Norwegian soil, and concern that the new regulation would pose inferior to the existing one (see http://www.tv2.no/a/9148446/)

period) and the system of concession power, which ensures direct economic benefits to municipalities which provide waterfall resources to outside businesses, were established in this period.

The big expansion in hydropower capacity took place during the 1950 – 1990 period. In addition to supplying energy to the expanding heavy industry, thus driving the modernization of the nation, it also made available cheap and reliable energy for other sectors of society. This opened the way for an expansion in the use of electric equipment and appliances in these other sectors, and it resulted in a widespread use of direct electrical heating systems in the building sector. Such heating systems are inflexible in terms of energy carriers, and this dependence on electric energy has become a major issue regarding energy security in Norway. The fact that Norway is second only to Iceland in terms of per capita electricity consumption, illustrates this dependence on electric energy. Even so, the latest building regulations have, after a period of focus on alternative means of heating, resigned to a lenient stance towards direct electric heating, as it makes sense in the Norwegian market context of cheap, clean hydropower.

Through most of the 20th century the production and distribution of electric energy was mostly publicly owned, and as an effect of the strategic role of this sector in the industrial sector after WWI, it was heavily regulated through a complex of legislation. Local monopolies, differences in investment strategies, etc. had led to an inefficient energy system with an overinvestment in generation capacity. A centrally controlled and regionally administered electricity system, investment decisions and prices were decided by parliament on a yearly basis. Counties had their own electricity utility responsible for a guaranteed supply. Prices were held constant with the help of price subsidies, meaning that new generation was paid for with income from existing ones. Whenever the demand would catch up with supply, this would spur generation expansion. There was no market, and a single entity was responsible for production, transmission and sale of electricity to customers.

The work commissioned in 1980 by the government and led by Professor Einar Hope at Centre for Applied Research in combination with the ascendancy of a center-right government in 89, paved the way for a reform of the energy system with a strong focus on market economic principles (Karlstrøm 2012). Hope and his team described through more than 60 reports the system that would be implemented during the deregulation process. Production and distribution capabilities were separated, and a spot and futures market were established. The spot market would function as the mechanism for setting the prices, and the futures market allowed for insurance against fluctuations in price and quantity. Different contract schemes were introduced both in long and short-term variants, futures trading and separation of production and distribution was meant to introduce better price signaling to consumers, and thereby improve basis for investment decisions. A strict income regulation was mandated on the distribution monopolies. With the new energy law of 1991, Norway became one of the first countries in Europe to deregulate the electricity market and establish market principles as the basis for energy production, trade and investments. The new market model was soon made to include the rest of the Nordic countries, and the introduction of a common Nordic spot market for electricity.

Most low-hanging hydro resources are utilized by now, remaining potential large scale projects in general have too high environmental costs to be developed. Realistic potential new hydropower projects are therefore mostly related to smaller scale and local developments.

Oil and gas
Another main energy political area in Norway is the oil and gas sector. This industry developed from the 1970s on, primarily off the shores of southern/western Norway. During this period, the country became among the largest global exporters of oil and gas. Related supply industries and technology development followed the expansion of the offshore industry, and became important parts of the general industry structure of the country. In addition, revenues accruing from exports of oil and gas became very important in the state finances. A large proportion of this public income stream has been set aside in a designated investment fund (The Government Pension Fund Global). The political discus-

sion related to the future development of this industry reflects the uncertainties introduced with the climate issue, and the key question is whether to expand and continue developing this industry, possibly into the risky waters of the Arctic, or to downscale and leave most of the remaining resources in the ground. In the latest development, several environmental organisations have engaged in a civil suit against the government for pushing development in the far north, citing constitutionally embedded laws on the environment[2].

Other market developments

A common Swedish-Norwegian green certificate system was introduced in 2012, designed to add 28 TWh new renewable electricity into the system by 2020 (this volume represents around 10 % of the current normal year's production in the two countries). Most projects are realized as wind and CHP projects in Sweden, and as new hydropower in Norway. A number of concessions have already been granted for onshore wind farms, but low electricity prices have yet to make such projects economically viable, and the concessions have been shelved. The short-term effect of this instrument is to increase the surplus of electricity in the Scandinavian system, and thus to maintain the low spot market price of electricity that has been observed in the last years.

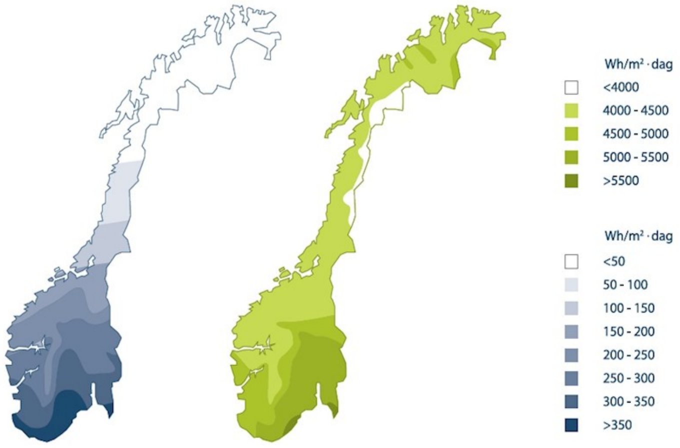

Figure 1: Solar radiation against a horizontal area in January (left) and july (right)

Solar PV has long been a common addition to Norwegian vacation homes, the cabin, typically located in sparsely populated and extremely rural areas far away from any kind of infrastructure. Traditionally, these types of solar panels have not been connected to the grid. In later years however, solar energy has become more common as prices have reduced, both in residential and industrial contexts. Once again, the reason for the low influx of solar in Norway in the past has mainly been because of low energy prices, making investments into panels economically prohibitive, compared to for instance Germany. But as of 2016, the amount of new solar installed in Norway was 11 MWp, which represented a growth of 366% compared to 2015. 10% of this was not connected to the grid. The total aggregated power capacity was increased by 75% compared to 2015 and amounts to around 27 MWp at the end of 2016. The share of this that was connected to the grid is 13,6 MWp – around 10 GWh/year. A Norwegian solar panel can usually produce around 700-950 kWh/KWp. In other words, the solar influx is higher than expected for such Northern latitudes (see figure 1), and adding to the feasibility is the relatively cold weather, which works to increase the efficiency of most panels. There are also extensive support schemes and subsidies in place to further the proliferation of solar in Norway. For instance, Enova, the Norwegian energy authorities, will typically grant £1,000 for a production rig plus €125 per kW up to a total of 15 kW, but not more than 35% of total costs. There are no other requirements.

Bioenergy resources, used as traditional firewood, in central heating systems, or as biofuels, are not utilized near their potentials today. As a broad "landscape overview", we may therefore conclude that Norway is a country rich in energy resources. It is a large exporter of oil and gas and with a domestic energy system built around a plentiful supply of cheap and clean electric energy.

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[2] https://www.tu.no/artikler/dette-blir-konsekvensene-om-staten-taper-den-historiske-rettsaken/411646

The current structure of the Norwegian energy system
The Norwegian transmission system is divided into three levels, the central grid, the regional grid and the local, distribution grid; however, according to EU rules there is an ongoing process to merge the two lower levels. The central grid is high voltage transmission based on 300 or 420 kV, and is used to transfer electricity throughout the five Norwegian market areas as well as across national borders. The central and regional grid is operated by TSO Statnett, and some of the regional and distribution levels are served by 129 DSOs. International interconnectors are established between Norway and Sweden, Finland, Russia, Denmark, and the Netherlands, and there are interconnectors to Germany and Britain planned (Cigre, 2014). Total production in 2015 was 145 TWh, 95.8% of which was due to hydropower. Thermal power and wind generation represented 2.5% and 1.7% respectively. Norway imported about 7.4 TWh, whilst exporting 22 TWh. Gross domestic consumption was 129.8 TWh, and the net was 120 TWh. In 2015 Norway had 1065 power stations with a total output of 33 837 MW (SSB 2017b).

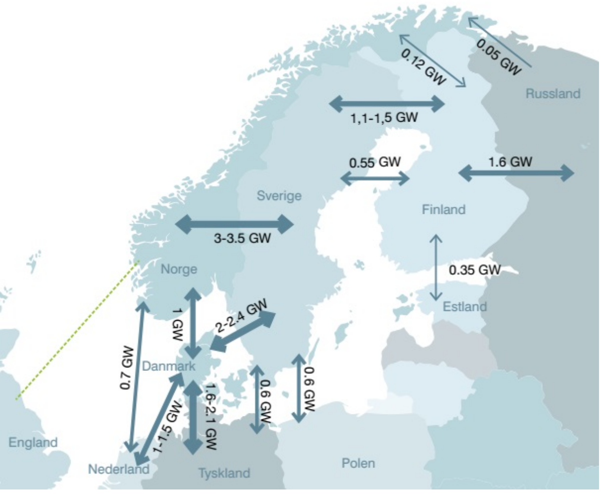

Figure 2 The Norwegian and surrounding transmission systems (Source: Statnett)

Due to the presence of huge hydropower resources in the country, it poses a rather unique case in a European or even global perspective. Half of the energy used on the mainland is based on electricity, and close to all of that is renewable. Since its deregulation in the region in the 90s, the power markets were consolidated on a common Nordic power trading market called Nordpool. Electricity is generally difficult to store, but in case of hydropower this is possible by trapping water behind a dam, in principle making it possible to turn on and off the power supply according to demand. Norway also imports power in low-price periods to conserve the stored capacity, and it will ideally be made use of only when demand is high. Low-price periods can also be used to pump water back into the magazines, however the extent to which Norway does this is not extensive (only two facilities, 640 and 56 MW). The versatility of hydropower makes it suitable for base load regulation. This makes the hydropower quite valuable in the market, and there are often talks about developing the role for Norway as a “green battery” in the European system, and provide much needed stability for a wider introduction of renewable energy and displacing coal and gas. This might however be unrealistic, mainly for two reasons: the total Norwegian foreign transfer capacity is about 4-5 GW, which represents only 10% of the load demand for solar during dinnertime in Germany. In addition, the capacity of Norwegian hydropower in total is about 33 GW. An optimistic share of this of about

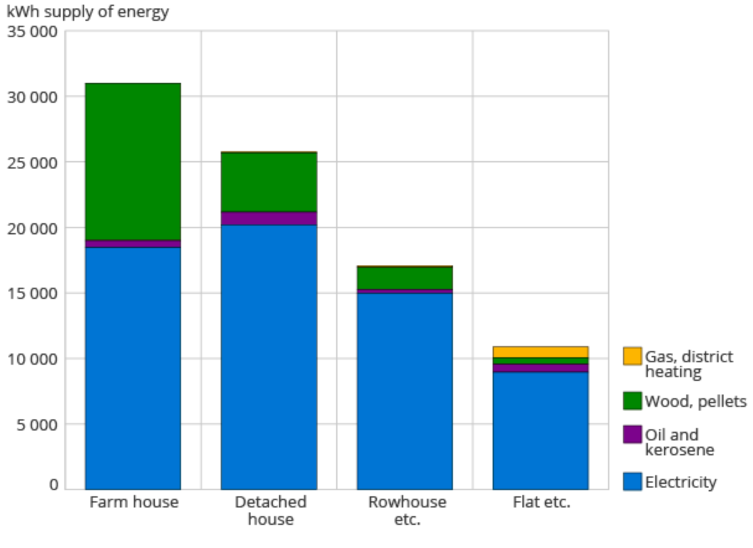

Table 1 Distribution of consumption by energy source and type of house (Source: Statistics Norway)

20-30% would still be a tiny contribution on a German scale (Bendiksen 2014). This is not to say Norway does not supply energy to the Nordpool spot market in terms of kWh over the import/export balance, which it does in large quantities as mentioned above.

When it comes to Norwegian CO2 emissions, these are often considered negligible because of the high penetration of renewable energy. This is, however, not entirely true. Emissions per capita in Norway in 2013 were 11.7 tons/year, higher than both Denmark (6.8) and Austria (7.4) (The World Bank 2013). Total emissions from Norwegian territories in 2015 were 53.9 million CO2 equivalents, a 4.2% increase since 1990. Of this, 15.1 and 11.9 come from oil and gas extraction and industries/mining respectively. The second largest culprits in the Norwegian economy is road traffic and other kinds of transport like aviation and navigation (i.e. fishing), netting 10.3 and 6.4 million CO2 equivalents respectively. Agriculture is another contributor, with 4.5 million CO2 equivalents, whereas the energy supply itself and heating in households and industry amount to 2.9 (SSB 2017c).

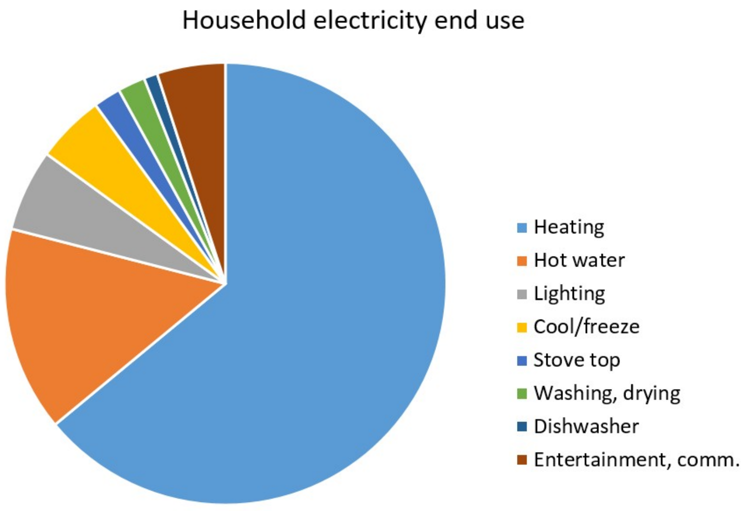

Figure 3 Electricity use based on source of consumption (Source: REMODECE)

As mentioned earlier, the prevalence of cheap, reliable, clean electricity in Norway makes it the preferred source for most anything, even heating. Even so, there is a tradition for using wood burners for space heating, as can be seen in Table 1. As shown in figure 3 (based on household measurements), space heating (64 %) represents the one dominating end use of electric energy in the household sector. This reflects both the cold Nordic climate and the characteristics of the energy system, discussed above. Addressing the use of direct electrical heating in buildings therefore is one of the priorities of Norwegian energy policy in an energy efficiency context.

1.3 Policy and regulation of the energy market

The national energy policy rests on two fundamental documents: first, there is the 2008 “Climate agreement”, a consensus document endorsed by a majority of the political parties represented in the Norwegian parliament, recognizing the challenge of climate change and specifying climate goals. Goals include reducing *global* emissions equivalent of 30% of Norwegian 1990 levels, as well as reaching carbon neutrality by 2050[3]. Second, a white paper published in 2016 on energy policy toward 2030 both reinforces and adjusts the main lines in national energy policy. The paper specifies four main goals for energy policy: (i) Enhanced security of supply, (ii) Efficient production of renewables, (iii) More efficient and climate- friendly use of energy, and (iv) Economic growth and value creation through efficient use of profitable renewable resources (Meld. St. 25, 2016).

The electricity production in the Norwegian energy system is, as mentioned, already mostly renewable. Reducing GHG emissions from electricity generation is therefore not the major motivation for energy efficiency, although exported surpluses may replace fossil fuels based electricity generation in the European market. On the other hand, development of both hydro and wind power installations will have negative local and regional

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[3] https://www.regjeringen.no/no/tema/klima-og-miljo/klima/innsiktsartikler-klima/klimaforliket/id2076645/

environmental effects, and most new projects are controversial on these grounds. Avoiding the need for some of these potential projects is therefore desirable. Energy efficiency is therefore considered a general tool for strengthening both the economic and the environmental sustainability of the energy system. The goal of enhanced security of supply reflects challenges inherent in the basic design of the Norwegian electricity system. It partly reflects an energy availability issue as determined by the reservoir filling (a factor determined by precipitation rates), as well as availability of imports.

A more pressing issue is related to the load profile of the electricity system. The locked-in dependence on electric energy, also for heating, poses a challenge in terms of power capacity. Furthermore, the typical morning and afternoon power peaks are not expected to be dampened as the number of induction tops and EVs continues to increase. In addition, in periods with cold weather, the need for electricity-based space heating causes an additional spike in demand. "Security of supply" therefore is mostly a matter of managing the power needs in this context. Energy efficiency (i.e. load reduction), load shifting with the aid of demand response measures, and conversion to non-electricity based heating systems are principal measures for improving security of supply. In other words, this is not about balancing demand and production on the grid, which can easily be handled by flexible hydro production. Rather it is a challenge of managing the load of an electricity grid with capacity limits. This is different from for instance the Danish context, where grid capacity has been "over-invested" in, and the challenge instead lies in issues of stability and large amounts of fluctuating renewable energy.

The last of the Norwegian energy-political goals poses a strategic challenge. The long-term fate of the oil and gas industry is becoming more uncertain, seen in light of the climate issue and the Paris agreement. If the large national incomes generated in this sector should be drastically reduced, and the current level of national welfare be maintained, it would be necessary to replace this income shortfall by value generated in other sectors of the economy. Given the low energy intensity in the creation of economic value in the oil and gas sector, this transition would imply a need for a substantial increase in electricity generation. The need for energy efficiency is obvious in this scenario. The built environment – existing building stock – is a large potential source of energy efficiency measures. The passive qualities of the building stock (insulation level and air tightness of climate shell) together with technical installations are keys in energy use in this sector, although the behavioral aspects of the user of the building also matters significantly.

1.4 Market structure and energy consumption

The Norwegian energy grid is divided into five areas, south-eastern Norway, south-western Norway, western Norway, central Norway, northern Norway (Statnett SF 2013). This means that there are different electricity prices in different parts of the country depending on supply and demand in each area. This is of course due to the market based system of selling and buying power, which in turn produces a market based system for handling bottlenecks which arise in the grid as a result of the different elspot areas. The Norwegian Transmission System Operator, Statnett SF, is obliged by regulation to divide Norway into these five elspot areas as it is a method of handling expected energy shortage in a geographically restricted area and to handle large and prolonged bottlenecks in the regional and central grid.

Thus, the price is not regulated by authorities, but is a result of supply and demand within the specific market area, which is reported to the power exchange. Thus, the power and market situation of each area will determine which direction the power flows between the elspot areas. When the supply in a region is diminished, the price goes up, enabling electricity to flow in the direction of demand. In areas with an energy shortage, power producers usually set their prices higher than producers in areas where the energy balance is better. This will in turn mean a lower production of power in areas with energy shortages, while areas characterised by better energy balance will produce more than what is required within their own area, ensuring that power will flow from low-price areas to areas of higher prices.

In general, the prices in Norway are rather low compared to the rest of Europe. On average, the retail cost of electricity in first quarter of 2017 was 0.34 NOK/kWh, and the grid tariff was about 0.28 NOK/kWh. In addition to this came fees and taxes to the sum of 0.34 NOK/kWh. This means the average total price of a kWh in the first quarter of 2017 was only about 1 NOK, or about ten eurocents. As we have seen in table 1, the yearly consumption of electricity per household in Norway is around 10-20 000 kWh depending on the type of housing. In the third quarter of 2017 prices increased on some parts of Norway by around 30%. This is explained mainly by two things, 1) scheduled maintenance of Swedish nuclear capacity, and 2) an increase in fuel cost, affecting Norway's neighboring countries dependent on thermal capacity, increasing their demand for Norwegian power.

The system operator in Norway is Statnett, operating about 11 000km of high-voltage power lines and 150 stations all over Norway. Operations are monitored by one national control center and three regional centers. Statnett is also responsible for the connections to Sweden, Finland, Russia, Denmark, and the Netherlands. Statnett is a state enterprise, established under the Act relating to state-owned enterprises, and owned by the Norwegian state through the Ministry of Petroleum and Energy.

Source: NVE

Figure 4 Sectorial division and overlap among actors granted concession (numbers from 2013)

Around 90% of Norway's power production capacity is publicly owned. This fact, and the presence of a wide variety of actors involved in many different activities, is distinctively characteristic of the Norwegian power sector. All actors producing, transmitting, or trading electricity in Norway need a concession grant. Figure 4 provides an overview of the actors and the overlap in activity. Of 183 companies involved in production, only 54 of these are doing nothing else. Statkraft is the largest producer of electricity in Norway, and together with nine other actors, their share of production is about 75 %. In addition, there are about 159 grid companies in Norway, 47 of which are purely grid operators. Most of these are wholly or partially owned by municipalities or county administrations. There are about 241 retailers in Norway, 89 of which have this as their only activity. Norway also has a large number of vertically integrated companies (separate entities under the same parent company), or companies that deal with production, transmission and/or retail. There are 112 companies who operate in some form of competitive market (production and/or retail), and 59 of these (defined as being legal entities) are involved with all three branches. Importantly, even though these various activities often are included in so called vertically integrated companies, the activity still belongs to formally separated entities according to the unbundling principles of a liberalized market. Even so, many of these formally separated entities share office buildings, and these buildings then have sections that are separated by metaphorical bulkheads.

As briefly mentioned above, one central characteristic of the Norwegian power sector is the concession system with the reversion principle. Reversion means that the government takes over means of production compensation-free after concession time expires. This means production facilities are often sold to the public sector when the due time approaches, or otherwise is returned to the government when the concession expires. This comprises an important structuring force in the Norwegian power system. After 2008, water resources legislation was amended to allow concession for property rights to existing waterfalls and constructed facilities exclusively to public actors (OED 2015).

1.5 The Smart grids landscape in Norway

The mandatory rollout of smart metering infrastructure is to be completed by 2019, effectively putting in place a prerequisite for the diffusion of smart solutions. As mentioned in the introduction, grid bottlenecks and power limitations at different levels in the grid is the most pressing current issue regarding security of supply. Improved energy management is an alternative to investments in grid expansion in this case. It is expected that an increase in intermittent generation capacity (wind, solar), parts of it distributed, will add to the demands of smart energy management.

A central smart grids actor in Norway is the Norwegian Smart Grid Centre, which is a technology platform consisting of members from power companies, telecom, and the supply industry, as well as universities and research institutes (ETP Smartgrids 2016). The center coordinates the Norwegian Demonstration program for smart grids, or “Demo Norway”. It has “real-life” demo sites at power companies comprising more than 20 000 network customers and a national smart grid laboratory at the Norwegian University of Science and Technology/SINTEF. The center also coordinates with the European Technology Platform on smart grids and other European actors such as ERA-Net.

A survey has identified three central “smart energy” projects (GSGF 2016), all of which the Norwegian part of the MATCH project is involved with. They are Demo Steinkjer, Smart Energy Hvaler, and Demo Lyse. The Demo Steinkjer and Smart Energy Hvaler projects have a broad focus on different smart grid solutions (electricity saving, load management, micro-generation and power balancing capacity), as well as different areas of household consumption. Both projects, which are still in their initial phases, are shaped by being based within a specific geographical area (the town of Hvaler and the area of Trøndelag), giving each project unique characteristics. Both have a specific focus on smart meters and their potential use for developing smart grid solutions. Demo Steinkjer and Smart Energy Hvaler are subprojects of the DeVID (Demonstration and Verification of Intelligent Distribution grids) project, the work of which was continued in the Horizon 2020 project EMPOWER. It is a demonstration project with the aim of providing knowledge and experience for the planning of the coming rollout of smart meters in Norway.

The third project, Demo Lyse, focuses on the potential for combining smart meters with new ICT infrastructures like fiber optics and new devices such as tablets etc. Energy-related aspects like load management or energy saving are not the primary focus of this project, which instead focuses on the potential of new technologies for home automation (like controlling appliances or heating and lighting) and developing new welfare services like tele-medicine. This demo is an integral part of the Norwegian commitment to the Horizon 2020 INVADE project.

Smart grid infrastructure is slowly but steadily proliferating in Norway, as smart meters are being rolled out. The Energy and Water Resources Directorate has found that as of this summer, about 875,000 meters have been installed, which amounts to around 31% of the entire metering infrastructure. They report that grid companies estimate 57% of meters will be installed by 2018, a rate that is 6% lower than grid companies reported in January 2017[4]. In terms of structural changes in the market, the director of the Energy and Water Resources Directorate publicly expressed their plans for the future tariff structures, stating that “we want grid tariffs […] to be shaped in such a way that it will be profitable to move consumption from periods when the grid capacity is strained, to periods of less load”[5]. The purview of the mandate of the directorate includes setting this tariff, and a draft hearing on new tariff structures is expected November 2017.

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[4] https://www.nve.no/Media/5662/ams_status_juni17.pdf

[5] https://www.nrk.no/norge/vil-gjore-det-dyrere-a-lade-elbilen-pa-ettermiddagen-1.12975883

2 Norwegian case studies

The three Norwegian cases represent a variety of the smart grid landscape in Norway at the present time, each covering different aspects of the three research layers technology, actors and markets. Two of the cases target mainly household end use and both represent cutting edge attempts at creating prosumer activity in the Norwegian grid. The final case is represented by a rather large SME, and is one of the largest PV parks in the country for industrial scale power production. The first case focusing on households showcases one of two projects initiated by an energy, production and grid utility company called TrønderEnergi. In addition to its branches dealing with production and energy sale, its grid operation division is one of two DSO in the Trøndelag region. The other project included in this case is the neighbor of TrønderEnergi, which reigns in the south, Nord Trøndelag Energy, which apart from similar activity related to energy sale and production, is the DSO in the northern parts of the region. Both companies initiated a solar PV pilot project into which they enrolled end users in households in order to gather knowledge about the impacts of solar production in the grid, as the “plus customer” regulation, obliging grid companies to accept electricity from small scale production into the grid, was introduced in 2017. This effort was part of an ambition to keep their competitive edge in a changing market.

The second case studies the activities of a framework program called Smart Energi Hvaler, initiated by Smart Energy Markets (a research organization), Fredrikstad Energi (ESCO/DSO), and the municipality in Hvaler. Operating on the island of Hvaler, the project showcases a demonstration project on residential PV systems in combination with prosumer market models and novel consumption monitoring and control systems. It is also a testbed for the first power tariff in Norway, charging customers not for energy use, but peak load demands.

The third case is a study of ASKO midt-Norge, a large grocery wholesaler, and their attempt at becoming self-supplied with energy. In order to achieve this, they have installed a vast solar PV rig on their warehouses, the surplus energy of which is going to power a hydrogen production facility. The hydrogen will subsequently fuel delivery trucks which operate in the middle and low north regions of Norway. This case is also interesting because the solar power will be used to keep goods cold, and contrary to most other use scenarios which include solar power the demand curve thus follows the production curve of their PV system.

Table 1 Norwegian cases in comparison

	Case 1	**Case 2**	**Case 3**
Name	PV demo Trøndelag	Smart Energi Hvaler	ASKO midt-Norge
Main focus	Two regional solar PV projects	Test area for developing future smart grid	Transition to a post-carbon energy system
Type of consumers	Households	Households	SME
DSM	Create prosumers	Demand side management, prosumption, in-home monitoring devices, market models	Prosumption, solar powered hydrogenproduction, hydrogen fuelled transportation
Micro generation	PV systems	PV systems	Large PV system
Storage	None	(Car batteries)	Hydrogen fuel

In terms of demographics, the case studies cover a varied area of urban to suburban to rural. In the case of the northernmost prosumer pilot directed by Nord Trøndelag Energi, the setting is quite rural. The other PV pilot in Trøndelag, TrønderEnergi, is in the city of Trondheim which is the third largest city in Norway. Smart Energi Hvaler is located on the archipelago of Hvaler, close to the city of Fredrikstad, but the southernmost landmass of this region in Norway on the border to Sweden. ASKO is located outside Trondheim but their activites cover a vast portion of the country, from central to rural, as goods and groceries are transported to and from the edges of Norway and within densely populated areas in between. The cases were thus selected not only in order to cover various regions in the country, but also in order for our study to represent some of the most cutting edge smart grid development projects in Norway.

The data gathering and analysis has been carried out by researchers at the dpt. of Interdisciplinary Studies of Culture, Norwegian University of Science and Technology. The methods used were primarily qualitative in the form of interviews (with users and experts), site visits and field trips, participation with users and experts at public meetings. The interview guides that were used were developed before the start of the data gathering, and followed largely the format used in the other countries. Interviews were recorded, transcribed and analysed by the researchers (however, at the time of writing this report, a second round of interviews has yet to be transcribed and thoroughly analysed). Some detail about each case and the data gathering process is summarised in the following:

PV demonstration Trøndelag
TrønderEnergi was initially a partner in the Centre for Sustainable Energy Studies in Norway, a Norwgian centre for environmentally friendly energy research (FME), with which the Norwegian research team was also affiliated. Collaboration with Nord Trøndelag Energi was on the basis of earlier work, mainly that which was undertaken in the IHSMAG (Integrating the Housholds in the SMArt Grid) ERA-Net project. Contact information was provided for solar PV participants and contact established in order to undertake interviews. Interviews were conducted face to face and over telephone with the participants. This case study also provided some expert interviews.

Smart Energi Hvaler
This demonstration project came into the project on the basis of our project partner in MATCH Smart Energy Markets, which had access to household participants and experts as a part of the Smart Energi Hvaler framework programme. Lists of participants were provided and contact was established in order to conduct interviews. The interviews were usually conducted in the home, with one or more household dwellers. This also provided some insight into the actual setup in the households, which were varied. Some of the households did not have solar PV at the time, offering valuable insight into the role of PV for end user engagement with smart energy technologies.

ASKO midt-Norge
This participant was selected on the basis of being one of the largest solar PV producers in the country, and contact was established without any prior connection. After contact was established, researchers were given access to several experts in the organization in order to conduct expert interviews. The research into this case was also conducted on the basis of desktop research and document analysis

2.1 Case 1: PV demonstration Trøndelag

2.1.1 Background and project characteristics

In the summer of 2016, the largest energy companies of the Trøndelag region in Norway, Trønderenergi and NTE, each initiated residential solar power demonstration projects, independently of each other. The demonstration projects are very similar in scope, size, and they were implemented during the same period. Trønderenergi is based in the city of Trondheim, and has as its main area the urban center, as well as southern part of the region. NTE is based in the northern part of the region, which is generally more rural. Both companies include grid operation of their respective areas, and both companies were motivated to engage prosumers as a part of grid trials in order to discover what kind of effects on the grid infrastructure could be expected.

Each company published a call for participants in a residential PV demo. Targeted marketing was made, aiming to recruit especially householders with a particular interest in technology. The response was positive, and the companies quickly settled on 15-20 households to participate in each of their projects. The selected households were chosen based on an estimated financial ability to participate, suitability of house and roof (house must be freestanding, roof must be big enough and the angles of the roof considered suitable in order to produce electricity, meaning that houses with roofs permanently covered by shadow due to other buildings, trees etc. were excluded). Trønderenergi further valued expressed motivation to participate when selecting their households, whereas NTE favoured an approach where the houses in question were dispersed and covered remote areas to which they cater. The projects work as a packaged deal, where the customers purchase the instalment – either outright or through regular down payments (with ensuing interest) over 15 years. The panels are all the same size and type, and the respective companies decided on this as a “standard” solution. Participants are bound to the energy provider in question for 15 years during which time the company is responsible for maintenance and any problems that may arise with regard to the instalment. Moreover, during this period, the participants sign a contract to become prosumers, or so-called “plus-customers” of the energy provider, which means that any surplus energy generated by the PV panels is sold back to the grid and the energy provider at spot price. In the spring of this year, NTE increased their purchase price by a few NOK cents.

A third party installed the PV on the roofs of the houses, and installed smart meters as well, where this was not already in place. The participants in the demonstration project are eligible for a fixed sum subsidy from ENOVA, the Norwegian environmental agency. This however, applies to all households that acquire solar power and is not managed through the demonstration projects. The first households to receive the PV did so in late autumn 2016, and the latest in January 2017.

The participants of the NTE demonstration project were given access to a website, accessible by computer, tablet, or smartphone on which they could monitor their electricity use, the production of the panels, and monitor whether they had produced any surplus energy. For the participants in the Trønderenergi demonstration, the same service was provided in a smartphone App in addition to a website. At the time of our interviews, however, not all the participants had successfully downloaded the App or familiarized themselves with the website, indicating that its content was of very varying importance or interest to the participants.

2.1.2 Socio-technical configurations applied in the project

Due to the striking similarities of the two demos (conducted at approximately the same time, including the same number of customers +/- 5, the same conditions applying in both demos, same geographical region, etc), we decided to merge the two demos into one case. This did not preclude the researcher(s) from noticing differences in the findings from each demo. Had there been consistent differences in the empirical findings from each demo, it is likely that the two would have been split once more into two separate cases. As it were, however, there were no marked differences in the findings from the two demos. Consequently, we continue to consider these one case; “PV Demonstration Trøndelag”. Our study of the Trøndelag solar panel demonstration projects has included 11 semi-structured interviews with members of households who are involved, and 4 interviews with representatives from the two companies. The interviews were conducted in person or over the phone.

Findings indicate that the companies both have initiated these demos, not primarily to test or develop a new set of technologies, but rather to expand and adapt their business to changes that are expected to come in the energy sector. As large providers with a main focus on hydropower and a traditional relationship with customers, representatives of both companies express unease with the prospect of being out competed or rendered irrelevant by new actors arriving in the energy sector that focus more on wind and solar power, and that have a stronger focus on digitalisation and service providing. The demonstration projects were therefore an attempt on the part of the two companies to familiarize themselves with a new customer relationship, testing the waters with regard to customer engagement and eagerness to adopt new renewable sources of energy, as well as to familiarize themselves with the operation of the technologies themselves.

Table 2 Sociotechnical configurations

	PV
Technical elements	PV panels Inverters Smart meter App for Smartphone Website
Social elements	30 households (15 each) Households own or lease the PVs Facebook group for participants (NTE) Subsidies by ENOVA 15 year agreement/maintenance (=no risk for homeowners) Participation in unspecified research (including workshops held by the companies themselves, as well as outside researchers)

Findings from the first of two rounds of interviews with customers, now solar energy prosumers, indicate that the environment is an important factor for many, yet not for all. Nor is it the deciding factor for most when it comes to joining such a project. An interest in owning new technology and self-identifying as a technology front-runner was the most important motivation for most. Among the participants, we identified pieces of a sociotechnical imaginary of the future, in which solar power would become increasingly important, and where energy prices would rise and become quite volatile. This motivated the acquisition of residential PV in two ways. First, wanting to be on the forefront of a development, which was considered undeniable. Secondly, keeping up with continental Europe, which is perceived to be more advanced than Norway. Thirdly, the sociotechnical imaginary of high and unpredictable variable pricing justified the investment in PV, as partially producing one’s own energy could contribute to lower (future) electricity bills. Some participants express that they would like to be more self-reliant and consume more of their “own” electricity. For most however, this is not an issue as it is experienced as empirically impossible without batteries (see below). Indeed, at present, participation in the solar power demonstration is not a financially lucrative engagement due to a number of reasons. The cost of the instalment is quite high, whether payed outright or through monthly payments is much greater than what the households earn by selling electricity and much greater than what they save by using their own electricity. Furthermore, households are not able exploit most of the electricity they produce (because most are not at home during the day), the electricity sold back to the grid is purchased by the companies at such low prices that even when subtracting this from a household’s electricity bill, they have spent more than they have earned. Consequently, even if the instalment had been free of charge, the households would not, at this time, profit from their PV.

Environmental concerns are in one way rather paradoxical in this context, as Norway has abundant hydropower. Both the company representatives and several of the participants in the demos pointed out this fact. However, as Norway imports energy during winters, some of which may come from coal, gas and nuclear power. Thus, the environmental concerns were part of a bigger framework, in which transnational energy-transactions were taken into consideration. The participants in these demos are not under the illusion that their ownership of residential PV will solve the problem of Norway purchasing unclean energy during the winter, nor do they think that it will directly influence the country’s energy shortage during winters. They are well aware that there is little sun in Norway during the winter, and consequently that their PV will not produce much during the months in question. What our study shows is that the participants locate themselves in a larger national, international, and global context. They hope or claim to be, early adopters and frontrunners of what they think will be the future norm. Many hope that by participating in demonstration projects, they are helping companies develop services and technologies, which may, in the longer run, positively influence the Norwegian energy situation (in the shape of new technological invention, innovative solutions etc.). In short, they perceive themselves as partaking in innovation and in research, and the development of so-called new renewables therefore, was situated in a context precisely of development, of a larger shift with regard to environmental concerns. There was a desire to become more self-sufficient, to be able to visualize energy (both production and consumption) as a tool to pass on better attitudes to the younger generations (concretely, to one's children), and a feeling of being part of something *bigger than oneself.*

Our work on this case is ongoing. We have recently begun a second round of interviews with the participants. These new in-depth interviews will be conducted in the participants' homes and include as many members of the household as possible.

2.1.3 Discussion: Success and outcomes

It is not yet possible to evaluate whether the PV demonstration projects have been successful, or to what degree. The initiation of the projects certainly was a success judging by the sheer number of interested households. However, any evaluation of the overall project can only be done at a later point, and our research is still ongoing. Moreover, it seems pertinent to ask; whose success is in question? As we have seen, the companies themselves have a long-term, complex motivation behind the demonstrations. This complex motivation importantly consists in wanting to remain relevant in the national context, to continuously develop their services, and not to be outcompeted or rendered irrelevant by newer actors in the Norwegian electricity market. The companies do not refer much to the international context. Consequently, it is likely that any definitive "result" of the demonstration projects will materialize in other branches of the companies (e.g. innovation) or in different business strategies, in time. With regard to the participants too, more research needs to be conducted, preferably over time and we are currently arranging follow-up interviews.

We see that motivations behind the initiation and the participation in demonstration projects such as these, illustrate well the ways in which the social and the technical are intertwined and never function independently of one another.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: The demonstration projects showed that there is considerable interest in the existing residential customer base to engage in pilot projects and install solar PV on their roof. The technology related to this was however somewhat immature, e.g. monitoring devices and facilities were not widely adopted by the users. The very early state of these projects must be taken into consideration however.
- Actors: The energy companies engaged in this seem to be motivated by an anxiety for lagging behind in a market environment that seems to be developing quickly with steadily increasing digitalisation and novel energy service provision. Judging from the customers, there is a large demand for this development as well.
- Markets: Markets for prosumer activity is not well developed with respect to the view of customers, and selling back energy to the grid does not nearly provide sufficient economic incentives for investing in rooftop solar PV for end users. However, many have stated other concerns as sufficient, for instance a desire to reduce carbon footprints (even in context of Norwegian hydropower, which, as many point out, gets exchange with continental brown power). Many were also keen on the idea of market independence and self-sufficiency, though at current the size of installations and continued grid dependence (solar PV does not work during power outages) makes this hypothetical.

2.2 Case 2: Smart Energi Hvaler

2.2.1 Background and project characteristics

Smart Energi Hvaler (SEH) is a framework program that has been running for 7 years, meaning it is a collaborative project between the local energy utility Fredrikstad Energi AS (FEAS), the local municipality, and the Norwegian Centre of Excellence for Smart Energy Markets that is situated at the nearby Østfold University College. As such, coordinating activity in what we could consider a triple helix arrangement, the program has undertaken a self-proclaimed mission to shape “the energy markets of the future”. A part of this includes employing demo technology and solutions in the small island municipality of Hvaler, a small archipelago on the border to Sweden including five islands covering 86 km^2, with a total of 4000 vacation homes, 2700 domiciles, and some commercial properties. A main focus of the demo, which has been studied here, has been smart metering with solar photo voltaic (PV) panels with the aim of making customers into prosumers.

Currently there are also plans to make use of local battery storage on the neighborhood scale, and there are burgeoning results from a newly placed micro windmill in conjunction with a waste recycling facility. In parallel, there is also a plan to roll out a good number of public charging stations for EVs on the island in addition to the ones already there. The island is a holiday destination for many EV owning vacationists, as well as being a thirty-kilometer deep cul de sac; a trip from the nearest city to Hvaler’s southernmost point would consume a quarter of the ideal capacity of a Nissan Leaf.

The island community of Hvaler municipality lies in the south east of Norway, located outside the larger city of Fredrikstad. It has around 5,000 permanent residents. During summer however, the number of seasonal visitors can reach as high as 30,000, due to the island being the location of many summerhouses.

In a Norwegian context, Hvaler is an ideal location to implement solar PV, because it is one of the places in Norway with the most days of sun – which also coincides with high tourist demand. However, there are some concrete challenges that has made Hvaler attractive as a demo site for distributed microgeneration in the form of solar PV. For instance, the island only has a single power line connecting it to the mainland. This means that if it should be interrupted, any part of the community downstream from the breaking point will be without power until the situation is resolved.

Throughout the years, this has been happening infrequently. Two years ago, half the community was without power several hours during the day as an unlucky bird had flown into a switch. Only this summer there were two incidents of private sailboats shorted the main line by navigating into it with its mast, resulting in the entire archipelago losing power. Power fluctuations pertaining to grid balancing issues has also been a problem, and many incidents of ruined home appliances on the customer side has been reported.

These events have led to the local citizen’s action group, among others, to demand the commissioning of an underwater cable to service the islands, in an argument with the grid company that is still ongoing. One grocery store owner – claiming losses during tourist season in the hundreds of thousands of kroner because of each of these commonly 4-5 hour long outages – upgraded his store with a diesel generator. He claimed the investment quickly paid off[6]. With local municipal council seated ambitions regarding environmental goals that include the roll out of more EV chargers, as well as the influx of ever more EV driving visitors, the redundancy of the island’s electricity system is going to

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[6] https://www.f-b.no/nyheter/norgesnett/hvaler/stromstans-satte-sinnene-i-kok-pa-hvaler/s/5-59-820761

be tested further. Last but not least, these developments are contentious in a public perspective due to the issue of security of supply.

SEH started out in 2010 as an attempt at delaying a refitting that was due of about 2000 failing electricity meters. This was at a time in which it was clear that new smart metering was about to be introduced, as it was scheduled in a revision of the regulation in the two years earlier. The entire project was thus premised on an ambition of avoiding newly refitted metering infrastructure becoming obsolete immediately after installation. This revelation encouraged the stakeholders, which would later form the framework program, to use the upcoming revision of regulation to delay refitting in order to make sure they could properly exploit any future advantages of an obligatory smart meter roll out. In other words, instead of simply rolling out new meters, they wanted to make sure the meters were an investment that would support hypothetical future gains in the smart grid.

The main activity soon involved rolling out private PV installations with 3 or 5 kW capacity, capable of producing around 3-5000 kWh/year. After having introduced the panels, it became evident based on customer demand that it was necessary to introduce monitoring capabilities. Thus, Smart Energi (a subsidiary of the local energy company) was established, and it started work on an Internet portal for keeping track of production, consumption, and selling of energy to the grid. The portal was introduced soon after, together with smart plugs that had the ability to monitor consumption in the home based on appliances, and provide data of this to the user via the internet portal. The focus for the utility and grid operator has been on rolling out remote control abilities to some customer, which based on the data from the plugs would be able to orchestrate household loads for network benefits. These control modules were not accessible for the end user, however. Demand side management is important in Hvaler due to the redundancy issues mentioned above, as it is a way of increasing grid robustness without costly grid expansion – costly in terms of money, but also in other terms, such as interfering in nature. Large parts of Hvaler has national park status defined as protected.

The efforts of Smart Energi has garnered quite a lot of positive attention on Hvaler, as efforts that deal with the issue of security of supply is warmly welcomed by the population. This is in addition to the environmental aspect, which has appeal to many of the quite well off citizens of the largely suburban parts of Hvaler. The project also benefitted by its close collaboration with the municipality. This has made it possible to fast-track paper work necessary for the fitting of PV installations, as well as providing increased public trust through public meetings with the attendance of local community leaders, like the mayor. In addition to the face-to-face aspect of the framework (according to an informant from our interviews 85% of solar panel customers knew the project leaders by name, and would call them directly with questions), SEH benefited from rather strong neighborhood effects, and in turn the project managers talked warmly of the most «forward leaning» energy customers in Norway. Something of the truth in this is indicated by an Enova competition that elected the domicile of a customer in Hvaler “Norway’s smartest house”. Having a close relationship to the people in this way also benefitted customer research undertaken by the utility, which provided information on cost benefit analysis like price sensitivity and down payment duration tolerance. The triple helix configuration has also been widely successful in establishing international EU projects on their own. SEH are in the process of finishing up their first large Horizon 2020 project, EMPOWER (Local Electricity retail Markets for Prosumer smart grid pOWER services), which is set to end this year. This project is already set to be followed by the new H2020 project INVADE (Smart system of renewable energy storage based on INtegrated EVs and bAtteries to empower mobile, Distributed and centralised Energy storage in the distribution grid), which is the largest smart energy project in Norwegian to date and which SEH is also a part.

As one of the first areas in Norway, the grid operator in Hvaler has also introduced power tariffs in Hvaler. At the time of the study SHE had rolled out PV to about 100 houses, which have provided this case study with 17 interviews, 15 with households conducted in the home and two with experts working within the SEH framework. The total number of respondents were 22. At the time of writing this report, 8 interviews has yet to be transcribed and fully analysed. Their contribution to this chapter is thus preliminary.

Of experience, the most interested customers were older segments. The area had the largest buyer group of solar panels in the country in 2015 which was the year the solar roll-out started, and the average age was 60 (oldest 87). This could relate to cost: the cheapest PV setup at Hvaler was around €2000 (average €5000, most expensive €12 500). PVs in seem to appeal to a rather grown up, mature buyer group that have a stable economic situation, characterized by having a decent amount of disposable income. Additionally, many of this generation still remember the ‘over consumption meter’, which was a gauge usually placed in the kitchen and that would assert a maximum limit on load demand in the household. It has long since lost its relevance after power tariffs were abandoned.

2.2.2 Socio-technical configurations applied in the project.

With the re-introduction of the power tariff in Hvaler, there is some reference to the tariff structures of the past, constituting a motivation to reduce peak loads in the home. This is in contrast to what is seen in younger participants. In general, participants with PV rigs state that they are concerned about contributing towards handing over the planet in a decent condition to their kids, and tend not to carry concern only about economic incentives. In a few cases participants were not greatly aware of their own production, and one household reported not having used the web portal to get an overview of consumption, use, and production. In this case the only indication participants had of the panels even functioning as they were promised was by checking the display on the inverter itself.

A tailored and ready-made solar PV setup in a packet solution, is something that is very difficult to acquire independently by users in the current market for PV. Thus, some reported being engaged in the project simply because it was a good deal on solar panels, which some had already read up on quite extensively. As for those who had not invested in solar panels a few reported cost, one reported that the technology was not good enough (they wanted solar roof tiles), others reported joining to learn more about smart energy monitoring because of its relation to the persons work. Apart from PV, the households included in this case exhibited other socio-technical elements as well, the most relevant of which are listed in table 1.

Table 2 Sociotechnical configuration

	SEH participant with solar PV (11/15)	SEH participant without solar PV (4/15)
Technical elements	Smart meter	Smart meter
	eWave monitor (2)	eWave monitor (0)
	Web Portal	Web Portal
	PHEV / EV (6)	PHEV / EV (3)
	Households appliances	Households appliances
	Smart plugs	Smart plugs
	Demand side management unit	Demand side management unit
	Heat pump (6)	Heat pump (3)
	PV panels	
	Inverter	
Social elements	11 households	4 households
	Town meetings	Town meetings
	Participation in R&D	Participation in R&D
	Grid power tariff	Grid power tariff
	Feed-in tariff (PV)	
	Subsidies by ENOVA	
	Identity marker	

The solar PV consisted in most cases of 12 panels over an area of 18 square meters, amounting to a 3.2 kW output at peak production. The production of such a setup in a representative household was around 3600 kWh/year (of which 1000 kWh were sold), which amounted to around a quarter of total consumption. A 3.2 kW setup cost around €5000, but participants were eligible for Enova support in the range of €1500, making the total one-time cost for the panels including installation around €3500. The prosumer aspect of the panels, and what makes them competitive on the market, is the feed in tariff. The price of one kWh of electricity delivered to a Norwegian household averages at around €0.10, or one krone. This, the total purchase price, is an aggregate of grid tariff, electricity price, and taxes. The pure market price for electricity in this cost and tax bundle is only around €0.02, or 20 Norwegian øre.

This means there is in general very little money to be made selling electricity back to the grid, as the market will usually only give the market price. Thus, in a normal case without a feed-in tariff, the obvious choice for the prosumer would be to attempt using most of the produced electricity on site rather than selling it. In our case however, due to a feed in tariff that sets the selling price at a flat €0.10, a kWh bought and a kWh sold makes no difference. This increases the incentive for buying a solar PV rig, giving it at return on investment of about 10 years (3500 kWh per year for 10 years at one krone per kWh), but it does reduce incentives for load shifting. The future of the feed in tariff was uncertain, though, and it is not guaranteed to last for 10 years. A short return on investment time in the future is dependent either on rising prices (which is relatively likely due to the increased export capacity planned for Norway), or on a customer's ability to spend own production to shed loads to reduce the impact of a grid tariff (not easy without a battery, as the sun shines during periods of low demand).

Other ways of incentivizing the acquisition and operation of a PV are being planned. A type of tariff structure that was under testing was called Smart Neighborhood. It made it possible for neighbors to purchase electricity at a 30% discount if there was a surplus of locally produced solar power anywhere in the neighborhood. This was proven very difficult to achieve however, because at this time the structure and organization of the billing service which was used. The billing systems were simply not able to cope with the amount of flexibility this kind of account settling would require. This points to a weak link in the service chain, making evident the need for smart grid innovation in areas which have previously not been closely associated with it.

From a perspective of the electricity system, the locally produced electricity and demand side management relieves the connector supplying the islands and the local grid. This is where the power tariff comes into play. Previously, the part of the electricity bill made out by the grid tariff was determined in the same way as the retail part, namely in accumulated kWhs. Since the introduction of smart meters, however, the all residents in Hvaler have received a power based structure on their grid tariff, meaning that the cost of electricity delivery is measured by peak load. To be specific, it is based on the average of the three largest consumption peaks (peak is per day) within each month divided by 3, multiplied by 65 kroner (~€7), with an additional flat charge of 600 kroner (~€65). The math ends up looking like this:

$$((p1+p2+p3)/3)\text{kW} \times 65$$

Or, if we insert numbers that are representative:

$$((5.1+5.3+6.1)/3)\text{kW} \times 65 = 357 \text{ kroner}$$

This means the customer is greatly incentivized towards reducing the operation of many appliances at one time, thus reducing the share of their households' strain on the distribution grid. A not uncommon peak among representative dwellings would be in the range of 4-7 kW, and one household in the sample (with solar power) had managed to consistently reduce their usual peak to less than 2 kW. The activities related to this was avoiding the simultaneous use of power hungry appliances, like PHEV charging, dishwasher, tumbler; and alternative means of heating, like wood burners and solar thermal for water heating. Some of the customers were also mindful to consume necessary services when the sun was shining in order to reduce load; however, this was really only doable for those staying at home during the day (home-workers, seniors, etc.). At the time of the study, the project was in the process of installing controllers that would automate shut down of slow loads like water heaters, but had yet to make it operational. This would greatly benefit the usefulness of panels, as automated water heaters is a viable way to shift or replace load demand by storing power in low-peak hours or when the sun is shining.

When it comes to visualization techniques in the households of Hvaler, some of the project participants had two years prior received a small pad-like screen that monitored energy consumption in real time, the eWave. Many of the respondents reported having very positive experiences with the little box that would smile at them when they were treading lightly on the grid, and a newspaper reporting on a competition spurred between users of eWaves maintained that many households had managed to reduce electricity cost by 15% simply by avoiding peaking their load. The eWave was a rather simple means to improve the understanding by residents of the consequences of energy consumption in the households, paving the way for a more knowledgeable relationship with the solar panels two years later.

The other means of visualization, the web portal keeping track of produced, consumed, and sold electricity was necessary for giving people a chance to make sense of the relation between their consumption and the PV panels. The way this worked in practice was by connecting a small antenna via a TP-link to the inverter that – in addition to converting the solar power into usable 230 V – collects data, even though it does not have a proper user interface beyond a simple digital display. The antenna thus functions as a means of placing the inverter on the internet, and the data it generates ends up in a cloud based interface operated by the utility. This was proven crucial in order to aggregate timely and relevant data about consumption and production to the participants. The idea of delivering another type of pad instead of just an internet portal was dismissed due to cost.

The majority of customers claimed they were informing themselves with the web portal, and some reported energy savings in addition to an added overview of consumption and an increase in general energy knowledge and awareness. Even so, there were a number of participants who reported little interest in the portal. In one case the solar PV investment was mainly to ensure private environmental gain, and the actual profitability was not interesting. In most cases there seemed to be a correlation between solar panels and web portal use. In the case where participants had not installed PV, the reported use of the monitoring portal was still quite high.

This is because along with the launch of the portal, participants were given a number of smart plugs that could be installed between appliances and sockets, reading and sending information about consumption to a hub which then communicated with the web portal. Thus it was interesting for customers even without PVs to follow up on their own consumption by using the portal. This portal also provides a view of the three largest peaks which the participant has accumulated at any given time, and even without solar panels many customers reported using the portal to learn how to avoid peaks and monitor peak production to keep them low. This was true even for those without solar PV. The portal was lacking according to some, however. The automated demand side management system was completely black boxed, and one customer noticed it did not avoid running the water heater and heat pump at the same time. Other problems were related to the communication protocol of the plugs. Using radio mesh signals which are very weak, many plugs were out of reach from each other and the hub, making them useless in the house. This can only be solved by increasing the number of nodes in the mesh or by installing boosters, or using different communication protocols, like WiFi. This however has other drawbacks, like high energy use.

2.2.3 Discussion: Success and outcomes

The socio-technical element that perhaps caused the greatest impact in this case was without doubt the power tariff. Power tariff was introduced with public meetings, and also quite manageable in the web portal. In general, households in our sample reported having become more concerned with shedding and shifting load, even if the size of the monthly bill had remained more or less the same as in the previous scheme. A clear majority of respondents elicited a clear understanding of how to reduce loads, but found it difficult to avoid ruining a low load peak streak within each month. As the bill is made up of these three peaks a customer only has to “forget” about them three times in order for a whole month to be ruined. After producing large peaks in moments of stress or when there is little room for planning, the rest of the month it no longer becomes necessary to reduce peak consumption. A feeling of despondency was created, and motivation to reduce peaks would diminish. In both the opinion of the user and SEH, some level of automation in combination with the power tariff was much needed, as people often found themselves lacking tools to load shed easily. Even so, income levels are high enough that the financial penalty is quite weak. The customers engaged in load shifting did it more on principle, and found simply just not running appliances simultaneously a most achievable challenge.

The main ambition of the SEH project seems to be to incentivize people to buy and install local means of power production, in this case solar PV, and having them actively shift or shave their loads as a close secondary goal. This makes sense from the system perspective, where the goal on Hvaler is to reduce the strain on the local grid by increasing local production capacity at the end user and making consumption flexible on a neighborhood scale. But the Smart Neighborhood strategy – trading surplus energy among neighbors with some production capacity among themselves at a discount – also shows it is possible to allocate benefit to singular households as well in this manner, if still only in theory. But shared production facilities and individual book keeping by the smart meter of the amounts produced and consumed per participant is at this point not all that is necessary to start “load-pooling” among neighbors. As we have seen, the account settling technologies and organization are a clear area in which smart grid technologies need to catch up for this to be possible.

What is perhaps most interesting to note as well, is how the motivation of SEH and the local population, represented here by our case, is aligned when it comes to security of supply for the community as a whole. The feeling of living with a strained and weak power supply was a strong part of the collective consciousness of the people in Hvaler. The feeling that the grid was something tender that must not be strained too much was evident in many aspects, for instance skepticism to the roll out of EV charging infrastructure at a town meeting and subtle resentment for vacationers taking with them to Hvaler a carefree energy attitude from the mainland. The main success of the 'forward leaning' energy customer in Hvaler relates to their shared experience of the acuteness of energy shortage, and a common interest in increasing the robustness of their grid. This ties in with the reported motivation of many of the respondents in participating not for the sake of personal economic gain, but in order to take part in and contribute economically to a research project that they endorse. In this regard, the social value of placing a solar PV rig on the roof of ones' house or garage in a place like Hvaler should not be underestimated.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: The framework program which is Smart Energi has been successful in proliferating their demo site with various novel smart grid technologies, many of which have proven quite useful but some of which are hampered by the relative immaturity of some of the components, such as in the case of portal and smart plugs. Prosumers are producing energy and delivering back to grid however, and power tariffs are in place which incentivise load shifting. A necessary component in this configuration is the web portal.
- Actors: The triple helix configuration has been beneficial for the project, and contributed to enrolling many of the users. The participants were interested in and the project allowed for engaging with local political as well as environmental issues.
- Markets: Users are able to sell own produced energy, or use it themselves in order to save money or energy, and there is a return on investment. The panels are as of now quite heavily subsidies, and there are feed-in tariffs which may not last forever. Account settling between ESCO and customers presents as a reverse salient, a part of the smart grid front line that has fallen behind.

2.3 Case 3: – ASKO midt-Norge

2.3.1 Background and project characteristics

ASKO is a large Norwegian grocery wholesaler. Its core activity is to sell and distribute groceries to stores, retailers and the catering industry across the country. The corporation has 13 regional branches, all with their own storage facilities. In total, the company has around 600 trucks to do the delivery of goods.[7] In MATCH, we have studied a project undertaken by a regional ASKO branch located in the middle of Norway (ASKO Midt-Norge)[8], a project that is a collaboration between ASKO, the research institute SINTEF and the car manufacturer Scania.

ASCO Midt-Norge have around 280 employees. The company has 27,000m^2 of storage, which are located in an area called Tiller, roughly ten kilometers south of the city Centre in Trondheim. The storage is energy intensive, in part because much of it is used for keeping food frozen. In the Norwegian context, such space cooling as well as space heat-

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[7] https://asko.no/om-oss/

[8] https://asko.no/kontakt-oss/vare-asko-selskap/asko-midt-norge-as/

ing has traditionally been provided by hydroelectricity, which means that the electricity provision is already close to 100% renewable.

The storage at Tiller distributes goods to more than 1,700 stores and restaurants. They deliver goods to customers in three counties, covering a distance of more than 800 kilometers. To do this, ASKO Midt-Norge have around 50 distribution trucks. Inside the storage facility, they have around 20 forklifts, used to load the trucks. While the company covers a large area in their work, many of their deliveries consist of relatively short-range trips within and around the city of Trondheim.

Over the last years, the parent company ASKO Norge has branded themselves as one of the most environmentally ambitious corporations in Norway. This can largely be attributed to the engagement of a key group of individuals amongst ASKO's owners in the mid 2000's, a period when the focus on climate and environmental issues generally increased in the Norwegian public sphere (Haugseth, Blix-Huseby & Skjølsvold 2016). The corporation aims at being 100% renewable and carbon neutral by 2020. Since the use of electricity is already green, much of what the corporation is doing deals either with offsetting carbon emissions from transportation, or by actually decarbonizing their transport, e.g. through things like biofuels. A more in-depth discussion of this topic is forthcoming[9].

2.3.2 Socio-technical configurations applied in the project

The relationship between the parent company ASKO Norge and ASKO Midt-Norge is an important element in the studied socio-technical configuration. While ASKO Midt-Norge is a stand-alone unit with its own budget, the corporation and its owners have fixed requirements for return on investments. However, the board of directors have made a clear exemption from this rule when it comes to environmentally oriented technology. Here, they are ready to accept medium-term losses, and long-term break-even.

At a corporate level, ASKO has invested in a wind park in Rogaland with a production capacity of 60GWH. This covers roughly 70-75% of the corporation's total energy consumption. With this as a backdrop, ASKO Norge has challenged its regional branches to come up with new "cases", new ways of covering the last 25-30% to make all of ASKO self-sufficient in terms of electricity.

ASKO midt-Norge have responded to this in two ways. First, they have become prosumers in a relatively straightforward way. They have built 3,000 square meters of solar cells on their roof at Tiller, and by the end of 2017 this will increase to 12,000 square meters. Solar radiation conditions in Norway have been measured to be better than one might intuitively think for such a dark country. As an example, the solar radiation in Oslo is very similar to the measured solar radiation in Bremen,[10] and the entire region of the south and east resembles central Germany, where PV has become very important.[11] That said, there are some distinct Norwegian challenges. Located at 63 degrees North, Trondheim is relatively dark in the winter, which means that PV production decreases. At the same time, electricity demand peaks for most actors in the winter, since electricity for space heating is so important.

For ASKO midt-Norge, the situation is the other way around. They mainly use electricity for cooling and freezing, for which the need peaks during the summer months, when solar production is at its highest. Currently, ASKO midt-Norge feeds electricity back into the grid. During much of the summer, however, they produce more than they can feed back. While they have been contemplating microgrid solutions, they have not yet moved in this direction. Compared to buying hydroelectricity, the costs of producing electricity from the solar power facility has been described as relatively expensive. However, ASKO midt-

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[9] An article discussing this case in-depth in a sustainability transitions and social acceptance perspective is currently under review in *Environmental innovations and sustainable transitions.*

[10] https://www.nve.no/energiforsyning-og-konsesjon/solenergi/

[11] The norwegian solar organization, https://www.solenergi.no/norske-solforhold/ (accessed 15-11-2017)

Norge expects that with time, electricity prices in Norway will increase, and solar power production will make good sense also economically.

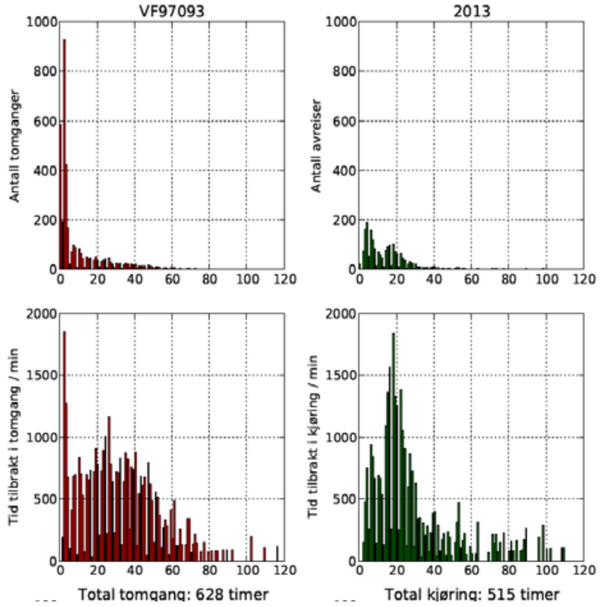

Figure 5 Hours of idling

This set-up is relatively straight-forward, even if what ASKO midt-Norge has built is a large solar park in the Norwegian context. The focus on solar production has been combined with promotion of pro-environmental behaviour amongst employees, in an attempt to nurture a sort of environmentally oriented habitus. An annual environmental fund of roughly €1 million has been established. This funds electric bikes, environmentally and energy efficient home renovations, or tickets for collective transport for employees. On-site, ASKO midt-Norge also has established electric vehicle chargers, which employees use freely. This appears to have been relatively successful, several of our respondents talked about a "sense of pride" in working for a company that was doing something important, and that it produced a sense of participating in something larger than themselves.

However, what makes ASKO midt-Norge particularly interesting in the MATCH context is their work to think about new modes of storing excess electricity production from the PV facility and decarbonizing their fleet of heavy-duty delivery trucks. To tell the story about how these ideas came about, we need to take one step back, and look at a parallel project that ASKO Midt-Norge has been involved in.

Together with a group of researchers from the research institute SINTEF, ASKO Midt-Norge has since around 2012 been looking into ways of reducing idling when doing urban deliveries. The story began in a quite unexpected way. SINTEF was working on a hydrogen reformer that produced hydrogen fuel cells from diesel. The idea was to use the fuel cell to power the lifts of distribution trucks. The rationale behind this was that on a typical route, trucks spent a considerable amount of time idling, in order to keep the battery for the lifts charged. By close study of three ASKO trucks, the scientists were able to determine driving a delivery truck for 515 hours in an urban setting, required 628 hours of idling (as illustrated by fig 5). Hence, there were enormous fuel expenses and emissions that could be cut. A report from the scientists concluded: *"The fuel cell system can remove the need for idling at delivery, and reduce the annual CO2 emissions per car with 4500 kg. If implemented across ASKO, 1350 ton of CO2 emissions can be avoided per year"*[12]

Through participation in this project, ASKO Midt-Norge reduced their emissions from this particular type of urban short-range delivery of goods with about 85% CO2 emissions. Figure 6 shows deliveries in and around Trondheim city centre on a typical Monday, which serves to illustrate why the small fuel cell could have such effects. In 2016 a similar system have been tested in another type of truck, where idling is caused by the need to power mobile refrigeration.[13] The technology is still a prototype,[14] but according to

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[12] https://brage.bibsys.no/xmlui/handle/11250/2378808

[13] For more technical detail, consult: http://www.powercell.se/asko

[14] http://www.powercell.se/wp-content/uploads/2016/04/PowerCell-Datasheet-PowerPac.pdf

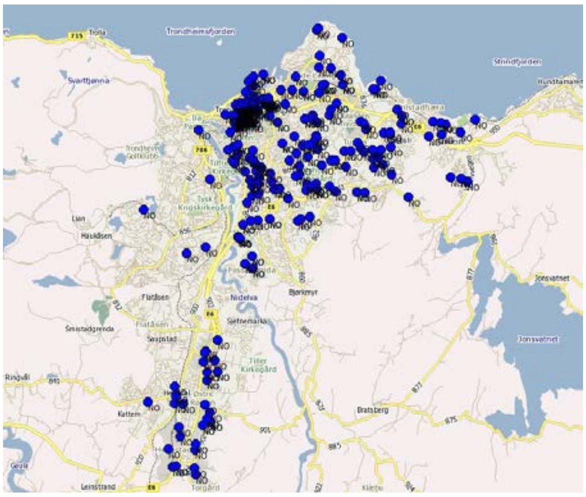

Figure 6 Deliveries in and around Trondheim on a typical Monday

statements made by executives, investments in this technology would pay off within three years.[15]

The fuel cell is not part of the configuration we have studied, but it is a technical add-on, which could make sense for delivery companies especially in urban settings under certain conditions. However, it is important for the configuration we study, because it sparked an interest for ASKO nidt-Norge for converting and storing energy in the form of hydrogen using fuel cells.

The ASKO management became convinced of the potential practical qualities of hydrogen fuel cells. Hydrogen, they were convinced, was an option to pursue in the strategy to decarbonize their fleet of heavy-duty transport trucks and forklifts. This was not only a result of being newly convinced of the qualities of hydrogen itself. The move was further motivated by the prospects of surplus electricity production from their PV installation. Thus, what was originally a move to engage in energy generating practices was suddenly an essential ingredient in a shift towards producing their own fuels, and decarbonizing their transport fleet through hydrogen.

Hence, ASKO started a pilot project where the goal is to produce hydrogen from excess solar power. They have invested 23 million NOK (around 2.3 million €) in an off-the-shelf hydrogen production facility which is installed on-site. The production will officially start on December 6th 2017.[16] The system is a containerized hydrogen production unit, an electrolyser that has a production capacity of more than 300kg of hydrogen per day. ASKO Midt-Norge has also commissioned a hydrogen filling station, to be installed on-site at Tiller. It will be installed with three separate dispensers, two dispensers at 350 bar dedicated for forklifts and trucks, and one dispenser at 700 bar dedicated to private cars[17].

The filling station for cars will be the first of its kind in the region, also making it possible for citizens to fill hydrogen. However, the hydrogen will first be used in three new 27-tonne trucks where the internal combustion engine in the powertrain will be replaced by an electric engine powered by electricity from fuel cells and hydrogen gas on board the vehicle.[18] A fuel cell creates electricity by an electro-chemical process using hydrogen and oxygen. The electricity generated by the fuel cells powers the electric powertrain. The system has an integrated battery buffer, and the only emissions are pure water. Figure 7 illustrates the vehicle.[19]

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[15] http://www.bequoted.com/bolag/powercell/pressmeddelande/genomforda-falttester-av-powercell-powerpac-har-natt-projekt-52082

[16] http://www.hydrogen.no/hva-skjer/aktuelt/steffen-moller-holst-har-kjopt-hydrogenbil-far-ikke-fylt-drivstoff

[17] http://nelhydrogen.com/news/nel-asa-awarded-contract-with-asko-for-hydrogen-production-and-fueling-solution-in-trondheim/

[18] https://www.scania.com/group/en/scania-and-asko-test-hydrogen-gas-propulsion/

[19] The image is taken from Scania's news item about the collaboration, and is available under a CC 3.0 lisence https://www.scania.com/group/en/hydrogen-a-fuel-of-the-future/

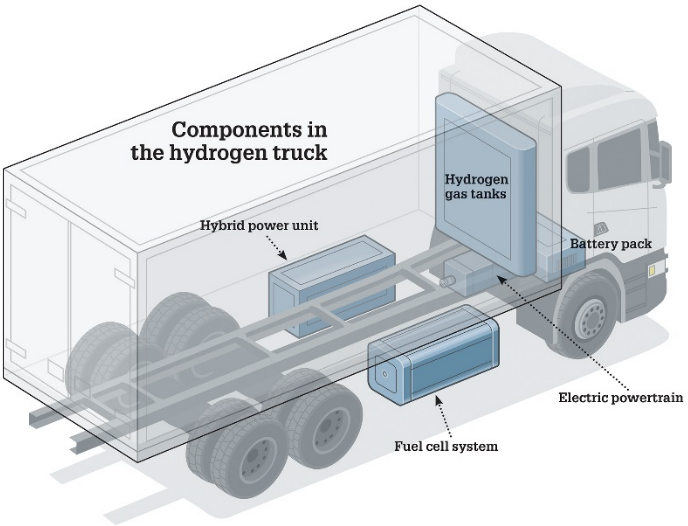

Figure 7 Hydrogen fuelled delivery truck

However, acquiring a contract for the purchase of such a heavy-duty vehicle was not straight-forward. ASKO negotiated with every car manufacturer that delivered trucks in Norway, but no-one believed that ASKO's plans were realistic. In the end, they were able to set up a project involving staff from ASKO, Scania (a long-time provider of vehicles for ASKO) and Sintef, who are now in the process of developing the truck. Furthermore, ASKO midt-Norges forklifts are being replaced with hydrogen powered forklifts. The project have received around 19 million Norwegian kroner (ca €1.9M) from the government enterprise ENOVA to realize the project[20]. In describing the process that resulted in this agreement, our interviewees highlighted long-term relationships of personal and organizational trust which had been built through working together for close to a decade as essential.

ASKO midt-Norge is an interesting case, because it represents a different way of thinking about how to deal with the intermittency of new renewable energy production. Whereas many "smart" solutions try to do this through matching supply and demand in the grid, the production of hydrogen matches the surplus production of solar power to another kind of demand than that for stationary electricity, namely that of heavy duty transport. Hence, it is a sort of internal demand management as opposed to within a system of electricity consumers and producers.

An important aspect of the socio-technical configuration, is ASKO midt-Norges expectations related to future framework conditions for their kind of company. They are convinced that electricity prices will increase, that environmentally oriented regulations will become stricter locally and nationally, and that the kinds of changes they are now implementing in their company will be vital in order to survive in the future. As an example, interviewees have shown how they think delivering goods with heavy diesel trucks in urban settings will likely become illegal. It is worth noting that they also work actively to create this future, lobbying for strict environmental regulations, nurturing pro-environmental attitudes, trying to persuade traditional electricity providers to begin producing hydrogen etc.

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[20] Info from ENOVA: https://www.enova.no/bedrift/transport/transporthistorier/asko-satser-pa-hydrogen-og-el/ (accessed 20-08-2017)

Table 3 Sociotechnical configurations

	PV	PV + hydrogen production + hydrogen trucks
Technical elements	Low-voltage grid 3,000 square meters of PV panels Large roofs Electric vehicle chargers On-site cooling systems Annual cycle of winter/summer solar radiation paired with pattern of electricity demand	12,000 square meters of PV panels containerized electrolyzer Hydrogen filling station (350 + 700 bar) 3 Hydrogen powered trucks 10 hydrogen powered forklifts
Social elements	Corporate structure and normative orientation, decreased demand for return on environmental investments Patterns of electricity demand during sumer/winter Practical and behavioural programs targeting employees. Sense of “pride” amongst employees Tariff schemes/contract with grid company?	Corporate structure with decreased demand for return on environmental investments History of cooperation between car manufacturer, research institute and company and trusting relationships. Company target to decarbonize by 2020 Expectations for future green society, and radically different framework conditions Active lobbying, targeting policy makers, other companies and individuals aiming to produce favourable framework conditions.

2.3.3 Discussion: Success and outcomes

The first configuration of this case mainly involves electric power production through PV and appears relatively successful. It is technically non-complicated and it does not represent a direct monetary loss for the company currently. There are now discussions in Norway concerning whether or not such facilities should be included in the Norwegian-Swedish renewable electricity certificate scheme. Currently, they are not, but Asko has managed to get dispensation for another similar facility in the east of Norway[21] could make their solar power production more profitable. As actors like ASKO begins to produce electricity on relatively large scales, they also cause controversy amongst traditional electricity providers and grid companies, because of their disruptive potential. Hence, the choices ASKO make over the coming years will be under close scrutiny by many actors. The company has managed to make a strong environmentally oriented brand, and it appears as if many employees see the “greenness” as part of the package of being an ASKO employee.

It is too early to say if the pilot project on hydrogen will be a success, or what the outcome will be. So far, however, it represents an interesting encounter between actors and technologies which come from traditionally relatively separated domains. The electricity system and the mobility system is increasingly merging in the Norwegian context due to the influx of electric vehicles, and hydrogen represents an interesting option for electrifi-

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[21] Asko Vestby has installed 19 000 m2 of PV. https://www.tu.no/artikler/na-er-norges-storste-solcelle-anlegg-blitt-nesten-tre-ganger-sa-stort/346914

cation of heavy duty transport. It also represents a potentially new way of matching excess production of electricity with demand in other spheres, such as the demand for heavy duty mobility and transport. For solar power the production is likely to vary according to season. ASKO is currently in dialogue with other actors such as wind farm operators, about using wind power to produce hydrogen e.g. at night, when the wind still is strong, but electricity demand low. As some of our respondents have told us, producing hydrogen from solar power is unlikely to be technologically “optimal” in the strictest sense of the word, but currently the alternative is that excess electricity production goes to waste when the production is beyond what can be delivered to the grid. As it stands, however, the current project would probably not have been possible without economic support from Enova.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: ASKO midt-Norge has successfully become one of the region’s largest solar power producers. Their venture into hydrogen represents a novel way to think about storing electricity and matching production and consumption across infrastructures, sectors and seasons. The case also illustrates the advantages of considering technologies in relation to each other, with the possibility of constructing new constellations.
- Actors: The case illustrates how the boundaries of the traditional electricity system is increasingly becoming blurry. ASKO is a grocery wholesaler, and have not traditionally been part of this system as anything but a large actor on the “demand side”. Now they produce electricity and are venturing into fuel production, hence illustrating potential for disruption. This was enabled by the close cooperation between ASKO, a commercial company and SINTEF, primarily a research actor. Further, the case illustrates the importance of trust built over time between actors when trying to establish unconventional solutions.
- Markets: Similarly, the case illustrates how new combinations of actors and technologies might open new market opportunities e.g. in hydrogen. So far, the pilot project relies on economic support, and it is difficult to predict if framework conditions will change enough to make this economically feasible. ASKO however, are prepared to take some losses.

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