NTRANS
Norwegian Centre for Energy Transition Strategies

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# Making the smart grid through pilot projects. Insights, lessons and ways forward

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# Executive summary and recommendations

## Background

- This report analyses 30 pilot and demonstration projects that advance *smart grids with flexible consumption and high levels of renewable energy production* in Norway.
- We see pilot and demonstration projects as key sites in the production of future societies.
- Such projects are usually evaluated based on techno-economic criteria, while their contribution to broader societal processes tends to be overlooked.
- We explore how they contribute to the shaping of energy transitions and societies.

## Results

- Smart grid pilots address two key overarching societal issues: a) The electrification of society and b) Maintenance, planning and optimization of the electricity grid.
- Many actors are involved in smart grid pilot projects, but a few actors dominate. We discuss this in terms of power concentration and address how this might hamper creativity.
- Smart grids need social change to work, but projects often take social aspects (trust, privacy, acceptance, ownership, access, behavior) for granted. Social science is marginal.
- Projects that deal with the electrification of society tends to focus on demand-management, flexibility, batteries, PV and (new) renewable energy, but there are few explicit links to broader transition debates, e.g., controversies around of wind power.
- Projects often involve users but tend to recruit non-representative samples. Lessons might not be generalizable, and in the worst cases misleading.
- Projects are often based on implicit assumptions about human rationality, access to technological capabilities, interest and capital. If scaled up, smart grids based on such assumptions might increase social and economic inequalities and lead to social backlash.
- Important drivers identified for success are shared visions and expectations, supportive public policy instruments and a culture of sharing amongst grid companies.
- Important barriers are social acceptance, regulations, and prices (e.g., of batteries).

## Recommendations

- To de-escalate potential controversies associated with societal electrification, a national strategy that addresses social, technical, and economic aspects of electrification should be developed. This includes a push to improve energy literacy and citizenship in local communities, industry, and amongst policy makers.
- Project funders should require smart grid innovation to become more inclusive by addressing social aspects from an early phase, and by involving a broader set of stakeholders. In the public interest, knowledge generation on social aspects should be done by research organizations rather than commercial actors. This can in turn contribute to developing methods within social sciences, making it more holistic and transparent.
- Scholars in the social sciences and humanities should engage actively in understanding the ways that electrification might change contemporary societies across scales.
- Future framework conditions (e.g., tariff structures, rules e.g., for battery ownership) should be made clear, to guide contemporary innovation.

# 1. Introduction

## 1.1 Background

This report is part of the work in the Norwegian Centre for Energy Transition Strategies (FME NTRANS). NTRANS studies conditions for and strategies of energy- and climate transitions. The work presented here is part of Research area one (RA1), *Deep decarbonization and wide societal change*. Deep decarbonization entails cross-sectoral and society-wide changes beyond the introduction of single technologies. RA1 uses social-science methods and perspectives to study transitions as socio-technical processes, focusing on innovation, participation, controversy, and political processes.

One of the focus areas in RA1 is pilot projects, demonstration projects and experiments. As part of this work we have conducted mini-case studies of 89 pilot and demonstration projects. This report is the first of several thematic reports, which in sum will provide a synthesizing analysis of the role of such projects in transitions, to provide lessons from a large number of projects, and to give advice to policy makers and actors conducting such projects.

We interpret pilot and demonstration projects as important in technology development and innovation processes. They are sites where key visions for energy and climate transitions are materialized, and they are projects that are often also used to develop places. In this report the thematic focus will be on

- Smart grids with flexible consumption and high levels of renewable energy production

Following thematic reports will look at themes such as:

- Value chains that link renewable energy production to the production of fuels, e.g. hydrogen, ammonia and e-fuels
- Maritime transport
- Public transport
- Greener industry
- Negative emissions
- Zero emission neighborhoods

These themes transgress single technologies and point towards a set of visions of systemic changes in the production, distribution and consumption of energy, as well as shifts in the broader Norwegian institutional and regulatory landscape.

In sum, the above suggests that pilot and demonstration projects give content, direction and speed to transitions across diverse sectors. They are modes of governance, or ways of steering the transition. This steering is done through a combination of public and private funding, and by mobilizing the skills of researchers, industrial actors and public actors. Such projects are often also the embodiment of public and political priorities. Some of the projects we will discuss have been debated publicly in the news media, others have been part of exchanges in the Norwegian parliament. This means that pilot and demonstration projects are also potential sites and subjects of politics, as well as contestation and competition. Such aspects of pilot and demonstration projects are seldom discussed, analysed or evaluated, but in this and subsequent reports we set out to do so.

To summarize, we understand pilot and demonstration projects as:

- Materializations of visions for future society
- Elements of innovation processes
- Modes of governance and sites of steering
- Sites of public politics and contestation
- Projects of place and community development

Pilots or innovation activities tends to be evaluated in socio-economic terms, or by focusing on technological performance. We complement such modes of analysis by providing an assessment of current activities that asks how pilot projects are changing society, how to understand those changes, and what the implications of such changes are. This opens for a stronger social anchoring of innovation, potentially more inclusive forms of transition work, and allows for asking critical questions about how we steer society through such projects, and how such steering can be improved.

Finally, it is worth noting that our analysis here does not, and is not meant to, represent a complete image of how smart grids develop in Norway or beyond. Many activities and developments unfold outside projects such as those studied here. Hence, what we study here is one type of site where the energy transition unfolds, but an important site.

## 1.2 Socio-technical perspectives

In this report, we use a socio-technical perspective to analyse the role of pilot and demonstration projects in the Norwegian energy transition. This perspective builds on decades of insights from research fields like innovation studies, science and technology studies, geography and sociology. We will not elaborate extensively on theory here but provide some insights into what this perspective entails. We build on the assumption that society consist of a series of socio-technical systems. These are made up of "*(networks of) actors (individuals, firms, and other organizations, collective actors) and institutions (societal and technical norms, regulations, standards of good practice), as well as material artifacts and knowledge*" (Markard, Raven and Truffer 2012). Such systems deliver societal services like transport, industry, and thermal comfort. A transition, then, is "*a set of processes that lead to a fundamental shift in socio-technical systems*".

A key aspect of conducting such analysis is foregrounding that technological developments and societal developments cannot be understood as independent processes. The development and implementation of technology always happens within a society and the results are always shaped by society. In turn, new technologies re-shape the conditions for future societal developments. Society shapes technology, while technology at the same time shapes society (see e.g. Jasanoff 2015).

With this as a backdrop, the work to transform energy and mobility systems becomes important not only to decarbonize Norway, but as a way to re-shape the Norwegian society: everyday-lives, commercial activities, the public sector and politics are all heavily affected by changes in the ways that production, distribution and consumption of electricity is done.

Therefore, this report starts from the normative assumption that research and innovation activities come with responsibilities to avoid potentially noxious consequences of such activities. Recent analyses suggest that as transitions accelerate, such societal challenges intensify. As examples, increasing the pace of change tends to happen at the expense of inclusive and participatory processes. Further, there is a tendency of accelerated transitions strengthening the already powerful at the expense of those who are weaker.

As such concerns have grown, a steady stream of voices have pointed to the importance of related concepts such as just transitions (Newell and Mulvaney 2013), energy justice (Jenkins et al 2016) or responsible acceleration (Skjølsvold and Coenen 2021). These concepts in turn highlight that the urgent need to conduct energy transitions, should be coupled with measures to ensure that these transitions also produces ethically sound and just societal outcomes.

We bring such ideas to our analysis of pilot and demonstration projects as we ask:

- What are the characteristics of pilot- and demonstration projects in the Norwegian energy transition?
- Which are the issues that such projects seek to address?
- What are the key drivers and barriers to successful innovation in such projects?
- Which are the potential positive and negative consequences of such activities?

## 1.3 Methods

This report has been built on a series of mini case studies, conducted by scholars (analysts) with knowledge of the field. We started with selecting cases based on existing centres of environmentally friendly energy (FME-centres). The list expanded when searching in key databases for projects active since 2018. For this, we probed the databases of the Research council of Norway, ENOVA, and innovation Norway. We have also conducted interviews with the leaders of most FME centres. For this report, the interview with Cineldi leader Gerd Kjølle has been informative. While our search was comprehensive, this does not ensure that we have included all relevant projects in this analysis. Nevertheless, we are confident that the report covers the broad topics of Smart Grid innovation in Norway today, and that the inclusion of other individual projects would not significantly influence our results.

For consistency, the case studies have been built on a template which asks about key characteristics of projects based on publicly available information. Further, the analysts were asked to make a series of analytical assessments, e.g., with respect to potential controversies/unintended consequences, the projects strategies of upscaling, drivers, and barriers for success.

The resulting material was then coded based on themes emerging from the case studies. These themes form the basis for the topics of the different thematical reports in this series. Policy recommendations have been produced based on an iterative process amongst the authors of this report.

# 2. Smart grids: flexible consumption and high levels of renewable energy production

## 2.1 Background and key issues

The theme of smart grids with flexile consumption and high levels of renewable energy production is the largest category of pilot projects mapped, with 30 projects in total. The projects vary in size and cost. The smallest projects have a budget of around 200 000 NOK, while the most expensive project costs around 100 MNOK. A general observation across thematic focus areas, is that there are very few pilot and demo projects in any domain that deal with single technologies. This is especially true in in projects that tests, pilots or demonstrates smart grid technologies. We use the term “smart grid” as an umbrella, to describe the use of ICT to transform how electricity is produced, distributed and consumed. This also includes projects that seek to digitalize and automate various aspects related to grid maintenance, such as fault detection and repair. This means that the types of projects covered in this report are diverse.

Most projects analysed, do not see smart grids as a goal in itself. Instead, implementing smart grids tend to be framed as a way of assisting or enabling other energy transition developments, or as helping to avoid negative consequences of implementing new technologies. Example of this includes:

- Catering for the introduction of new, variable renewable energy production, e.g., by introducing combinations of storage, new technologies and other mechanisms that seek to shift the timing of energy consumption across society.
- Catering for new patterns of electricity demand and production that arises from the electrification of transport, industry, and other sectors, as well as the production of e.g., green hydrogen and green ammonia.
- Avoiding challenges of voltage quality due to new patterns of energy consumption and production throughout the grid.
- Enabling new forms of communication between different actors and technologies in and around the energy system
- Enabling new forms of planning with respect to design and development of the distribution grid
- Improving decision making with respect to maintenance and repair in the grid, often based on combinations of new sensor technologies, big data and machine learning.
- Reducing and/or postponing costs associated with electricity infrastructure development.

## 2.2 The actors involved in smart grid pilot and demonstrations

In the 30 projects analysed we have identified 70 different actors that are involved in piloting and demonstrating technologies or other elements associated with the smart grid. Actor-constellations typically differ depending on the type of technology tested, or the goal of the pilot. Close to all projects, however, involve an electricity grid operator, and at least one research partner. The most active grid companies identified are Elvia, BKK Nett and Skagerak Nett. The truly dominant research partner in this field is SINTEF, followed by NTNU. In addition to a grid company and a research actor, smart grid pilot projects often involve the local municipality, and a more specialized commercial or industrial actor. Two examples of such actors who are active in several projects are Pixii, who specialize in energy storage, and FutureHome, who deliver smart home technologies.

*AT A GLANCE*

- Actor-constellations differ depending on type of project
- A few actors dominate the field
- This represents a concentration of power
- Might hamper creativity

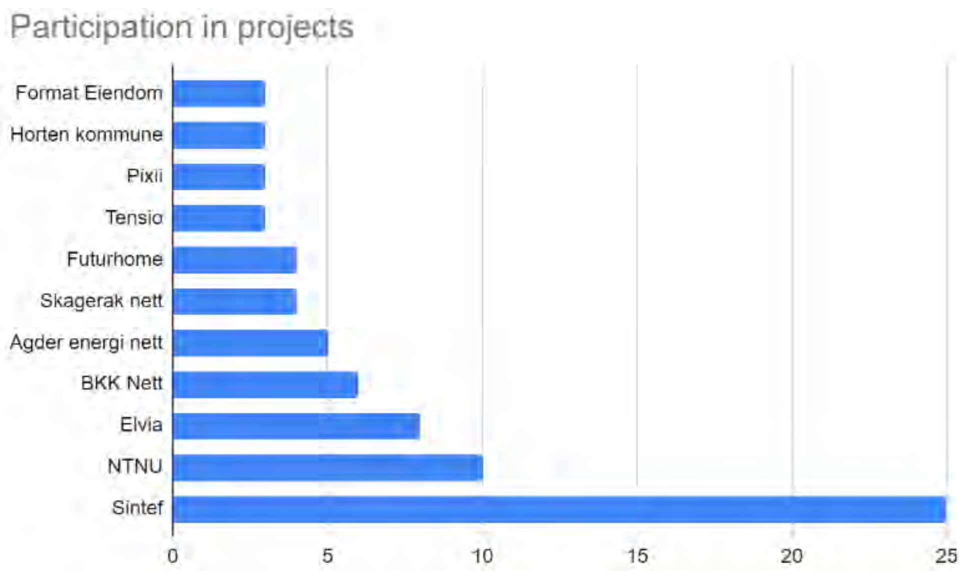


**FIGURE 1: ACTORS PARTICIPATING IN NORWEGIAN SMART GRID PILOT PROJECTS**

This landscape of actors is dominated by what we can call the incumbent actors of smart grid innovation in Norway. NTNU and SINTEF have conducted research, pilots and demonstrations in close collaboration with the industry in the smart grid field for around two decades. Actors like smart innovation Norway and Lyse should also be considered central in such a list of incumbents and would likely be very visible if the inclusion criteria for pilots studied here had been expanded. Many of the early smart grid research and innovation activities in Norway were triggered by policy decisions in the early 2000s which originally intended to result in a mandatory smart meter roll-out by 2013. This was later postponed, in part due to what was understood as a need for more innovation and further piloting (e.g. Skjølsvold 2014; Ballo 2015). Combined with funding for innovation and research, this has resulted in a legacy of pilot and demonstration projects in the smart grid field (Skjølsvold and Ryghaug 2015; Ryghaug et al. 2019; Throndsen and Ryghaug 2015), which primarily sought to realize economic value for grid companies and society.[1]

From a social-science perspective, such a concentration of actors and activities within one domain can represent a concentration of *power*. Avelino (2017) has discussed this form of dominance as re-enforcive power, suggesting that actor-constellations like this give strong direction to developments, solidify shared understandings, produce widely recognized 'rules of the game' and build up reservoirs of resources and competence about what it means to be smart grid innovators in the Norwegian context. This echoes past research on pilot and demonstration activities in Norway, which has illustrated that such projects often reflect and amplify the interests of the involved actors (Ryghaug and Skjølsvold 2021).

These dynamics likely enable continued growth and accumulation of ideas and resources within this network of actors. Given that this work and these actors now have significant momentum, they will probably remain important actors and interests in shaping the future of smart grid innovation. This critical mass and their shared directionality suggest that many new projects and innovations are likely to emerge from this network. However, it also makes it difficult for newcomers and alternative voices to propose new modes of working, to ask different types of questions, and paradoxically: to bring radically new ideas and methods to the table. Hence, too strong reliance on a dominant set of actors and networks might entrench smart grid innovation in a path that could produce unforeseen challenges in the both the long and short term.

## 2.3 Funding

Of the 30 projects analysed, seven case studies did not provide any information on economy. Combined, the 23 cases that do provide numbers have a total budget of at least 275 million Norwegian kroner. Based on average costs, a conservative estimation is therefore that the pilots covered in this report amount to at least 350 million Norwegian kroner.

*AT A GLANCE*

- Studied projects worth approx. 350 MNOK
- All projects involve public funding
- Acquisition of funding is a key competence in smart grid innovation

[1] See e.g., https://www.regjeringen.no/contentassets/816c63dcb0ea49768ec03cd64828af5a/effekter_av_energiforskningen.pdf for a discussion that illustrates this

These funds primarily come from Norwegian public policy instruments, sometimes in combination with private funds, as well as with a large component of in-kind funding. We have seen one example of an H2020-funded project. With a broader scope, the share of H2020-funding would likely have increased, though the phenomena studied would not change substantially. This suggests that there is a substantial public policy push for the development of and implementation of the Smart grid in Norway.

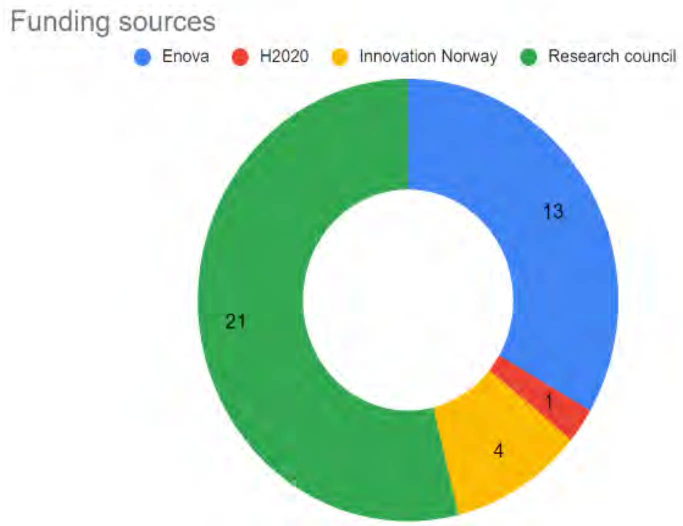


**FIGURE 2: FUNDING SOURCES FOR NORWEGIAN SMART GRID PILOT PROJECTS**

Some initiatives should be noted. First, several of the pilot projects mapped here are conducted within the national centre for environmentally friendly energy (FME) Cineldi. Further, several projects analysed for this chapter have been funded through the joint program Pilot-E. This program is a joint funding mechanism where the Research council of Norway, ENOVA and Innovation Norway all provide resources through what has been characterized as a mission-oriented policy instrument to address prioritized sustainable societal transformations. It is also worth noting that several of the analysed pilots are part of stand-alone projects funded by the Norwegian research council.

The funding for projects such as those we analyse here, also illustrates that a key competence in innovating for the smart grid, is the competence to acquire public funding in itself. This is likely also one of the reasons why SINTEF and NTNU are so dominant in this field. They are specialists in research and development work, but also experts in practices and strategies of acquiring funds, and through this becomes what some scholars have described as *obligatory passage points* (Callon 1984) in the development of the smart grid in Norway. In other words, actors who seek to conduct smart grid innovation in all likelihood needs to collaborate with these actors to acquire funding.

## 2.4 The role of social science

The role of social science in smart energy pilot activities in Norway is marginal. Social sciences are integrated in the development of and execution of only one identified project. In four projects, social scientists have been involved by conducting studies during or after the pilot. 25 of 30 projects have no social science-involvement. This echoes international research which has found social science to be marginalized equally in terms of funding and in being able to frame research questions and agendas (Foulds and Christensen 2016; Øverland and Sovacool 2020; Baum and Bartowski 2020)

*AT A GLANCE*

- Social science is marginal in the studied activities. This is a missed opportunity – the smart grid explicitly depends on active societal participation to succeed.
- The social sciences have diverse interests that lends themselves to pilot work and analyses.
- Access to pilot customers is a key challenge for social scientists interested in studying established pilots.

It is worth noting that the one project that has social science as an integrated element of its pilot activities is set-up by a consortium of actors that are largely not part of the earlier discussed incumbent smart grid innovators. This strengthens the assumption that a diversity amongst researchers and innovators is likely to produce a diverse set of innovation practices, and that social science is currently not considered integral and important to smart grid innovation in Norway.

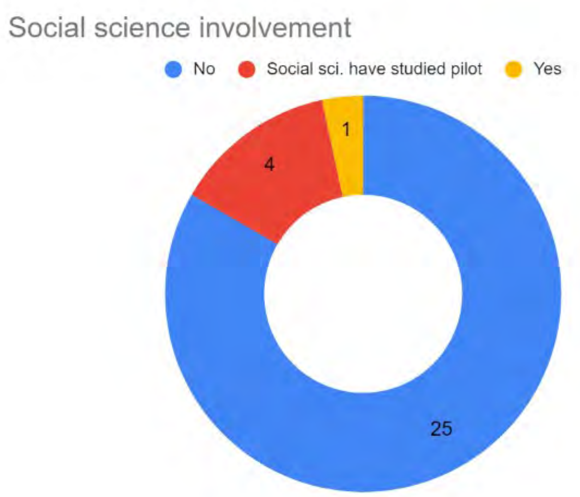


FIGURE 3: SOCIAL SCIENCE INVOLVEMENT IN SMART GRID PILOT ACTIVITIES

In this project ("Smart Senja") social scientists from UiT - the Arctic University of Norway are directly involved in the project and steer local anchoring processes and engage local communities e.g., by organizing regular open gatherings in the community hall, "energy cafes", in addition to taking part in the education of school children. Further, the social scientists in this project work to understand issues such as the relationship between society and technology, material ownership to technological solutions and project ownership, the introduction of small-scale, new renewable energy production, the (future) role of grid companies, and the relationship between the visions of the project and local social and economic values (both commercial values and community values). This means that this project is based on a broader scope of questions, and a broader practical analysis about what it might take to make the future smart grid work in practice, than most comparable projects. In four projects, social scientists are studying or have studied the pilot processes without being directly involved. One example of this is the iFlex project, where social scientists associated with FME Include, FME Cineldi and FME NTRANS are in the process of conducting interviews with citizens that have been exposed to a price experiment. The other three examples are similar: social scientists have come onboard at a late stage to study and evaluate outcomes. There is also one example in our data of activities resembling social science being conducted by a communications agency. This is problematic, because it might hamper increased systematic understanding of the social challenges of implementing smart grids.

*Energy café at Husøy, Senja in November 2019 as part of the pre-project to Smart Senja. Photos: Berit Kristoffersen/UiT.*

A key challenge reported by some of the social scientists who seek to study such pilots without being an integrated part of the development or project is the matter of access to pilot customers. Today, electricity grid companies are subject to very strict privacy rules. When customers become part of R&D activities, they typically sign letters of consent, e.g., with respect to access to meter data, or about agreeing to be part of a technology trial. These letters also tend to specify who can be provided information about the participants. Thus, to access and e.g., interview such pilot participants today, social scientists often have to pass substantial legal and regulatory barriers which in practice often stops the research. This would have been avoided if they had been involved from the beginning. Today, this stands out as a key barrier to broader studies of how technology users experience participating in such trials, and strongly suggests that funding bodies should require the inclusion of social science from the start in such processes in the public interest. One can also argue that the involvement of social scientists in projects involving pilot costumers could contribute to addressing social issues, such as involving a broader set of society as pilot customers, to make it more socially just, and to have a more representative sample.

Going further, compared to other key technologies that are heavily piloted as part of the Norwegian energy transition, smart energy technologies are often found close to citizens, sometimes embedded within their homes and local communities, and are often developed with the explicit intention of changing how citizens interact with energy and not the other way around. Often, success hinges on the active participation and engagement of citizens. This is strongly echoed in policy discourse that highlights the need for proactive consumers, flexible consumers, and the introduction of prosumers – all of which are key elements in many of the projects analysed for this report.

With this as a backdrop, the relative absence of competence on social, political and institutional aspects of smart grid developments is surprising. Funding mechanisms such as Pilot-E explicitly seeks societal transformation, but the types of projects selected for funding only to a very limited degree engages with aspects beyond making technology work and learning from technological operation in the projects we have studied in this report.

Husøy, Senja. Photo: Jørn Berger Nyvoll/UiT.

# 3. Key issues of smart grid pilots

All case studies have been tagged with what the responsible analyst have dubbed to be key words that are important to describe the case in question. Through this we have identified two main clusters, or types of smart grid pilot and demonstration activities. These clusters have also been informed by the project descriptions. The first, and largest of these clusters seeks to address issues that are associated with broader trends within the energy transition, and entails using ICT to enable what we call the future electric society. The second seeks to optimize or improve practices of grid planning, grid maintenance or grid operation. In what follows we will describe what characterizes the two types of projects. Building on this, we will reflect on key societal issues discussed by the analysts (e.g. user involvement, future visions and strategies of upscaling, drivers, and barriers of success and potential controversies or challenges surrounding the project).

## 3.1 Issue 1: Future electric society and its consequences

Projects that have been grouped in this category have typically been tagged with key words such as "demand-management" (12 projects), "batteries" (11 projects), "flexibility" (9 projects) and "PV" or "renewable energy" (9 projects). These key words point towards elements that involved actors see as central in future electric society, and which ICT technologies are expected to enable.

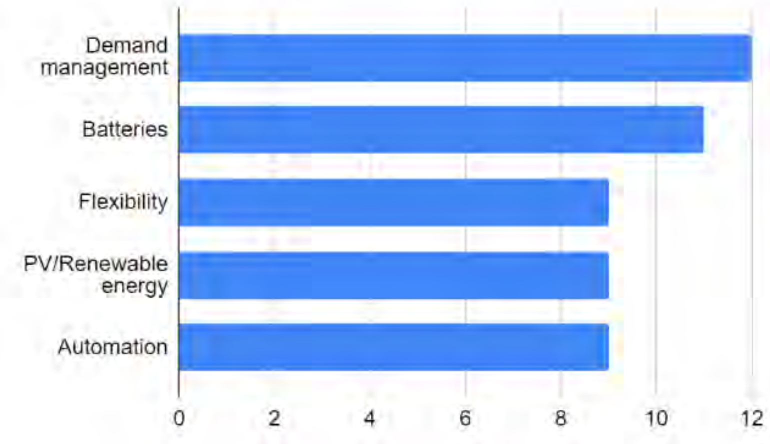


FIGURE 4: TOP TAGS FOR FUTURE ELECTRIC SOCIETY

A key selling point of these projects is that large scale trends in the energy transition such as the implementation of new renewables, the electrification of transport, or the use of battery storage throughout the grid, results in a series of new challenges for actors who operate electricity grids (e.g. DSO's), users of the electricity grid (e.g. citizens, electric transport operators) or actors who seek to expand the electricity grid. When explaining why the funding agency ENOVA prioritizes projects in this direction, their market director recently noted:

> *"We have a robust energy system today, but this will be challenged when society is increasingly electrified through the transition to a low emission society. Then we need to develop and implement new technologies and business models"* Market director, ENOVA

Similar sentiments were expressed by the centre director of FME Cineldi who we interviewed for this report. She highlighted that the energy grid can be thought of as an enabler of transitions:

> *"The electricity grid is an enabler for the energy transition. This is becoming more and more important in the energy transition, since the goal is to electrify and to decarbonize"* (Cineldi director, interview)

While these projects address what is understood to be generic challenges of the energy transition and electrification, they are often conducted also to address quite specific challenges, which are sometimes also quite localized. Four ideal-types of projects deserve mention.

*FUTURE ELECTRIC SOCIETY: FOUR TYPES OF PROJECTS*

- **Islands**: Transform consumption and production of energy, often due to new energy demands for aquaculture industries and weak grid connection to the mainland.
- **Peripheral areas of the grid**: Resolve challenges (e.g. voltage variation, fallouts) due to new technologies, e.g. PV, EVs
- **Urban developments:** Part of broader push for urban transformation, deal with new complexities of supply and demand in densely populated areas e.g. through ICT and batteries
- **Behavior change:** Targeting citizens, e.g. through price experiments, information campaigns, smart home technology

First, four of the case-study pilot projects are conducted on three islands. This adds to past Norwegian smart grid pilot activities on islands, and echoes the strong international focus on transforming the energy systems of islands (e.g. Skjølsvold, Ryghaug and Throndsen 2020). The focus of these projects is to holistically transform how energy is produced and consumed trough combining new forms of renewable energy production with demand management, flexible consumption, and energy storage. In some projects this has been flagged as an alternative to building new sub-sea cables or relying on diesel powered generators. However, the islands also differ substantially. Of the projects studied here, Froan and Utsira are small islands, while Senja is larger and in many ways resembles the mainland in terms of energy system, supply, and consumption. All these islands have seen a rapid growth of new industries related to fish farming and aquaculture, and a related growth in industrial electricity demand. Hence, these projects on the one hand illustrates the importance of natural resource-based industries for innovation in Norway (see e.g., Haugland 2020), and on the other hand they are very illustrative of the challenges associated with new forms of industrial electrification, and the interplay between industry and household energy demand in a system with high shares of new renewables. All projects also strongly flag that upscaling of the solution entails utilizing them on the mainland.

The second type of project focuses more specifically on what we can call peripheral areas of the grid, and challenges that emerge e.g., with the introduction of new technologies (e.g., electric vehicles, PV). Examples include large voltage variations and voltage drops amongst customers, overloads in transformers, overloads on conductors and electricity fallouts. Projects of this type are interested in how a combination of batteries, digital technologies, and automation (and sometimes flexible consumption) can serve to stabilize conditions in the grid and through this avoid the need for new investments in infrastructure. While a few of these projects are associated with flexible consumption, these projects only to a marginal degree involve citizens. This category of projects also involves instances where (mobile) batteries are tested as a solution in the event of temporary increases in electricity demand. An example of this is a project that focuses specifically on how a mobile battery and digital technologies can be used to manage supply and demand at a construction site.

The third type of project deals with what we can call urban challenges and urban developments. Some projects of this type are associated with large-scale modernization and development initiatives in cities (Bodø and Fredrikstad), where smart energy pilot projects are part of a broader push to develop new neighborhoods or urban transformation. They tend to combine many elements, e.g., covering combinations of renewable energy technology, batteries, and flexible consumption. Some projects of this type (e.g. Skagerak energilab) are also microgrid-projects, which means that they can operate in a stand-alone (island) mode, or that the area as a whole in principle can be used to provide flexibility to the broader energy system. This vision is elaborated on further in the concept of positive energy blocks or positive energy districts, which will be discussed in a subsequent thematic report which deals with zero emission neighborhoods (See e.g. Baer et al. 2021 for a discussion).

While projects on islands and peripheral areas often seem to be driven by a desire to re-produce the stability of old electricity grids in new conditions ("lys i husan"), some urban projects are wrapped in a rhetoric that is focused much more on disruption, and on changing the ways we as societies live with and interact with energy. One example of this is the Mikroflex-project in Fredrikstad, which uses smart energy technologies as the basis for a vision that is intended to disrupt how we live ("Just like Tesla, but for buildings"). There is a strong element of energy and engagement with energy being understood as a constituent element of future lifestyles, e.g. through hoping that future citizens will adopt and actively use smart-home technologies to a much larger extent than they do today.

The fourth type of project focuses specifically on consumption, and typically experiments with different types of instruments (e.g., price, information, automation) that are intended to make consumption flexible. Some projects of this type seek to investigate how effective new price schemes are, e.g. by trying variable pricing during peak load periods. Examples include communicating artificial price signals via SMS (iFlex), combining new power tariffs with different communication strategies and smart home technologies (Aktive hjem), or through remote control solutions where customers allow grid operators to control certain loads such as floor heating under certain conditions (Boligflex). These projects are typically based on the normative assessment that citizens should become more active in their engagement with energy, and through this, provide flexibility to the grid.

## Reflections on current work to promote the future electric society through smart grid pilots

Seen altogether, the four types of projects discussed above mobilizes smart energy technologies to enable what is seen as a future electric society. The analysts conducting case studies have provided reflections on the pilots, which range from the very concrete to the more speculative. We will begin by discussing what was identified as concrete drivers and barriers for conducting pilots such at these in a successful way, before we discuss analytic points highlighted by the analysts. Tables 1 and 2 describe drivers and barriers.

| Important drivers | |
|---|---|
| **Shared visions of future electrified society** | Actors from across industries and sectors share an understanding of what the challenges and opportunities are for electrification and decarbonization. In several projects this is described as drivers in terms of translating into strong networks, enthusiastic actors and public-private partnerships that work to enact and materialize these visions. |
| **Supportive public policy instruments** | Technologies such as batteries are not yet cost competitive, which means that they will continue to rely on public funding instruments that promote them. Further, the public policies and funding instruments that support the developments described above importantly stimulate more holistic projects than single-technology developments, and through this provide a shared directionality towards future electric society that transgress individual technologies. |
| **Culture of sharing** | Grid companies are natural monopolies which means that they do not necessarily compete and cannibalize each other. Several projects flagged that this enables the sharing of results between projects in ways that differ from what is common in other industries, allowing for learning across projects and regions. |
| **Technology development and falling prices** | Prices of solar power and batteries are falling and is expected to fall further while the technological capacity increases, and experiences are increasing. This has been flagged as a central driver in many projects. |

TABLE 1: DRIVERS OF SUCCESS

| Important Barriers | |
|---|---|
| **Social acceptance** | In several projects, social acceptance of tested solutions was flagged as a key barrier to the success of pilot projects. |
| **Regulations** | Several projects flag that regulatory conditions are barriers to establishing and expanding pilot activities, as well as to giving direction to the work. Examples of this include insecurities about future grid tariffs, as well as ownership models and regulations around batteries. |
| **Price of new technology** | While prices of technologies such as batteries are expected to drop, they are currently so high that most projects are not feasible without financial support. |

TABLE 2: BARRIERS OF SUCCESS

The drivers and barriers identified above are quite concrete and relate to the specific activities of pilot projects. Beyond this, analysts provided notes on broader challenges or potential controversies that was either visible within the project material, or which appeared plausible to the analysts given their knowledge of the field. Based on assessments of such challenges and controversies, table 3 provides some broader qualitative assessments of issues and challenges that are likely to emerge around the development and implementation of the future electric society.

| Emerging societal issues and challenges | |
|---|---|
| **Tendency to see smart grid in isolation:** | Many of the projects noted that smart grids would bring large organizational changes, as well as potentially disruptive changes in markets and society more broadly. Few, if any projects, sought to evaluate and position the involved actors in relation to such changes. This can create challenges e.g. for incumbent actors down the line, as the innovations they help implement might potentially undermine their own operations. |
| **Tendency to take social aspects for granted** | Many projects are built around visions of a future society where citizens e.g. allow remote control of certain elements in their households, where batteries in e.g. EVs are used as a source of flexibility, or where renewable energy production, e.g. from wind turbines are combined with smart grid technologies. Yet, few, if any projects discuss or address how the relationship between future citizens and future technologies will play out in practice. There is a strong potential here for strengthening insights on Issues of trust, legitimacy, privacy, acceptance, ownership etc, as well as to develop and test social innovations, such as the recently proposed notion of social licenses to automate (Adams et al 2021). If this is not done, it might result in social backlash upon attempting to scale-up the pilots. |
| **Problems of generalization** | Projects that involve technology users e.g. in efforts to make consumption more flexible tends to be heavily biased towards involving older segments of the population, more men, people that live in larger houses than the general population, fewer singles and more couples without children living at home. Future provision of flexibility, however, and the active participation of citizens tends to be framed as involving broader segments of the population. Hence, lessons generated during pilot and demonstration projects are difficult to generalize, and if applied to broader segments of the population, lessons drawn from such projects might create new or different problems down the line. |
| **Justice Implications:** | Challenges of generalization might also feed into questions of justice in energy transition processes. Analysts noted that in several projects, the future society envisioned seemed to center on a combination of economic affluence, technological capability, and interest in energy issues to reap the benefits e.g., of being able to provide flexibility. This suggest that if not done reflexively, smart grid innovation might reinforce existing social and economic divisions in society. This appears especially important in developments that implements smart energy technologies as a part of a broader set of urban transformations. How can we avoid producing new high-tech ghettoes for the wealthy, while enabling participation in the transition also for the less fortunate? Energy justice literature tends to emphasize the distributional, procedural, and recognition-based aspects of energy justice. |
| **The invisible politics of assumptions** | In several projects, analysts have pointed to what we can call the invisible politics of the assumptions made in such projects. Examples of this includes a strong tendency to implement "set-and-forget" automation, where users are expected not to notice the changes made, as well as assumptions about the ways that citizens react e.g., to price signals. The literature has indicated that such assumptions tend to promote incremental rather than transformative changes in consumption. |

TABLE 3: EMERGING SOCIETAL ISSUES AND CHALLENGES

## 3.2 Issue 2: Maintenance, planning and optimalization

The second issue addressed by smart grid pilot and demonstration projects broadly seeks to optimize operation, maintenance, and planning of the grid. The projects clustered in this category of projects are located further away from citizens, and hence also appears to have fewer direct societal consequences. The key selling point of these projects is that operation and maintenance of the electricity grid has tended to be a resource intensive, cumbersome, and typically, manual process, were there has been a significant need for manpower to investigate substations, power lines, cables, and other elements of the power grid.

Through the implementation of sensors throughout the power system, new forms of software, often combined with machine learning capabilities, the ambitions of these projects circles around reducing the costs of such activities, improving the security of transmission and supply, and generating new commercial activities e.g. within sensor production. Hence, these projects are parts of a broader push towards the digitalization of critical infrastructure.

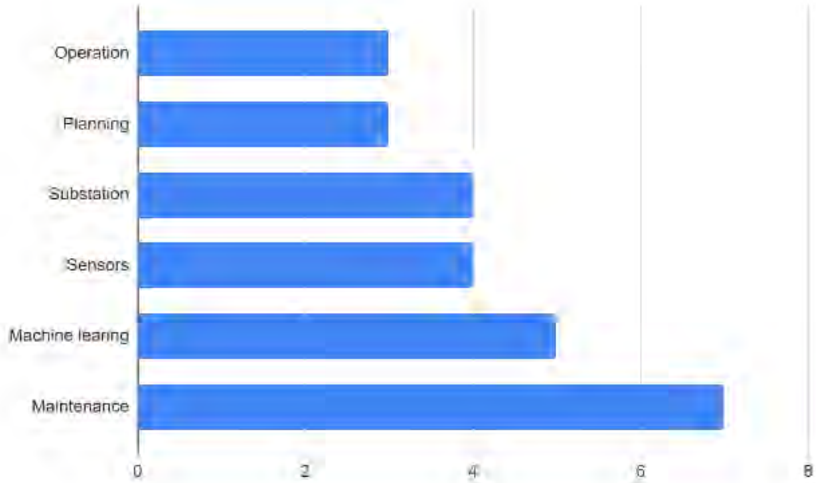


**FIGURE 5: TOP TAGS IN PROJECTS FOCUSED ON MAINTENANCE, PLANNING AND OPTIMIZATION**

### Reflections on the work to implement smart grids for maintenance, planning and optimization

The work to pilot and demonstrate these forms of smart grid technologies differs from those discussed over the last pages. One aspect of this is that the technology users involved in these projects tends to be the electricity grid companies, and not citizens. Further, the companies are often both users and innovators, and the projects tend to be conducted with the ambition of immediate implementation in mind. Hence, users here are what Schot et al (2016) have called user-producers. Hence, while pilots targeting the future electric society tends to be anchored in future visions, projects under this banner tends to target more immediate concerns. This is also reflected in the identification of drivers and barriers.

| Important drivers | |
|---|---|
| **Prospects of economic benefits:** | Saving money on manpower, replacement of equipment and increased security of supply for the grid companies. |
| **New market for technologies:** | Producers of new technology, particularly sensors, see the energy system as an important future market and a steppingstone for broader markets. |
| **Culture of sharing** | As grid companies are have monopoly over the power lines in their regions, they do not compete directly with each other. A number of projects flagged that this enables them to share results between projects in ways that differ from what is usual in other industries, allowing for learning across projects. |
| **Perceived inevitability and benefit of digitalization** | Many projects are framed as part of a broader frontier of digitalizing society. This shared vision seems central for this push for further digitalization also in this domain. |

TABLE 4: IMPORTANT DRIVERS

| Important challenge | |
|---|---|
| **The interpretation of big data** | Many projects note that while generating big data on the state of the electricity system is quite easy, the complexity of data interpretation is noted as a challenge in most projects. How to deal with false indications, as well as how to translate data into better predictive models? |

TABLE 5: IMPORTANT CHALLENGE

Given characteristics of this theme, it is not surprising that the identified long term societal issues are fewer and more speculative. This also reflects a lack of prior social science engagement with issues such as those discussed here, and hence points towards a need for new forms of engagement by social scientists. This is a dual challenge for social scientists and funders alike.

| Emerging societal issues and challenges | |
|---|---|
| **Ownership of data and related infra-structure** | Analysts noted a concern for the relationship between ownership of data, and the relationship between data and analyses. Some pilots used proprietary system software, which means that capabilities might be taken away from research organizations, standards organizations and other public interest actors and agencies, at the expense of more purely commercial actors. This hints at the possibilities of a broader research agenda rooted in relationship between public and private interests in this domain in the years to come. |
| **Loss of jobs/Need for new competence:** | Contemporary activities along power lines and power stations provides important jobs. The development described above might result in the need for substantially fewer, but more specialized labor in electricity grid companies. |
| **Changes to cultural landscape** | Analysts have in several cases speculated about the multiple roles played by maintaining access to electric power lines, cables and sub stations, including the way that such access helps to cultivate cultural landscapes in a large, but sparsely populated country such as Norway. Exploring how increased reliance on automation might affect this seems important. |

TABLE 6: EMERGING SOCIETAL ISSUES

# 4. Final remarks

This report has provided an empirically driven discussion about the role of smart grid pilot projects in the Norwegian energy transition. The goal has been to shed light on issues beyond the techno-economic, to discuss broader implications of the activities in such projects. The report does not comprise a complete image of the energy transition, nor of Norwegian smart grid pilots. That said, the phenomena described in this report should be recognizable to actors within the field, and points to important aspects of contemporary and future smart grid innovation at the intersection of industry and research. We hope it will prove useful in developing the work in this domain further.

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