Studying smart energy solutions for small to medium consumers

Skjølsvold, Tomas Moe; Ryghaug, Marianne; Throndsen, William; Christensen, Toke Haunstrup; Friis, Freja; Ornetzeder, Michael; Sinozic, Tanja; Strauss, Stefan

Publication date:
2017

Studying smart energy solutions for small to medium consumers

Version 1.0

Tomas Moe Skjølsvold, Marianne Ryghaug, William Throndsen
NTNU, Norwegian University of science and Technology

Toke Haunstrup Christensen & Freja Friis
Danish Building Research Institute, Aalborg University

Michael Ornetzeder, Tanja Sinozic, Stefan Strauß
Institute of Technology Assessment

19 September 2016

ERA-Net Smart Grids Plus | From local trials towards a European Knowledge Community

This project has received funding in the framework of the joint programming initiative ERA-Net Smart Grids Plus, with support from the European Union's Horizon 2020 research and innovation programme.

INTERNAL REFERENCE

- **Deliverable No.:** D1.1
- **Deliverable Name:** Studying smart energy solutions for small to medium consumers
- **Lead Partner:** NTNU
- **Work Package No.:** 1
- **Task No. & Name:** xxx
- **Document (File):** D1_Framework.docx
- **Issue (Save) Date:** 2016-09-19

DOCUMENT SENSITIVITY

Not Sensitive	Contains only factual or background information; contains no new or additional analysis, recommendations or policy-relevant statements

DOCUMENT STATUS

	Date	Person(s)	Organisation
Author(s)	04.07.2016	Tomas Moe Skjølsvold, Marianne Ryghaug, William Throndsen, Toke Haunstrup Christensen, Freja Friis, Michael Ornetzeder, Tanja Sinozic, Stefan Strauß	NTNU, SBi, ITA
Verification by			
Approval by			

CONTENTS

Disclaimer

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.

www.eranet-smartgridsplus.eu

1 Introduction

This is the first report from the project *Markets, actors, technologies: a comparative study of smart grid solutions* (MATCH). Its purpose is to outline an analytical framework for how to comparatively study smart energy solutions for small to medium customers. We will primarily work with electricity solutions, but are also open to solutions involving more hybrid set-ups. The framework primarily targets MATCH-researchers, but its content should also be of interest to others studying the smart grid from socio-technical perspectives. The framework will inform the work conducted in subsequent work packages.

On a basic level, the framework will ensure that we sufficiently cover "markets", "actors" and "technologies", and that we ensure comparability across countries and cases. This should allow us to analyse and assess how the smart grid solutions are configured, both in terms of social and technical elements involved, as well as how these socio-technical configurations "work" in a given context. The focus on work suggests that we have a process-oriented view on smart energy system solutions. In other words, they are not static or fixed entities, but rather shifting and fleeting, changing as actors learn, as practices are changed, as technologies are introduced or changed, as meaning is ascribed to technologies etc.

Thus, when we aim to assess how the solutions "work", we also have to ask for *whom* the solution works, and be open to the possibility that we might find diverging answers for different actors, even within the same context. As an example, a solution that is deemed "successful" from the point of view of a grid operator, might be seen as intrusive or exploitative from the perspective of small-to-medium consumers.

Based on case studies in the three countries we will gain impressions of how different socio-technical configurations work under different conditions, and how they work for different actors. This will most likely paint heterogeneous images of the studied solutions. This, however, does not mean that we will not search for patterns and similarities across the cases, which might allow us to formulate more or less explicit advice on what solutions to choose under which circumstances. For instance, are there types of actor and technology constellations that seem to work better than others? Are there examples of configurations that should be avoided? Further: are there lessons to be learned from the studied solutions that relate to the up-scaling or system effects of individual (local) solutions?

The remainder of this report will be structured as follows: We begin with a brief note on the research perspectives of the MATCH-partners, before we move on to a general discussion about how we understand the current smart energy system. This includes a discussion of three core "solution foci" of MATCH: DSM/DR, Micro generation and integration of storage. This is followed by discussions of how we should understand the categories "markets", "actors" and "technologies". Finally, we have a set of methodological discussions: How can we study such matters?

2 MATCH-perspectives

The MATCH consortium consists of three core research partners, who will study smart grid solutions targeting small to medium customers. The cases will be analysed individually as well as comparatively in order to develop a framework which can be used to assess projects by how well they work, for instance through developing a loose typology of solutions that illustrate the solutions' core social and technological characteristics, in order to be able to compare and assess configurations across contexts.

The three MATCH research partners come from somewhat different, but related theoretical and analytical backgrounds. In common, we share an interest in the social and the technical, and the role of technology in society. The three perspectives also share an ambition of analysing these in relation to each other. Technology is an integral element of society, which means that we cannot analyse society without a view to technology. This argument also goes the other way, we cannot analyse technology without accounting for "the social".

Combined, these three perspectives allow the consortium to generate a set of research questions for our case studies, which it would have been difficult to do without our combined strength. At the same time we should also recognize that the differences between our perspectives could lead us to pick up on different aspects of the studied solutions, and that we might analyse similar cases differently. In order to begin grasping these issues, this report begins with a brief discussion of the respective perspectives of the partners.

2.1 Science and Technology Studies (STS)

Historically, Science and Technology Studies (STS) have primarily been concerned with the production or construction of (science and) technologies, highlighting the non-deterministic character of the relationship between the development of technology and society. In other words, technology is not an autonomous force, unilaterally affecting social affairs. As an example, instead of asking how "TV has changed society", one would ask something in the lines of "which social developments created the conditions for the development of TV?" Thus, STS has asked how social processes influence technological development, and in turn, how this development feeds into social processes (e.g. Bijker, Hughes, and Pinch 1987, Russell and Williams 2002, MacKenzie and Wajcman 1985). In this context it has been argued that technology does not develop as a result of some inner logic, but rather as a function of social, economic, technical, and political factors. Using historical data Bijker has argued that relevant social groups contribute to the construction of technology, and that there are no criteria to attribute a special status to specific actors or social groups. In a similar but less strict way, Collins and Evans (2002)

have pointed out that laypeople have contributory expertise that shapes the future design, form and function of technologies. In Actor-Network Theory (Callon 1986b, Latour 1987), often shortened ANT, the argument of how technology is shaped has been taken one step further, as a radical kind of symmetry is employed to explore how innovation is the outcome of assemblage work in hybrid collectives of humans and non-humans.

In the early 1990s, many STS-scholars turned their attention from the production and development of new technologies to the way that these technologies became parts of the everyday lives of technology users (Sørensen 1994, Pinch and Oudshoorn 2005). This signalled a more active role for technology users, where they were not only considered passive consumers or non-consumers of ready-made technological artefacts. Instead, it was highlighted how users are central to technological innovation processes through their active engagement with, ascription of meaning to and further development of technologies. One way to conceptualize this process is as domestication, a metaphor that highlights how technologies are shaped by their users, while shaping and influencing the very same users.

The MATCH project will study smart energy solutions, with a focus on the experiences of small and medium consumers. To this end we will draw inspiration both from the literature on the construction of technology, as well as the literature on user engagement with technologies. First, we have an interest in the work conducted by various actors to assemble or construct smart grid demonstration projects. Many of these solutions are relatively new, which means that they are subject to interpretative flexibility (Pinch and Bijker 1984). This means that different social groups, different groups of actors, might have different understandings of the solutions at hand, and different understandings of what their purposes are, what the goals are with the trials etc. Thus, it is interesting to study the translation (Callon 1986a) strategies employed by involved actors, as they try to enrol other actors from various spheres as allies working for specific versions of what the smart grid could and should be. One potential outcome of this is that the smart energy solutions end up looking radically different, because they have been constructed by different kinds of actor groups and technologies, with different understandings and expectations.

More generally, this can also be related to an interest in energy transitions, with a focus on the many controversies involved in such transformation processes, as well as the work done to overcome such controversies, and the many sites that needs to be mobilized across society to cater for shifts in complex systems like the energy system (Jørgensen 2012, Pineda and Jørgensen 2015, Farla et al. 2012, Åm 2015). Smart energy system demonstration projects and solutions studied in MATCH could be considered a kind of transition experiment, where various actors negotiate how potential futures could look.

On the other hand, we have an interest in the technology users, and the experiences of the users with the smart energy solutions we study. However, with an ANT-inspired perspective, distinguishing between "users" and "producers" of smart energy system solutions might be somewhat misleading. Users of different kinds are part of a collective "solution", and it is through the relations between the various elements of a solution (e.g. solar panels, feedback monitors, humans, organizations, buildings) that a working or non-working outcome is produced.

For this reason, it is interesting to look at how other actors frame potential user groups, how they attempt to enrol them in demonstration projects, and which issues the smart grid solutions are understood to address. This is related to an interest in understanding

how technologies such as those associated with the smart grid might (or might not!) cater for public material participation (Marres 2012) in processes such as an energy or sustainability transition. An interesting route to explore could be if the kinds of solutions studied in MATCH might serve as conduits for the production of new kinds of energy citizenship (Devine-Wright 2007), something which has been argued to be necessary to achieve low-carbon energy transitions.

As a practical entry to the study of users and their interaction with technologies, the concept of domestication stresses how technology users ascribe meaning to technologies, establish new practices in association with technologies, and that there is a constant process of learning in the interaction with the new technologies (Sørensen 1994). The concept is sensitive to the fact that there is interpretative flexibility amongst different user groups, something which means that a solution might work very well for some, while alienating others.

- How are strategies employed to configure smart energy solutions for small to medium users differently (including the role of users) and how do different configurations work in practice?
- What are the implications of our case studies for the wider European work of "doing" sustainable energy transitions?
- What are the relationships between different ways of engaging small to medium users in the smart energy solutions and the relative success of the solution?

2.2 Technology learning approaches (constructive technology assessment)

Innovation studies, transition research and transition management, as well as technology assessment approaches, put much emphasis on learning and experimentation in socio-technical niches. According to these approaches innovation depends on practical experiences as well as theoretical reflexion in early phases of technology development. In MATCH we will build on these ideas in a twofold manner. On the one hand, our cases will be viewed as niche experiments aiming at processes of learning and articulation. On the other hand, learning and reflexion will be stimulated and facilitated as part of the project. In the following we will give a brief overview of learning oriented approaches that will guide the empirical analysis within MATCH.

The concept of socio-technical niches plays an important role in transition research (Kemp, Schot, and Hoogma 1998, Schot and Geels 2008) and design-oriented forms of Technology Assessment (Schot, Hoogma, and Elzen 1994). According to these early approaches, niches are defined as temporary protected spaces to support the development of more sustainable technologies; as a kind of local breeding spaces that enable learning and experimentation. Once the technology is sufficiently developed, in a broad sense, initial protection may be withdrawn in a controlled way (Kemp, Schot, and Hoogma 1998).

A similar notion of the niche concept is applied in the multi-level perspective (MLP) approach, an analytical framework to conceptualize and explain long-term transitions of socio-technical systems towards greater sustainability (Geels 2002). Here, niches are conceptualized as less structurated spaces that offer conditions for action: the numbers of actors involved are small, the degree of alignment between elements is low (Geels 2011), and existing rules and standard procedures are put up for negotiation. Literature on niche innovation (Schot and Geels 2008) defines a number of core processes that are essential to transform inventions and ideas into robust socio-technical configurations. Accordingly,

niches have to support three crucial processes, (a) the articulation and the adjustment of expectations and visions; (b) the building of social networks and the enrolment of a growing number of actors; and (c) learning and articulation processes on dimensions such as technical design, user preferences, or symbolic meanings (Geels 2011). Taking this perspective, smart energy system pilot and demonstration projects can be described and analysed as niches, which – to be successful regarding their output – have to provide and maintain these core processes to a certain extent. Activities at the niche level may influence the more stable configurations of prevailing socio-technical systems only if the activities gain internal momentum, become more visible and therefore attract an increasing number of actors (Geels 2011). To learn from our case studies we hence should not only ask whether the mentioned core processes are fulfilled but we should also explore generalisability of our findings by asking how and why and in which wider context the cases are able to meet these hypothetical requirements.

Constructive Technology Assessment (CTA) aims to support the development of technologies that have desired positive impacts and few or at least manageable negative impacts (Rip, Misa, and Schot 1995). The general idea of CTA is to 'manage technology in society' by narrowing the gap between innovation and the societal evaluation of new technology and by putting technology on the socio-political agenda. CTA therefore has to:

> "*integrate the anticipation of technological impacts with the articulation (and promotion) of technology development itself. The co-production of impacts must become reflexive, i.e. actors – whether they see themselves as "promotion" actors or "control" actors – must realize the nature of the co-production dynamics, and consciously shape their activities in terms of shared responsibility*" (Rip, Misa, and Schot 1995, 3-4).

Since broadening the design process should enrich the discourse and improve the quality of the results, Schot (2001) argues that the performance of CTA should be monitored using three process-oriented criteria: (1) anticipation, defined as the opportunity for involved social groups to be able to define problems by themselves and take long-term effects into account, (2) reflexivity, a dimension to measure the ability of social actors to consider technology design and social design as one integrated process, and (3) societal learning, a criterion to assess to what extent first-order learning (the ability to articulate user preferences and regulatory requirements and to connect such conclusions to design features) and second-order learning (the ability to question existing preferences and requirements in a more fundamental way and perhaps come up with very different demands or radical design options) have occurred. These criteria are intended to monitor whether the design process itself is changing, or whether a modulation of the network and actual content of the interaction is required.

In the context of CTA, strategic niche management (SNM) has been developed as to organise and understand processes of learning and experimentation in socio-technical niches. SNM (Weber et al. 1999, Hoogma 2002) directly refers to the creation and growth of protected spaces for promising technology. A central aim of the development of niches is to enable learning, in realistic social contexts (e.g. market niches, controlled field experiments), about the needs, problems and possibilities of the technology under experimentation, and to help articulate design specifications, user requirements or unexpected side effects of new configurations. SNM is a comprehensive and advanced form of managing technological innovations through the organisation of social learning processes, involving producers, technology designers and users in a joint long-term process.

In a similar vein, Vergragt and Brown (2004, 2007) put a special focus on small-scale experiments aiming towards sustainable solutions. They propose a conceptual framework

for social learning within what they call 'Bounded Socio-Technical Experiments' (BSTE). In a BSTE learning may occur on four different levels: On the first level, learning is conceptualised as a problem-solving activity, on the second level as a discourse about the problem definition (with regard to the particular technology-societal problem coupling), on the third level as questioning of dominant interpretative frames, and finally on the fourth level as a debate on fundamental preferences for social order. Compared to other conceptions of social learning in the context of BSTEs, the range of possible results for learning clearly surpasses the narrow limits of a given technology and provides room to refuse given alternatives and move to completely different solutions.

Research in CTA is also contributing to the question of how to define and predict the impacts of future technologies. If technology is socially constructed, its impacts are open to diverging interpretations as well. Sørensen (2002) has pointed out that the evaluation of impacts operate on a rather fragile basis because the interpretations of technologies are dynamic and situated, and thus inherently flexible. Thus, CTA treats the impacts of technology as dynamic, as involuntarily co-produced during the implementation and diffusion stage. CTA researchers also argue that societal consensus on which impacts are desirable is rarely present and/or achievable (Rip, Misa, and Schot 1995). Because of this dynamic nature of technology impacts, CTA is conceptualised as a process of learning and experimentation (Grin and Van de Graaf 1996). Possible impacts are to be discussed and anticipated earlier and more frequently (Schot 2001) and assessments are seen as integrated and repeated parts of the innovation process, applied at preferred loci for intervention.

Based on these conceptual and theoretical considerations, the following research questions are proposed to guide the investigation of learning processes in smart energy innovation niches:

- What has been learned about the technology, social implications and wider system effects and what is needed to further broaden the innovation process?
- How do structural conditions affect learning in smart energy niches? What is the role of local and national conditions?
- What is needed to support processes of replication and scaling up? How do actors involved assess their achievements?

2.3 Practice theories

Practice theories are not a new or common agreed upon, unified theory, but rather an approach or "turn" in sociological thinking, which places "social practices" as the central unit of analysis (Gram-Hanssen 2011, Schatzki, Knorr-Cetina, and Von Savigny 2001). In the words of Schatzki, a social practice can be defined as a "temporally unfolding and spatially dispersed nexus of doings and sayings" (Schatzki 1996, 80).

The practice theories approach seeks to overcome the structure-actor dualism regarding whether human behaviour is primarily determined by social structures or individual agency. Instead of seeing practices as individual acts, practices are seen as collective actions where the individual can be viewed as a carrier (Reckwitz 2002).

An important observation from practice theories is that consumption of energy (and resources more generally) is the outcome of *performing* practices. As Alan Warde observes: "(…) consumption is not itself a practice but is, rather, a moment in almost every practice."(Warde 2005, 137). Thus, everyday practices such as cleaning, preparing food, doing the dishes, washing clothes, commuting and many entertainment activities (like watching television) all involve some form of energy consumption. Consequently, the

timing of energy consumption (*when* energy is used) is closely tied to the temporality associated with the performance of practices.

Within practice theories, a common understanding is that a practice (the "nexus of doings and sayings") is hold together by heterogeneous and mutually dependent elements, which together constitute the practices. Reckwitz (2002) defines a practice as "a routinized type of behaviour, which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (2002, 249). Different authors have suggested different typologies of these elements. Within consumption studies, Shove and Pantzar (2005) developed the most widespread typology, which distinguishes between three forms of elements: meanings, competences and materials. These elements are specified as:

> "(…) 'materials' – including things, technologies, tangible physical entities, and the stuff of which objects are made; 'competences': which encompass skill[s], know-how and technique; and 'meanings': including symbolic meanings, ideas and aspirations." (p. 14)

Using car driving as an example of an energy-consuming practice, this practice entails some physical "materials" (e.g. the car, but also the material infrastructure), "competences" (e.g. the embodied competences and skills of driving) and "meanings" (e.g. understandings of driving as associated with freedom or necessity). Through the performance of driving, the practitioners (the "drivers") activate and perform different links between these elements and in this way reproduce and change the dynamics of the collectively shared driving practice (Shove, Pantzar, and Watson 2012, 8).

Practice theories depart from the dominating human-centred psychological and economic theories often applied within consumption and environmental behaviour studies. Instead of placing the individual actor (and his/her preferences, values and attitudes) as the key to understand behaviour and behaviour change, practice theories shift focus from the individual actor to the complex of elements (including material elements like technologies) that constitutes practices. Thus, interventions aimed at changing practices, e.g. within households, should ideally address all elements involved in performing the everyday practices of the residents.

From a practice theoretical perspective, the key research questions of the MATCH project can be phrased as:

- How are the specific configurations of elements in the studied demonstration projects decisive for how the smart grid solutions work out in practice (the "success" or "failure" of solutions)?
- Can the "lessons learned" in relation to the role of specific configurations of elements in a specific case be transferred to other contexts/countries? And under what circumstances?
- What implications do the changes in practices have for the energy consumption (size and timing) of households and other small-medium customers?

3 Smart grids and smart energy solutions: what do we mean?

The overall objective of the MATCH project is to "*expand our understanding of 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"* (from project proposal). To do this we will conduct at least three case studies in the three countries involved in the project: Austria, Denmark and Norway. The cases will be compared, and based on this exercise we will develop recommendations based on the results from our studies. These recommendations will feed into discussions on how to design and implement future smart grid solutions in the three countries and beyond.

In order to do so, we need a more or less coherent understanding of what we mean when we say that we want to study the "smart grid", as well as what we mean when we want to study how to make specific "solutions" work better. Thus, we will now briefly discuss how we understand the smart grid, as well as the associated "smart grid solutions" that we will study variants of in MATCH. This discussion will also take into account earlier relevant research on such solutions, and through this lay the ground for discussions and decisions on how to choose case studies later in this report.

3.1 The smart energy system

Energy systems across Europe and beyond are changing, and many of the changes tend to be discussed under the umbrella heading as the emergence of a "smart grid". The term has countless definitions. As an example, the council of European energy regulators highlight that a smart grid is:

> *"an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to its generators, consumers and those that do both in order to ensure economically efficient, sustainable power systems with low losses and high levels of quality and security of supply and safety"*[1]

The Norwegian national research strategy on smart grids rather stresses that there is no short, clear and concise definition of the term, which do justice to the many meanings that it has taken on.[2] Thus, rather than aim for a new and precise definition of what is likely to be a moving target, our goal in the following is to give a practically useful description of some elements, or "solutions" typically associated with the smart grid. In this way we are close to the understanding fronted by the U.S. office of electricity delivery and energy reliability who point out that:

---

[1] CEER status review on European regulatory approaches enabling smart grid solutions, p. 10 http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Electricity/Tab3/C13-EQS-57-04_Regulatory%20Approaches%20to%20Smart%20Grids_21-Jan-2014-2.pdf

[2] Norwegian smart grid research strategy, p. 5 http://smartgrids.no/wp-content/uploads/sites/4/2015/08/Norwegian-Smart_Grid__Research_Strategy_DRAFT_June10_WT_ks_hii.pdf

> *"the 'Smart grid' generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing [technologies]"*[3]

In part, the understanding of the smart grid in the MATCH project has emerged from a previously funded ERA-Net project. In the project *Integrating households in the smart grid* (IHSMAG) many researchers involved in the MATCH project wrote the following:

> *"our approach has been relatively open as we understand the smart grid as basically characterised by:1) An increased integration of new ICTs (including an Advanced Metering Infrastructure, AMI) that enables new ways of communicating between different actors. 2) The integration of new actors in the electricity system as well as the assignment of new roles to existing actors (e.g. households as both consumers and producers of electricity)"* (Christensen et al. 2016, 6).

In MATCH, we build on this, and continue to pursue a relatively open approach to what the smart grid is, what problems it is set to solve and what it can offer. However, this broad focus actually means that we look at many things that are strictly speaking not part of the "grid". Thus, we find it fruitful to shift our attention slightly, from a previous focus on "the smart grid" to change focus a bit to highlight that what we are actually studying components of broader, smart or distributed energy systems. In practice, we might end up using the words interchangeably, but there are good reasons for the slight change of focus. While the word "grid" literally deals with transmission of electricity through wires, smart energy systems can be much more comprehensive. They are expected to change the historically quite stable relationships between production and consumption through introducing a broad range of new technologies, modes of organization, market structures, new roles for actors across the system, rules, configurations, etc. This might include technologies that do other things than deliver electricity, e.g. combined heat- and power plants (CHP), solar collectors or bioenergy installations. Hence, our shift to a focus on smart energy systems rather than smart grids imply a broadening of scope and perspective.

The starting point for discussions about smart grids and smart energy systems are often the digitalization of data about electricity consumption and production, and new modes of two-way-communication between what has traditionally been described as the supply and the demand side of the electricity system, the overarching goal being to *"better align energy generation and demand"* (Goulden et al., 2014) to provide for a more flexible grid. Therefore, while this is not a precondition for all smart energy system solutions, many projects over the last years have had "smart" or advanced electricity metering infrastructure as their starting point, replacing the old, mechanical electricity meters of the past with new, digital meters.

On a basic level, smart electricity meters might help illustrate the difference between "smart grids" as a generic concept, and what we will study in the MATCH project, namely "smart grid solutions". The meter is a component in the smart grid, one of countless potential technologies. For some actors, simply "rolling out" smart meters could be considered implementing a "smart grid solution". In what follows, we will turn to such solutions,

[3] http://energy.gov/oe/services/technology-development/smart-grid

while discussing some past research relevant to the MATCH project. Our primary focus is on solutions that are relevant to small and medium sized customers.

3.2 Smart energy solutions for small and medium sized users

In what follows we will outline three proposed "solution focus areas" that are intended to help MATCH researchers navigate the field studies of their native smart energy solution trials, in a similar fashion as a botanist might bring along a flora, a handbook of flowers on her quest to discover the forests botanical life. However, just as the botanist, we should not see this as a forced straight jacket, for what could be more exciting than discovering a new breed of flowers? That said, even new flowers are likely to contain some elements that are known from the flora: the color, the shape, the numbers they come in, etc. The point of this metaphorical de-tour to the forest is to highlight that we should also keep our eyes open to different and unexpected configurations, and to new combinations of humans and technologies that work in other ways than pointed out in the discussion of solution focus areas.

From the beginning, much focus has been put on the rollout of "smart metering". Advanced or "smart" electricity meters typically measure the use of energy and the power output (effect) (Löfström 2014) from consumers, and send this information to the electricity suppliers. At the same time, the meter has the capacity to provide real-time data to consumers about the levels and costs of consumption. One practical outcome of this is that meter readings do not have to be done manually, the process is automated. In some countries such as Denmark and Norway, this has in the past been done by the customers.

However, research quite clearly indicates that stand-alone smart meters do very little to achieve reduced energy consumption, shifting the time of energy use or increase customer engagement with the energy system more generally (e.g. Bertoldo, Poumadère, and Rodrigues Jr 2015, Darby 2010, 2001). Actually, some studies have suggested that the use of smart meters without additional technologies might do more harm than good since it allows for complete automation of the relationship between householders and electricity providers, and therefore potentially limits engagement with the electricity system (Jørgensen 2015, Throndsen and Ryghaug 2015).

For us in the MATCH project, it is therefore unlikely that we will be interested in studying smart meters as such. On the other hand, the smart meter quite often serves as a sort of technological hub, facilitating the connection of many other technologies as well as the construction of new services and tariffs etc. related to households or small-medium businesses. As such, it is quite likely that smart meters will be one of many components of the several solution constellations that we study in MATCH. For us, then, it will be important to try to understand what role they play in the specific solutions studied, how they are made sense of or interpreted, how they enable or disable certain modes of action, etc.

With these introductory words about smart metering etc., we will now present the three solution focus areas, which will be in focus for this study.

3.2.1 Demand side management/Demand side response

Demand-side-management refers to a set of technologies or technological set-ups, where the goal, as the name indicates, is to manage or steer the demand of electricity by reducing it and/or shifting it away from peak load periods. Thus, it concerns trying to trigger change amongst consumers in some way which means that it is highly relevant for MATCH. As Fell et al. (2015) state, it refers to creating "*change in electricity consumption patterns in response to a signal*". A "signal" often refers to the price in combination with some sort of information device, but in principle the signal can be any impulse meant to trigger change, including automated response.

Such schemes are typically built "on top of" smart meters, and in line with the definition above involve some sort of technology that sends a "signal", and often also some sort of technology meant to facilitate the consumption change. Broadly speaking, it is possible to differentiate between two ideal typical strategies. In the first, the active choice of changing consumption is left to the consumers, in the other, making this choice is delegated to technologies, i.e. they are automated. In practice, of course, solutions are often placed somewhere between complete automation and complete active engagement. Thus, the level of automation or agency given to users is something we should study empirically, because choices made with respect to this issue tends to produce very different smart energy system solutions, with different expectations for the actors involved. In turn, this will most likely also influence how different actors evaluate the solution, and ultimately how the solution "works" with the present actor constellation and in the present context.

An example of the first strategy includes providing customers with in-home-displays (IHD) or other direct feedback technologies (Hargreaves, Nye, and Burgess 2010, 2013, Wallenborn, Orsini, and Vanhaverbeke 2011). These technologies use the data generated from smart meters to provide customers with feedback (signals) e.g. about the cost of their current consumption, about the environmental impact of the consumption or about the level of current electricity use. Such feedback can be given at an aggregate level (household), but earlier research indicates that achieving energy savings is more likely if the feedback is given in a non-aggregate way, e.g. broken down per appliance (Hargreaves, Nye, and Burgess 2013), which facilitate both ease of use and understanding (Darby 2010).

Another point which has been made in the past is that the feedback given should provide information deemed relevant to the users. One way to achieve this could be to ensure some sort of comparability: how does the current household perform compared to neighbors and other relevant households? (Christensen et al. 2016). Another potential example: what are the current environmental "expense" of the households' consumption, compared e.g. to other phenomena such as air travel or driving a car? On a general note, it should be pointed out that "what is relevant" will most likely differ between user groups and contexts, a point that highlights the importance of trying to design solutions inclusively (Sørensen, Faulkner, and Rommes 2011), e.g. through actively incorporating the competences of prospective users and their everyday practice in the design of smart grid solutions (Jelsma 2003, 2006, Skjølsvold and Lindkvist 2015). On a cautionary note, it should be added that the positive effects of feedback seldom reach the optimistic assumptions provided by engineers and some economists, because raised awareness levels do not necessarily translate into altered practices.

Solutions like IHDs can be implemented as a stand-alone technology or in combination with other technologies, incentives and modes of organization. One example of this is the implementation of new incentive structures such as time-of-use pricing (TOU), e.g. making electricity much more expensive during peak hours. This can be done in different ways.

As an example a recent study from Denmark shows that schemes based on fixed price intervals (also called *Static time-of-use pricing*) are easier to understand for the households compared to schemes based on prices that change continuously from hour to hour and day to day (also called *Real-time pricing*). Static time-of-use pricing makes it easier for the household members to develop new routines and shift electricity consumption on a permanent basis. The Danish study indicates that the time-shifting in electricity consumption was not so much depending on the actual cost savings (which were in general small), but rather because the static time-of-use pricing conveyed a general knowledge about at what times it would be most suitable for the system and for the participants personal economy to consume electricity (Christensen et al. 2016)

The other strategy focuses on delegating the response to signals to pre-programmed technologies. This can be done quite crudely through reducing the allowed volume of electricity consumption at any given time, often described as load capping. Another alternative is so called direct load control (DLC) where operators are allowed to remotely switch off electrical appliances such as water heaters when this is deemed necessary. Other prospective technologies involve washing and drying machines, freezers and refrigerators, which may provide some flexibility. Studies that MATCH researcher have been involved in earlier, however, suggest that this has limited effects on the grid (Meisl et al. 2012). Still, many actors argue the case that making these applications become "smart", interacting directly with new price signals or other pre-programmed settings, and limiting the need for user involvement, is a feasible strategy.

Some earlier studies have indicated that for many users, such solutions might entail a sense of loss of control of vital elements of everyday life (Rodden et al. 2013), while other studies (Fell et al. 2015) suggest that this is an area where users are quite open to relatively radical innovations and change. To us this indicates that there is significant interpretative flexibility here, both across cases and contexts, which we should explore empirically. Another consideration to make is that while automation might facilitate change, it might also entrench and solidify new practices to the extent that they become even harder to change, more "naturally" integrated in everyday life than pre-existing patterns (e.g. Strengers 2013 for a critical discussion).

When we discuss how solutions meant to trigger changes in energy usage patterns work, it is in light of the above likely that we will come across different formulations of what the "goals" of implementing such solutions are. Some might see these technologies as components of strategies meant to empower end-users to become more engaged in the energy system[4], or even producing new forms of energy citizenship (Devine-Wright 2007). For others, these technologies are part of a strategy where the primary goal is to reduce consumption and shift loads, for instance as a way to reduce peaks, or to cater for new intermittent renewables.

In sum, the discussion indicates that technologies meant to change consumption patterns on the so-called "demand side" (DSM or DR) is a broad class of technologies, often targeting the kinds of consumers that are of interest to the MATCH project. While they have been extensively studied, discussed and criticized in the past, there is little indication

[4] This is at least rhetorically stressed in many of the calls from the European Commission in the Horizon 2020 work programme. For an example from an upcoming call, see EE-07-2016-2017 "Behavioural change toward energy efficiency through ICT", http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/5059-ee-07-2016-2017.html

that they are disappearing or that there will be fewer experiments with them in the years ahead. We thus make this one of the key MATCH solution focus areas.

3.2.2 Micro generation

Another frequently discussed option for the smart energy system is to turn the attention towards micro generation of electricity. Typically, this can be done through rooftop solar PV, micro wind turbines, small CHP-systems or in some instances even small-scale hydropower.

For MATCH, this development raises interesting questions with respect to the role of actors in the energy system, new technologies, as well as the market structures of the energy system. As far as the actors go, a key issue to ponder is the relationship between actors at what has traditionally been called the supply and the demand side of the electricity system. With the introduction of micro generation, the small and medium sized electricity consumers might actually become suppliers of electricity, both producing electricity that they can use in their own buildings, and selling electricity to the grid. Thus, this is a potentially disruptive development, which includes technological changes, huge implications for market structures, and changed roles for many different actors in the electricity system. In a recent paper discussing the emergence of so-called "prosumers", Parag and Sovacool (2016) highlight:

> *"Fundamentally, markets for prosumption services are different from existing engagement platforms, such as demand-reduction or demand-response programmes. That is because, in prosumer markets, users on the demand side not only react to price signals, but also actively offer services that electric utilities, transmission systems operators, or other prosumers have to bid for"* (p. 1)

While micro generation will often be accompanied by many of the technologies discussed under the header of demand side management, it is a more novel smart energy solution, which has so far been less studied in practice. However, there is currently much experimentation going on in demonstration sites, which is also one of the main reasons for making this one of the key solutions studied in MATCH.

How the prosumer-energy system relationship will look like, and how prosumer markets and actor-relationships will unfold, will likely depend on local context, on the goals set by operators of smart grid demonstration processes, on the potential for renewables like wind and solar in a given area, the levels of trust amongst electricity users, between electricity users and utilities, pricing structures, national regulation (e.g. taxes), etc. As an example, one can easily imagine situations where groups of citizens who distrust the government, central grid and traditional electricity market want to develop prosumer models to become independent and go "off grid", while other groups might use the very same technologies to create new social and business opportunities within existing market structures. There are already examples of controversy emerging in some contexts, e.g. Spain has recently enforced a "sun tax" which effectively removes many of the potential incentives for prosumption and distributed electricity production.[5]

Parag and Sovacool (2016, 2-3) discuss three potentially emerging models of prosumer markets, all with their distinct characteristics, potential upsides and potential downsides,

[5] http://www.renewableenergyworld.com/articles/2015/10/spain-approves-sun-tax-discriminates-against-solar-pv.html

for different actors across the electricity system. Fig. 1 is a graphical representation of these potential models.

The first model is a *peer-to-peer model*, an organic and not very structured model, involving decentralized and relatively autonomous networks, developed bottom-up (fig 1, model a). Some have envisaged an Uber or Airbnb-inspired model, where a social platform of some sort allow consumers and producers of electricity to bid and sell services. This would entail a radical shift in market structures, the role of actors and involved technologies, and as such, it is likely that incumbent actors have diverging views on the model, and that new types of actors might push this development. In Norway, such models of energy sector "revolution" are promoted primarily by ICT actors. In 2015 a group of such actors joined forces with actors from the energy sector and sought funding for a centre of excellence from the Norwegian research council with the goal of "unlocking" this potential.[6]

The second model – termed *prosumer-to-grid models* – is more structured and involves prosumers linking up to local microgrids through brokerage systems. Parag and Sovacool point out that microgrids can be connected to a main grid, or that they can operate in an "island mode" (see fig. 1, models b and c). Connection to a main grid implies the possibility of selling to the grid, a potential incentive to produce as much as possible, while an "island mode" introduces many challenges of local optimization and balancing of the grid. While "island" in Parag and Sovacools instance is a metaphor, several potential cases in the MATCH project are located at actual islands, which we might hypothesize creates conditions favourable to "island mode" microgrids with a high penetration of local, small scale renewables.

The final model, an organized prosumer model, is a model where groups of prosumers organize in new ways to establish virtual power plants (fig. 1, model d). This is more organized than peer-to-peer models, but less so than prosumer-to-grid models. Parag and Sovacool foresee potential for such models in urban areas where local communities, neighbourhoods or organizations might collectively manage and pool their resources in new ways. This model poses interesting questions with respect to collective action and the management of common pool resources, where collective gains depend on individual decisions (e.g. Ostrom 1990, and Wolsink 2012 related to electricity).

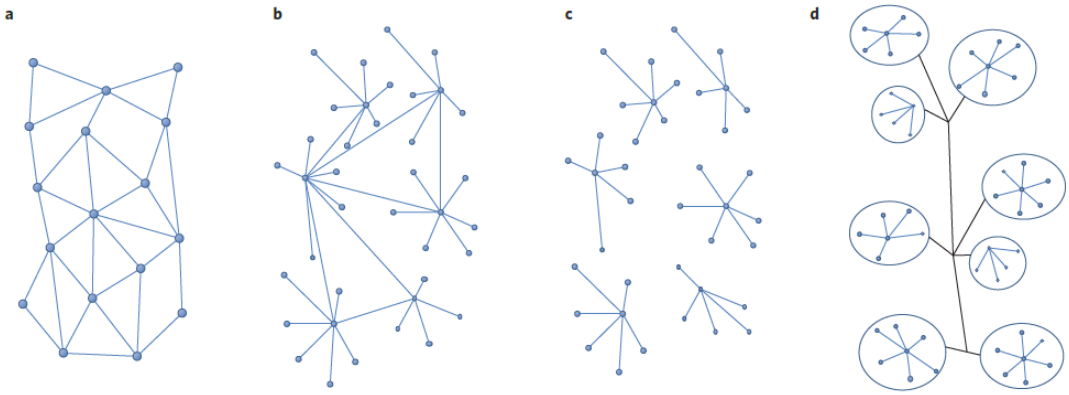

Figure 1 Potential structural attributes of prosumer markets. Parag & Sovacool 2016, p. 3

[6] See: http://www.uis.no/research-and-phd-studies/research-areas/information-technology/energy-informatics/. The centre was not funded, but the research group pursues this agenda.

The introduction of micro generation and prosumption as a smart grid solution is highly interesting in the MATCH context as it has the potential to re-configure key parameters of how markets, actors and technologies interrelate in the energy system. Also for this reason, we will make it one of three key smart grid solutions to be studied in the project.

3.2.3 Integration of storage technologies

As the share of intermittent renewables increase, many energy systems are facing challenges of balance. Since wind and solar power production depends on the sun cycle and weather conditions, there is a question of how one should secure a reliable low-carbon base load or reserve capacity. One promising way of handling the issue is the installation of some sort of storage technology to decrease the dependence on fluctuating wind and sun. One option can be to install batteries in households, in the way that Tesla has proposed through its high profile Powerwall project.[7] In other sites, thermal storage is more likely to be implemented, or other kinds of building-to-grid technologies. Another type of storage that we might come across, particularly in the Norwegian case, is the aggregated use of batteries from electric vehicles (EVs). These can potentially play a dual role in future smart energy systems, because they on the one hand might generate new need for electricity production and increased power capacity, while on the other hand serve as a flexible load by ways of the batteries.

Introducing storage technologies could be a particularly promising strategy in contexts characterized by some sort of micro grid organization with a high penetration of intermittent renewables. As Wolsink (2012) wrote, with a specific focus on the potential of EVs:

> *"The flexibility in time-of-loading, inherent in the energy storage of a large electric vehicle fleet, offers opportunities to increase the feasibility of smart applications of renewable energy. Hence, options for reloading electric vehicles within the domain of microgrid community (e.g., at home) becomes a significant factor in advancing the deployment of renewable energy"* (p. 826)

Other storage technologies can play similar roles as a solution in reconfiguring the future smart energy system. Thus, storage integration will be one of the key MATCH solution focus areas.

3.3 From individual solutions to integrated hybrid configurations

As is emergent from the discussion above, the introduction of smart energy solutions entails reconfigurations of social and technical character. As a pragmatic choice, and to ease the burden both of writing and reading this report, the thematic description of the solution areas above has taken the introduction of new technology as a sort of starting point.

This, however, does not mean that we study technological solutions. As discussed in the section on theoretical considerations, our perspectives in different ways ask us to account for the social elements of any solution we study. This does not mean that we study how what many engineers would call "the human factor" are influencing technology performance. Rather, we are interested in the configuration of smart energy system solutions as a whole, meaning that we want to grasp the relationships between human and non-

[7] see https://www.teslamotors.com/powerwall. There are, of course, many other actors working with batteries that we are more likely to come across in MATCH.

human actors in specific solution configurations or assemblages, and further, how these solutions interact with a broader contextual setting. Thus, we apply a symmetrical gaze, where neither humans nor technologies are privileged a priori. Their capacity to act, to do work, as well as the character and outcomes of this work needs to be accounted for on a case-to-case basis.

With this in mind, it should also be clear that we will seldom (though we might!) come across solutions that focus purely on one type of technology or one type of actor. One reason for this is that the world tends to be messier, and that any typology or classification implies some sort of reduction in complexity.

Another, more concrete reason can be found in the empirical field that we are interested in, which seems to have shifted away from a belief in individual solutions to more systems-oriented approaches. As an example, Norwegian policy makers had quite naïve ideas about what smart meters combined with feedback could achieve in terms of energy reduction and load shifting (Ballo 2015, Skjølsvold 2014). In the following years, however, studies of various individual solutions have provided sobering and somewhat disappointing results. As a response, many demonstration sites are now experimenting with much more hybrid, integrated solutions, where different components is expected to do different kinds of work. Arguably, we are currently seeing the exploration of second or even third[8] generation smart energy system solutions for small and medium consumers.

This would mean that a strict delineation of what we can study in MATCH based on the three categories of proposed solution areas would severely limit our possibilities both of being relevant and of producing meaningful, comprehensive analyses. It is the ambition of the MATCH project to move beyond individual solutions.

At this point it is difficult to practically say how a studied solution should be delineated, beyond stating that what the solutions consists of is an empirical question. As an example, it would make little sense to study exclusively a rooftop solar PV "solution", if what is really installed is a combination of smart home technology, rooftop PV and battery capacity.

[8] Solutions for prosumers involving batteries or EVs could be said to be the third generation.

4 Studying how solutions work

By now, we have a basic understanding of what we mean when we say "smart grids". In fact, we have shifted our attention from the grid towards smart energy system solutions. We also have an idea of what we mean when we say that we want to study specific smart energy system "solutions". In MATCH we will study smart energy solutions targeting small to medium customers. In the above we have discussed three types of solutions that we propose should form a sort of basis for the studies in the three countries. These are:

- Solutions aimed at changing demand side consumption patterns: Demand side management or Demand-response
- Micro generation
- Integration of storage

As discussed, this forms a relatively open-ended starting point for our studies, which also should allow us to study various combinations of integrated solutions and how they work. These will be compared in order to develop sound analysis of which kinds of solutions that are expected to work under which conditions, and further to formulate recommendations that feed into various discussions on how to best implement smart energy solutions. This section of the report will do two things. First, it will roughly outline the process of doing case studies, from research questions and selecting cases to writing up case study reports. In doing this, we will discuss some of the challenges we will come across. We will then proceed to discuss some analytical challenges related to comparatively assessing what it means that something works (see 4.7).

Issues to be discussed here include aspects such as how we define what it means that a smart energy solution "works", how we move from cross-case comparative work to generalizations, and how we deal with issues such as "context".

4.1 The research questions

As stated, the overall aim of MATCH is to study how complexities of factors influence the effectiveness of smart grid initiatives in order to contribute to better and more comprehensive smart grid (energy) solutions. More specifically, the case studies will analyse both the direct implications of smart energy solutions on the (everyday) practices of the users *as well as* how the solutions (and how they are used in practice) are integrated in a network of mutually dependent actors. The case studies will apply both analytical perspectives on the studied solutions, which are essentially closely related.

An example of the focus on the implications of the smart energy solutions for *social practices* could be, e.g., how the combined ownership of PVs and electric vehicles affects households' (or other types of actors') daily practices. For instance with regard to driving patterns, the timing of EV-charging or other electricity-consuming household practices etc.? In addition, an important question would be how this affects the energy consumption patterns of the users?

Similarly, an example of the focus on the *network* of the smart energy solutions could be how the PVs and electric vehicles are related to (dependent on), e.g., local actors (electricity suppliers, DSOs, the municipality etc.), national regulation of EVs, subscription schemes for prosumers, accessibility to local/national network of EV charging stations etc.

In carrying out the case studies, the earlier presented research questions (Section 2) will work as guidelines for the analysis.

4.2 Choosing cases

On a basic level, three case studies should be conducted in each country. These case studies should be examples of smart energy solutions, targeting small to medium consumers. These consumers could be ordinary households, but small-to-medium companies are also viable as users for our purpose. Smart energy solutions consist of a set of technologies, services, incentives, actor groups, users, practices, processes, meanings, etc. Thus, they are truly heterogeneous sociotechnical collectives. That said, the easiest point of entry, or the easiest way for the MATCH researchers to recognize them as new solutions, will most likely be through the identification of some sort of trial site where someone is engaged with testing new technology.

When such a trial (or trials) has been identified, the three solution focus areas give some pointers with respect to what to study. This means that a trial or a demonstration project might not necessarily be the same as a "solution", because it could in principle be testing dozens of solutions for different purposes. On the other hand, a smart energy demonstration project could easily be limited to the testing of one solution. Table 1 is a very simple matrix illustrating how three imagined cases might incorporate several different aspects from the proposed solution focus areas. If needed, such a matrix could be expanded and concretized in order to visualize and make comparisons between cases more tangible.

	DSM	Micro gen.	Storage
Case 1	x		
Case 2		x	x
Case 3	x	x	x

Table 1: Matrix illustrating different degrees of hybridity and integration in three imagined cases.

The three solution focus areas are broad enough to allow us to cover a broad range of the aspects of what is frequently discussed as "the smart grid", or the smart distributed energy system. It also allows us to look into both relatively mature types of solutions as well as less mature solutions and different types of experiments with integration of different solutions.

For the purpose of the MATCH project, it would be useful to choose cases where some experiences – positive or negative – have been gained from the solutions at hand. That said, there are likely lessons that can be learned also from projects that have been established more recently.

4.3 Doing case studies: some preliminary thoughts

Once cases have been identified, how do we study them? The focus of the project has originally emerged from engagement with the three-layer model as emphasized by the

funding body for this project. This model proposes that there are basically three categories of elements involved in the development of the smart energy system. These are a) markets, b) actors and c) technologies.

As our discussion on potential solution focus areas indicate, it is quite clear that any smart energy solution entail some sort of re-configuration of these elements, and that a clear-cut differentiation between the three is not feasible. It will most likely be difficult at times to distinguish clearly between the categories. In the case of micro generation solutions, for example, small customers could potentially re-define market structures through the use of new technologies.

This brings some interesting questions for the MATCH consortium. In our proposal we have said that we want to study the relative "success" of such solutions. The very dynamic and shifting situation with respect to the smart energy system, however, suggests that a focus on success is too narrow. As an example, a solution could be a disaster for the business models of an incumbent industry actor, while at the same time being a raging success for a small consumer. In such a case – should we consider it as a success? Thus, we once again shift focus somewhat, and rather ask how the specific smart energy solutions work. This reflects our view on such solutions as hybrid collectives established by the relations between involved humans and technologies, and that what "works" is relational and contingent on the specific context of the solution. In practice, this means that it will also be useful to map how the solution in question works for different kinds of implicated actors.

However, while it is true, stating that "everything is complex" will not be very productive, at least not at this stage of the project. Hence, for the sake of making this report a more hands-on guide, let us begin with a brief and pragmatic discussion about what our key focus is when it comes to looking at the – admittedly simplistic – categories markets, actors and technologies.

4.4 Markets, actors, technologies

4.4.1 Markets

Market conditions are generally considered to be one of several framework conditions for smart energy solutions in the three countries. The countries have different taxation regimes, different market mechanisms for phasing in new renewables, different energy mixes, different levels of liberalization, integration with other countries, the EU, and most likely different public attitudes towards new regulations, new technologies, etc. Thus, one of the ways that we will incorporate markets in our studies is through doing a national study in each country. This study should be a descriptive and informative piece of text, which highlights the framework conditions in each country. This national study should be conducted before the actual empirical case study work begins (or in the very beginning of the case studies).

National study contents:

- A very brief description of the country.
- Information on current energy mix, and some broad historical lines on how this have developed over time.
- Information primarily on electricity use/consumption, and, if available, trends over time.

- A description of how the electricity system works together with/interacts with other parts of the energy system as well as some key statistics for the entire system.
- Information on the general state of the current electricity market – how is it regulated, how open is it, how does it relate to broader markets (EU, etc.),
- Information on general national policies, regulations, strategies for phasing in new renewables and/or other sustainable technologies (e.g. feed in tariffs, certificate schemes, subsidies, market liberalization, etc.)
- Information on specific policies, regulations, strategies, etc. targeting the development of the smart grid.
- Information on national smart grid initiatives, both research programmes and similar activities (players in the field, programmes, main projects, etc.) and industrial activities (networking activities, companies involved, etc.)

The production of the three national studies could provide interesting added value to our project. On the one hand, it opens for the possibility of doing some sort of comparative policy study. Further, we should also keep in mind that our empirical work on the smart energy solutions might shed new light on and create the need for elaborations on what we "know" about the three national energy contexts. Thus, while we should aim to have the documents on national context ready by the end of September 2016, we could consider keeping them "open" to be revisited at a later point in the project.

Related to the three case studies of smart energy solutions, MATCH researchers should also be sensitive to the business models built around the case solutions studied. What is done by whom in order to try to profit from the new solutions? What changes of the existing market rules would support the new solutions?

4.4.2 Actors

The key actors for MATCH are the small and medium consumers. Key questions to study are how they are involved and engaged in the smart energy solutions, and through this we should be able to give some recommendations on the potentials and limits to engagement. Typical modes of engagement could be as prosumers or as providers of "flexibility" when trying to balance the grid. We should also search for other (perhaps more innovative) ways that actors are engaged, e.g. through meetings, workshops, design exercises, empowerment mechanisms, etc.

However, actors are not only the small/medium customers. They could be the incumbent electricity generators, grid operators, ICT-companies, housing industry, heath care and welfare technology sector, entertainment industry, intermediaries of various types or others engaged in the development and testing of smart energy solutions. A key point here is that we should let the cases at hand direct us towards the actors. Who are involved, what are their roles, and what do they do? This also relates to matters such as organization of the solutions and the relationship between involved actors. Who formulates the solutions, and how do actors work to engage other types of actors in their proposed solutions? This could feed into related discussions about the ownership of various components in the "solution". As an example, Norwegian prosumers typically tend to purchase, and thus own, their PV panels, whereas similar solutions in other contexts have been based on home owners leasing PV panels, e.g. from DSOs.

For us, all of this might feed into discussions about what the organizational obstacles to making smart energy system solutions "work" are, and which modes of organization that

helps. On a practical level, this can be operationalized by studying matters like rules, contracts, responsibilities and organizational practices, etc. We should also look for patterns of which actors are involved, as well as which roles different types of actors take on across cases and contexts.

4.4.3 Technology

Our discussion of the three proposed solution focus areas contains relatively rich descriptions of some of the potential technologies that we will come across in the MATCH-project. However, we are not studying technologies as such. Rather, our interest is how technologies work in interaction with people, households, organizations, markets, industry actors, "old" technologies, existing infrastructures, etc. Thus, technology is simply one of multiple elements that make up a "solution".

The gateways into studying technologies in a project like these are many. One potential way is through what we broadly can call technology development. It is quite likely that many of our studied solutions are parts of demonstration projects where such development is one of the goals. Technology development here should not be understood to be limited to the engineering exercises of producing new "gadgets", or to being limited to exercises of design. Instead, it could just as easily refer to combining existing technologies in new ways. An example could be technologies coming from different industrial realms, merging in the smart energy context. Combination of ideas about welfare technology with ideas from smart energy systems and the ICT-realm could be an example of this, combinations that in the past have resulted in the emergence of new and increased focus on matters like universal design and usability (Skjølsvold and Ryghaug 2015).

Thus, for us the technologies are not only interesting as carriers of certain technical qualities that can somehow be realized, e.g. through achieving "social acceptance" of the new technologies. Rather, the technologies are elements of any solution that comes with a set of expectations (including wider societal implications) with respect to future use, as well as with respect to the competences, and abilities of future users. The technologies stand in relation to other technologies, to users, to technology developers, policy maker, etc., and it is in relation to other actors that we might be able to say whether a technology "works" as part of a solution. A novelty in the MATCH project compared to many other projects on the smart grid and smart energy systems is that we will not only conduct studies of this type for individual technologies, but for integrated hybrid solutions, or solutions that in a much broader sense allows for discussions about what it might entail to upscale and disseminate solutions profoundly.

4.5 Doing case studies: a proposed five-step plan

In order to account for the market aspects, actors and technologies of each selected case (smart grid solution), we propose a five-step plan for the case studies at hand, which should ensure that all cases include a common basis of elements, which will enable the cross-case comparative analysis. This will cater for the production of descriptive case study reports from the countries, where we should strive to provide relatively descriptive accounts of the solutions.

The proposed procedure should not be read as a straight jacket, and where it is needed, the case studies should absolutely be tailored and adopted to the local conditions. It is an attempt to anticipate what we might come across and what might be expected, but as such it is also filled with the preconceived ideas of the authors, which might not correspond well to what we actually come across in the field. Another way to think of it is as a sort of baseline, which should ensure comparability.

In addition, the individual research partners might have individual research interests that they want to pursue, which is not covered in the following procedure. It should be stressed that this would provide obvious added value to the project and that it is encouraged.

With all these reservations in mind, the following has been written with the purpose of helping to generate a rich, comparable narrative for all cases, which can subsequently be analysed in different ways by different members of the consortium. The five steps are as follows:

4.5.1 Context

To add contextual depth from the national study, we should begin by mapping and describing relevant insights into the local context of the studied smart grid solution. This includes:

- Local/regional energy system characteristics (energy mix, status of the grid in the area, etc.)
- If applicable: a brief description of the broader demonstration project that the particular solution is a part of.
- Historical actor-constellations in the local energy system. E.g., ownership structures: cooperative, centralized, municipal, commercial, etc.

In most instances, this local insight can be obtained through desktop exercises. If necessary, local research teams can supplement with interviews, etc. as they see fit.

4.5.2 History

We should also have a brief "history" of the solution at hand. What was the original idea behind it? Who was involved in developing the idea, and what was their rationale? For how long has the solution it been tested? What has been learned so far – from the perspective of those testing the solution?

Has the solution been researched in relevant ways in the past, and if so – are there available results from such studies that might be relevant to the MATCH project? Questions concerning the history of the solution are important to gain insights into the visions and expectations of actors behind the solutions, and to gain a sense of the dynamics involved as smart grid solutions change over time. In many instances, this exercise can be done as a desktop exercise, supplemented with interviews of actors involved in the project start-up if needed.

4.5.3 Map

Once we have an overview of the context and the history of the solution, we can begin mapping the current state of the smart grid solution, its actor and technology constellations. This includes details on infra-technological relationships, e.g. on how the solution at hand have been involved with existing energy systems, technologies and actors.

- Who are the actors involved, and what are their goals/rationales?
- How do these actors interpret what it means that such a solution "works", or that they are successful?
- What are the technologies involved, including existing energy system infrastructures?
- What small scale/medium sized consumers are involved?
- What is expected from them in the project?

- How are they recruited – what incentives are they given to participate?
- How are the involved elements configured?

On one level, this mapping exercise can be considered purely descriptive. However, once we begin to understand how users were recruited and on which conditions they were recruited[9], the levels of technology subsidy funding, or other ways that technological solutions might be "shielded" from ordinary technology selection criteria in such trials, we can also begin to think about the relationship between the "trial conditions" and "real world conditions". At this stage, interviews with implicated actors are needed.

4.5.4 Experience

Based on these three steps, we should have a good understanding of the smart grid solutions, and we should be ready to study how the small/medium consumers act and interact with the technologies, incentives, organizations, etc. introduced as part of the smart grid solution. Given the largely qualitative character of the work, and the likelihood that cases will differ substantially, it is difficult to standardize this exercise too much. However, some pointers can be given:

- We should seek out small/medium consumers using the solutions with the goal of identifying their experiences (e.g. "negative" or "positive") with the technology. This should both include the users' own *interpretations* of their experiences (e.g. how the solutions have affected their everyday lives, etc.), but should also include descriptions of how practices are changed (if so).
- We should interview a broad sample of users and intermediaries, reflecting to the extent that this is possible the diversity of users involved in the smart grid solution trial. Thus, we should avoid the trap of interviewing only "Resource men" (Strengers 2013), but rather aim to include as many as possible of the actors that make up everyday-life (or work-life) situations for the users involved.
- We should probe for rich stories concerning technology use and related practices, patterns of use, how technologies have been integrated in everyday lives (or work life for SMEs), difficulties, understandings and interpretations of technologies etc.

The methods used will, as said, primarily be qualitative (interviews, observations, focus groups etc.), but might also, if relevant and possible, include some statistical data of existing data (for instance in order to analyse the energy implications of the studied solutions for the energy consumption patterns).

4.5.5 Product

Finally, we are ready to write up case study reports. To facilitate the cross-country and cross-case analysis, these should describe the cases, the actors involved, relevant market dynamics and technologies, implications for the practices of the users etc. They should also aim to provide as clear narratives as possible concerning how the studied solution works, and for whom it works.

Following the discussions in this report, this assessment needs some extra considerations. It is clear that something can work in multiple ways, and that it can work in different ways for different actors. It is also clear that what works for one set of actors, might

[9] For instance: Did they invest in technologies, or did they lease/borrow them? Are they volunteers, or are everyone in a geographical location users? Are there other incentives for participating? Etc.

do the opposite for others. This also feeds into discussions about the relationship between the individual cases that we study and the wider energy systems and contexts that they are part of. The case study reports could be a good place to begin a preliminary analysis of such matters. This can be done in a two-step way, following the rich case description.

1) An evaluation of the case solution in hand. What was its core strengths and weaknesses? Why does it appear to work in the way that it does, or why does it not appear to work as intended? This step should include reflections on unintended consequences and wider implications of the introduction of the solution.
2) A first attempt at briefly exploring the consequences of upscaling the solution at hand. This would imply some sort of speculative scenario writing, where researchers contemplate potential consequences and pathways based on the information and knowledge available to them.

In the end, this will provide us with at least nine case study reports, three from each country. These will form the basis for the following comparative analytical work and should provide a rich and inspiring source to work further on.

4.6 A brief note on energy system models and scenarios

In addition to the qualitatively oriented work discussed above, MATCH will produce some energy system models and scenarios that might help producing narratives about the effects of certain types of solutions. It is currently somewhat unclear what types of data we need to be able to produce relevant model simulations. When and if such data are available, however, we should try to collect the following:

- Data on economics: the costs of installations and operation
- Data on how the solution in question influence the households power consumption. In practical terms this would be data indicating changes (or non-change) in load profiles for participant households.
- Data on savings per household (e.g. Kilowatt-hours per year per household)

As the case studies start, we should have an open dialogue within the consortium on the status of these issues, on what we need and what we can achieve through these and similar data collection exercises.

4.7 What does it mean that a solution "works"

A key outcome of the MATCH-project should be an increased knowledge about what smart energy solutions work under which circumstances. Thus, we should evaluate existing cases, and we should to a certain degree be able to harvest wider and applicable lessons from these evaluations. As the discussions throughout this report have indicated, this raises the question: what do we mean, when we say that something works? If we return to the earlier discussed peer-to-peer model of prosumer markets, it is clear that something like this could be said to work well for consumers, who in new ways become empowered and through this take control over the system in new ways. For incumbent actors, however, this would not necessarily constitute a success, because it undermines their business model and operation.

Thus, a "working solution" can be many things. Towards the end of this report we therefore find it fruitful to present a brief discussion of how to deal with the issue at later stages in the project. This section is mainly intended for reflection.

4.7.1 It works when the project goals are realized

MATCH is a project where researchers collaborate closely with industry/market actors. Several of these partners are owners of demonstration sites experimenting with the kinds of solutions that we aim to explore. For this reason, it might be argued that we should pay particular attention to what it would mean that a solution works for these actors.

One way to measure this is simply to look at the goals of the solution case in question, and to measure the performance of the trial in relation to this. E.g., some "solutions" might be implemented to "unlock" flexibility, or to reduce electricity demand. If data will be available, it would be relatively simple to determine if it works or not. If (sufficient) time shifting or electricity reduction has been achieved – it works. Thus, this way of identifying working solutions looks at performance output indicators before and after the trial started, and links this to the stated goal. The added value from MATCH compared to a more standard technical project would be to highlight that output in such instances is a result of the way that the socio-technical solution is configured, or the way that practices and elements of practices are bundled in the particular instance.

Through our interviews and studies of implicated actors we can get a sense of why and how the particular solution works for the particular actor groups, and through this be able to paint a richer picture of why the particular solution works to realize the industry actor goals. A concrete way to operationalize this in our studies would be to map the links between the expectations of the actors as they ventured into the smart energy system solution, and compare this to their actual experiences.

As an example, a study from Norway have indicated that when small consumers expect to save a lot of money, they have to re-interpret their participation in smart energy system trials, when they learn that they do not. For some small to medium consumers, this might lead to alienation from smart energy technologies as such, which leads to practices that do not cater for reaching the goals of the project operators. Other customers, however, are very happy to be part of a project where they mainly learn how cheap it is to spend electricity. This allows them to raise comfort levels. For such consumers, the solution has arguably "worked" in some way, in the sense that it resulted both in learning and the establishment of new practices, but obviously not for the benefit of the grid and the system in the way that the project owners would like.

4.7.2 Broadening the definition of a working solution

This indicates that it is probably wise to have a broader definition of what it could mean that a solution "works", when we do our analysis. Through our mapping exercises we gain insights into the rationales and goals of many actors, and we will most likely also gain much knowledge about their experiences. Further, we will learn much about how the cases in question relate to their contexts, and the ways that external actors work to influence the solution in question. For instance, are there shielding mechanisms involved, such as subsidies, or other schemes meant to influence either the technology choices made or the usage patterns of these technologies?

A key point for us is that we are aware that solutions might have different implications for different implicated actor groups. If we take the users as an example, these might be a very diverse group. Single men, elderly couples and families with children might have

very different ways of relating to energy, managing everyday lives and integrating new solutions into existing practices.

The realization that different actor groups might have different understandings, goals, aspirations and expectations does of course complicate things. However, for the MATCH consortium, it is arguably the strength that might give our recommendations more thrust than it would otherwise have.

This might also allow us to give advice with differing degrees of strength. The identification of a solution that is working, both in the sense that it fulfils the goals of the experimenters, and is integrated nicely into the everyday lives of various user groups, as well as works for other implicated actors, most likely indicate a relatively robust solution, with significant transfer value to other sites. Should the solution only work for some actors, however (e.g. grid operators and resource men), but leave other user groups (families, the elderly, teens, students, etc.) alienated or discouraged, this opens for recommendations on how to improve the performance. Table 2 is a crude idea for how we could begin to think about operationalizing this on a case-by-case basis. This rough sketch will have to be adopted to the situation for each specific case, and it is not certain that we actually end up using it in the end.

	Expectations			Experiences		
	Micro gen	DSM/DR	Storage	Micro gen	DSM/DR	Storage
Families w/children						
Single men						
Single woman						
Elderly						
Small company						
ICT company						
Construction company						
Energy producer						
PV supplier						
Description of solution «shielding mechanisms»:						

With nine case studies, it is likely that the degree of success for different implicated actors will differ across cases, and hopefully some patterns will emerge that we can exploit for the development of success criteria later in the MATCH-project.

References

Ballo, Ingrid Foss. 2015. "Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway." *Energy Research & Social Science* 9:9-20.

Bertoldo, Raquel, Marc Poumadère, and Luis Carlos Rodrigues Jr. 2015. "When meters start to talk: The public's encounter with smart meters in France." *Energy Research & Social Science* 9:146-156. doi: http://dx.doi.org/10.1016/j.erss.2015.08.014.

Bijker, Wiebe E, Thomas P Hughes, and Trevor Pinch, J. 1987. The social construction of technological systems: New directions in the sociology and history of technology. Cambridge, MA: MIT Press.

Brown, Halina Szejnwald, Philip J Vergragt, Ken Green, and Luca Berchicci. 2004. "Bounded sociotechnical experiments (BSTEs): higher order learning for transitions towards sustainable mobility." *System innovation and the transition to sustainability: theory, evidence and policy. Edward Elgar, Cheltenham*:191-222.

Callon, Michel. 1986a. Some elements of a sociology of translation. Cambridge, MA: The MIT Press.

Callon, Michele. 1986b. "The Sociologyof an Actor-Network: The Case of The Electric Vehicle." *J. Law and A. Rip (eds), Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World. London: Macimillan*:19-34.

Christensen, Toke Haunstrup, Freja Friis, Marianne Ryghaug, Tomas Moe Skjølsvold, William Throndsen, Sandra Riaño Fernandez, and Eutimio Sanchez Perez. 2016. Recommendations and criteria for the design of smart grid solutions for households. In *ERA-Net SmartGrids project report, "Integrating households in the smart grid"*.

Collins, Harry M, and Robert Evans. 2002. "The third wave of science studies studies of expertise and experience." *Social studies of science* 32 (2):235-296.

Darby, Sarah. 2001. "Making it obvious: designing feedback into energy consumption." In *Energy efficiency in household appliances and lighting*, 685-696. Springer.

Darby, Sarah. 2010. "Smart metering: what potential for householder engagement?" *Building Research & Information* 38 (5):442-457. doi: 10.1080/09613218.2010.492660.

Devine-Wright, Patrick. 2007. "Energy citizenship: psychological aspects of evolution in sustainable energy technologies." *Governing technology for sustainability* 63.

Farla, Jacco, Jochen Markard, Rob Raven, and Lars Coenen. 2012. "Sustainability transitions in the making: A closer look at actors, strategies and resources." *Technological Forecasting and Social Change* 79 (6):991-998. doi: http://dx.doi.org/10.1016/j.techfore.2012.02.001.

Fell, Michael J., David Shipworth, Gesche M. Huebner, and Clifford A. Elwell. 2015. "Public acceptability of domestic demand-side response in Great Britain: The role of automation and direct load control." *Energy Research & Social Science* 9:72-84. doi: http://dx.doi.org/10.1016/j.erss.2015.08.023.

Geels, Frank W. 2011. "The multi-level perspective on sustainability transitions: Responses to seven criticisms." *Environmental innovation and societal transitions* 1 (1):24-40.

Geels, Frank W. 2002. "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study." *Research policy* 31 (8):1257-1274.

Gram-Hanssen, Kirsten. 2011. "Understanding change and continuity in residential energy consumption." *Journal of Consumer Culture* 11 (1):61-78.

Grin, John, and Henk Van de Graaf. 1996. "Technology assessment as learning." *Science, technology & human values* 21 (1):72-99.

Hargreaves, Tom, Michael Nye, and Jacquelin Burgess. 2010. "Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors." *Energy Policy* 38 (10):6111-6119.

Hargreaves, Tom, Michael Nye, and Jacquelin Burgess. 2013. "Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term." *Energy Policy* 52:126-134.

Hoogma, Remco. 2002. *Experimenting for sustainable transport: the approach of strategic niche management*: Taylor & Francis.

Jelsma, Jaap. 2003. "Innovating for sustainability: Involving users, politics and technology." *Innovation: The European Journal of Social Science Research* 16 (2):103-116.

Jelsma, Jaap. 2006. "Designing 'moralized'products." In *User Behavior and Technology Development*, 221-231. Springer.

Jørgensen, Susanne. 2015. "Smart strøm - smarte kunder? En studie av norske husholdningers domestisering av smarte strømmålere og styringsteknologier."

Jørgensen, Ulrik. 2012. "Mapping and navigating transitions—The multi-level perspective compared with arenas of development." *Research Policy* 41 (6):996-1010.

Kemp, René, Johan Schot, and Remco Hoogma. 1998. "Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management." *Technology analysis & strategic management* 10 (2):175-198.

Latour, Bruno. 1987. *Science in action: How to follow scientists and engineers through society*: Harvard university press.

Löfström, Erica. 2014. "Smart Meters and People Using the Grid: Exploring the Potential Benefits of AMR-Technology." *Energy Procedia* 58 (0):65-72. doi: http://dx.doi.org/10.1016/j.egypro.2014.10.410.

MacKenzie, D, and J Wajcman. 1985. The social shaping of technology: how the refrigerator got its hum. Open University Press, Milton Keynes.

Marres, Noortje. 2012. *Material participation: technology, the environment and everyday publics*: Palgrave Macmillan.

Meisl, M, T Leber, K Pollhammer, F Kupzog, J Haslinger, P Wächter, J SterbikLamina, M Ornetzeder, A Schiffleitner, and M Stachura. 2012. "Demand Response Empfehlungen im Energieversorgungssystem 2020." *Oldenburg*.

Ostrom, Elinor. 1990. *Governing the commons: The evolution of institutions for collective action*: Cambridge university press.

Parag, Yael, and Benjamin K Sovacool. 2016. "Electricity market design for the prosumer era." *Nature Energy*:16032.

Pinch, Trevor J, and Nelly Oudshoorn. 2005. *How users matter: the co-construction of users and technologies*: MIT Press.

Pinch, Trevor J., and Wiebe E. Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14 (3):399-441. doi: 10.2307/285355.

Pineda, Andrés Felipe Valderrama, and Ulrik Jørgensen. 2015. "Creating Copenhagen's Metro–On the role of protected spaces in arenas of development." *Environmental Innovation and Societal Transitions*.

Reckwitz, Andreas. 2002. "Toward a theory of social practices a development in culturalist theorizing." *European journal of social theory* 5 (2):243-263.

Rip, Arie, Thomas J Misa, and Johan Schot. 1995. *Managing technology in society*: Pinter Publishers New York and London.

Rodden, Tom A, Joel E Fischer, Nadia Pantidi, Khaled Bachour, and Stuart Moran. 2013. "At home with agents: exploring attitudes towards future smart energy infrastructures." Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.

Russell, Stewart, and Robin Williams. 2002. "Social shaping of technology: frameworks, findings and implications for policy with glossary of social shaping concepts." *Shaping technology, guiding policy: Concepts, spaces and tools*:37-132.

Schatzki, Theodore R. 1996. *Social practices: A Wittgensteinian approach to human activity and the social*: Cambridge Univ Press.

Schatzki, Theodore R, Karin Knorr-Cetina, and Eike Von Savigny. 2001. *The practice turn in contemporary theory*: Psychology Press.

Schot, Johan. 2001. "Towards new forms of participatory technology development." *Technology Analysis & Strategic Management* 13 (1):39-52.

Schot, Johan, and Frank W Geels. 2008. "Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy." *Technology Analysis & Strategic Management* 20 (5):537-554.

Schot, Johan, Remco Hoogma, and Boelie Elzen. 1994. "Strategies for shifting technological systems: the case of the automobile system." *Futures* 26 (10):1060-1076.

Shove, Elizabeth, and Mika Pantzar. 2005. "Consumers, Producers and Practices Understanding the invention and reinvention of Nordic walking." *Journal of consumer culture* 5 (1):43-64.

Shove, Elizabeth, Mika Pantzar, and Matt Watson. 2012. *The dynamics of social practice: everyday life and how it changes*: Sage Publications.

Skjølsvold, Tomas Moe. 2014. "Back to the futures: Retrospecting the prospects of smart grid technology." *Futures* 63:26-36.

Skjølsvold, Tomas Moe, and Carmel Margaret Lindkvist. 2015. "Ambivalence, designing users and user imaginaries in the European smart grid: Insights from an interdisciplinary demonstration project." *Energy Research & Social Science*. doi: doi:10.1016/j.erss.2015.08.026.

Skjølsvold, Tomas Moe, and Marianne Ryghaug. 2015. "Embedding smart energy technology in built environments. A comparative study of four smart grid demonstration projects " *Indoor & Built environment*. doi: 10.1177/1420326X15596210.

Strengers, Yolande. 2013. *Smart Energy Technologies in Everyday Life: Smart Utopia?*: Palgrave Macmillan.

Sørensen, Knut H. 1994. "Technology in use: Two essays in the domestication of artefacts." *STS-arbeidsnotat* 2:94.

Sørensen, Knut H. 2002. "Providing, pushing and policing. Towards a new architecture of technology policy." *Technology studies and sustainable development*:65-94.

Sørensen, Knut H, Wendy Faulkner, and Els Rommes. 2011. *Technologies of inclusion: gender in the information society*: Tapir Academic Press.

Throndsen, William, and Marianne Ryghaug. 2015. "Material participation and the smart grid: Exploring different modes of articulation." *Energy Research & Social Science*.

Vergragt, Philip J, and Halina Szejnwald Brown. 2007. "Sustainable mobility: from technological innovation to societal learning." *Journal of Cleaner Production* 15 (11):1104-1115.

Wallenborn, Grégoire, Marco Orsini, and Jeremie Vanhaverbeke. 2011. "Household appropriation of electricity monitors." *International Journal of Consumer Studies* 35 (2):146-152.

Warde, Alan. 2005. "Consumption and theories of practice." *Journal of consumer culture* 5 (2):131-153.

Weber, Matthias, Remco Hoogma, Ben Lane, and JW Johan Schot. 1999. "Experimenting with sustainable transport innovations: a workbook for strategic niche management."

Wolsink, Maarten. 2012. "The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources." *Renewable and Sustainable Energy Reviews* 16 (1):822-835. doi: http://dx.doi.org/10.1016/j.rser.2011.09.006.

Åm, Heidrun. 2015. "The sun also rises in Norway: Solar scientists as transition actors." *Environmental Innovation and Societal Transitions*.