Final report

1.1 Project details

Project title	Integrating Households in the Smart Grid (IHSMAG)
Project identification (program abbrev. and file)	Energinet.dk project no. 10819
Name of the programme which has funded the project	Second Era-Net Smart Grid joint call
Project managing company/institution (name and address)	Danish Building Research Institute (SBi), Aalborg University (AAU)
Project partners	Danish Building Research Institute (SBi), SE, CLEVER A/S, Norwegian University of Science and Technology, NTE Holding AS, ZIV Metering Solutions / Tecnalia
CVR (central business register)	29102384
Date for submission	07.07.2016

1.2 Short description of project objective and results

English

The IHSMAG project explored the integration of smart grid solutions in household settings through studies of existing demonstrations with smart meters, electric vehicles, time-of-use pricing and monitoring and feedback to end-users in Denmark, Norway and the Basque Country (Spain). How relations between actors within the smart grid area as well as the regulatory context affect the development of household smart grid solutions were also studied. On basis of the findings, a number of recommendations and design criteria for better development of smart grid designs were developed. These include, e.g., the importance of being aware of possible negative (unintended) consequences of smart grid solutions, the need of taking the temporal rhythms of households into consideration in Demand-Side Management and of providing feedback data on non-aggregated levels.

Danish

IHSMAG undersøgte integrationen af smart grid-løsninger i husholdninger gennem studier af eksisterende demonstrationsprojekter med smart meters, elbiler, variable elpriser og moniteringfeedback til forbrugere i Danmark, Norge og Baskerlandet (Spanien). Endvidere studeredes betydningen af aktør-relationer inden for smart grid-området såvel som den reguleringsmæssige kontekst for udviklingen af smart grid-løsninger. Med afsæt i resultaterne udvikledes anbefalinger og design kriterier for udviklingen af bedre smart grid-løsninger. Disse omfatter bl.a. vigtigheden af at være opmærksom på potentielle negative (utilsigtede) effekter af smart grid-løsninger, behovet for at tage husholdningers tidsrytmer i betragtning i forhold til Demand-Side Management (fleksibelt elforbrug) og at levere feedback data på et ikke-aggregeret niveau.

1.3 Executive summary

The overall objective of IHSMAG was to contribute with new knowledge on how to develop a comprehensive design of household smart grid solutions. The main activity of IHSMAG was to do mainly qualitative studies of existing trials and demonstration projects in Norway, Denmark and the Basque Country (Spain) in order to analyse how smart grid solutions are integrated in the everyday life of households and how this integration is determined by factors related to 1) the design of technologies, 2) the everyday practices of households and 3) the broader electricity system and administrative and institutional rules. In this way, IHSMAG aimed at combining various perspectives and domains in order to provide a better understanding of how to develop smart grid solutions that works "in practice".

The studied demonstrations included a variety of solutions ranging from smart meters and feedback to customers to electric vehicles and time-of-use pricing. IHSMAG included five research-related work packages (and one work package related to project management, WP6). Each of the three main work packages (WP2-4) focused on one of the three earlier-mentioned domains or perspectives – although there was also overlaps between the work packages with regard to these perspectives (reflecting the complex and integrated nature of the smart grid area). In addition, one work package (WP1) developed a comparison of the energy system and smart grid R&D activities in the three countries and a final work package (WP5) synthesised the outcome of WP2-4 through developing a number of recommendations and design criteria for smart grid solutions in households.

On an overall level, IHSMAG demonstrates that developing and implementing smart grid solutions for households is complex and heterogeneous and dependent on factors related to all three domains covered by this project. Thus, designers and developers of smart grid solutions should take into account both technical details as well as details related to the everyday life of the households, who are going to use the technologies, and the broader system-regulatory context of the households. Without integrating all these aspects, it is difficult to develop solutions that will work in practice and have the intended effects.

Examples of details related to the technical level includes making exchange of consumption data possible without violating data privacy, ensuring interoperability between devices and making it possible to base feedback to consumers on real-time and non-aggregated data of the electricity consumption in the household. With regard to the everyday life of the households, IHSMAG shows for instance that aspects like taking the temporality (time patterns) of households into account then designing solutions for time shifting is of key importance. More generally, it is important to design solutions that fits into the daily practices of the household members. Financial incentives play a less important role for households' engagement than often assumed by designers of smart grid solutions. Rather, it is important to households whether smart grid solutions are "meaningful" in a broader context. Examples of important aspects related to the system and regulatory level include the need for intermediaries (e.g. network of actors) that can create arenas where actors from different sectors or spheres (including industry, regulators and consumers) can exchange experiences and opinions about common problems and solutions. Demonstration projects themselves can be seen as examples of such intermediaries or arenas for exchange between different actors. Also, on a more general policy level, the study shows that it is important to make strategies and regulations that, on one side, establish some end-goals that the actors within the smart grid area should work towards, but on the other side ensure ample time and flexibility for the actors to develop workable solutions through negotiation, exchange and collaboration.

A wide range of design criteria and policy recommendations has been developed on basis of the research findings of the individual work packages (WP2-4). They include very specific design criteria (e.g. promote energy saving through comparison with other consumers) as well as more general policy recommendations (e.g. ensure flexibility and openness in policy). The design criteria and recommendations are primarily targeted at developers/designers of household smart grid solutions, energy/system planners and regulators and policy makers.

1.4 Project objectives

The overall objective of IHSMAG was to *contribute with new knowledge on how to develop a comprehensive design of household smart grid solutions that integrates the specific characteristics of the three domains that intersect at the household level*: 1) Technologies in households, 2) electricity consuming everyday practices of the household members and 3) the electricity system and the administrative and institutional rules that affect the implementation of new smart grid solutions.

The outset of the project was that these three domains are mutually intertwined and decisive for the design and success of smart grid solutions for households. By synthesizing results from the studies of each of these domains (WP2-4), IHSMAG should contribute with a number of design criteria and recommendations (WP5) for how to promote the development of functional and effective solutions.

The specific objectives were:

1. To provide a survey of country-specific factors and existing research, existing development and demonstration activities in relation to smart grid solutions in households for all three countries. (WP1)
2. To provide knowledge about the effects of smart grid solutions in households and how they depend on everyday practices, the regulatory framework as well as the technical characteristics of the electricity system.
3. To develop a set of design criteria for the development of smart grid solutions for households that take into account the social and technical context of households. These criteria should be targeted at designers of smart grid technologies and systems.
4. To develop recommendations for planners and policy makers on how to promote user-oriented solutions.
5. To disseminate the results across Europe in cooperation between the partners of the project through publications targeted specific target audiences such as designers and planners.

The project was mainly based on studies of existing demonstrations and trials ("follow-research") applying primarily qualitative methods (but also statistics). The implementation was done through six work packages, each focusing on specific themes or parts of the overall project (except for WP6 on project management). The WPs were (with the WP-responsible partners indicated in round brackets):

WP1: Introductory survey of country-specific factors (SBi)
WP2: Interactions between systems/administrative rules and households (NTNU)
WP3: Smart grid solutions in everyday life settings (SBi)
WP4: Technological challenges and solutions at the household level (Tecnalia)
WP5: Design criteria for household smart grid solutions and policy recommendations (SBi)
WP6: Project management (SBi)

WP2-4 were to a high extent done individually by the leading partners (NTNU, SBi and Tecnalia), each focusing on particular demonstration activities in each country. In addition, and to ensure the exchange of results between countries/partners and the synthesis across work packages, WP1 and WP5 included close collaboration between all partners. WP1 established the knowledge foundation for the later synthesis in WP5 of the individual results of WP2-WP4 in order to provide a set of general recommendations and design criteria for smart grid solutions in households.

WP6 focused on project management. Here, an important activity was annual physical partner meetings in addition to annual Skype meetings. In this way, we had a partner meeting (physical or via Skype) every half year.

Overall, we believe that the project went very well and that we have provided a wide variety of data and results illuminating smart grid solutions in households from the three domains described earlier. Studies of smart grid initiatives based on social science methods are in general few, and therefore we are happy that IHSMAG has contributed with a range of publications (WP reports, journal and conference papers, PhD theses and Master theses) to the field.

Of course, a relatively large project like IHSMAG encounters various kinds of challenges or risks, which – in our case – included reduced funding for our Basque partner and parental leaves of key researchers on the project. As a result, we had to slightly moderate the ambitions for WP4 (due to less funding for ZIV / Tecnalia) and extend the duration of the project. For the same reason, we delivered several milestones later than originally planned. However, we did not encounter grave problems (such as bankruptcy of key partners etc.) during the project, and with the mentioned modifications, we have managed to fulfil the project objectives (see also later).

1.5 Project results and dissemination of results

In the following, we will summarize the main activities and achieved results for each of the work packages 1-5. These results are also documented in five WP reports (see Annex) as well as two PhD theses, two Master theses and a number of journal and conference papers. A full publication list is included at the end of this section.

Following the presentation of the main activities and results of WP1-5, we will make some general comments on the dissemination to non-academic actors.

WP1: Introductory survey of country-specific factors

The aim of WP1 was to provide an overview of relevant country-specific factors in relation to understanding the context of the development of smart grid solutions in each of the three participating countries (e.g. main characteristics of the energy system) and to give an overview of the status of R&D activities in relation to smart grid solutions in households. In this way, the survey should also serve as a common ground for the later synthesis of the country-specific results of the IHSMAG project (WP5). Understanding the differences and similarities between the countries was important when evaluating whether the country-specific results and insights would be "transferable" between the countries.

The outcome of WP1 was a report (See Annex) as well as three papers (Christensen et al. 2012, 2013b & 2013c). The comparison of country-specific factors was based on contributions from SBi (on Denmark), NTNU (on Norway) and Tecnalia (on Spain). Each partner filled in a template with key information about the energy/electricity system of each country as well as a survey of existing smart grid trials and demonstration projects. This was developed into the WP report and papers.

The survey showed, among other things, important differences between the countries with regard to source of electricity production (see Figure 1).

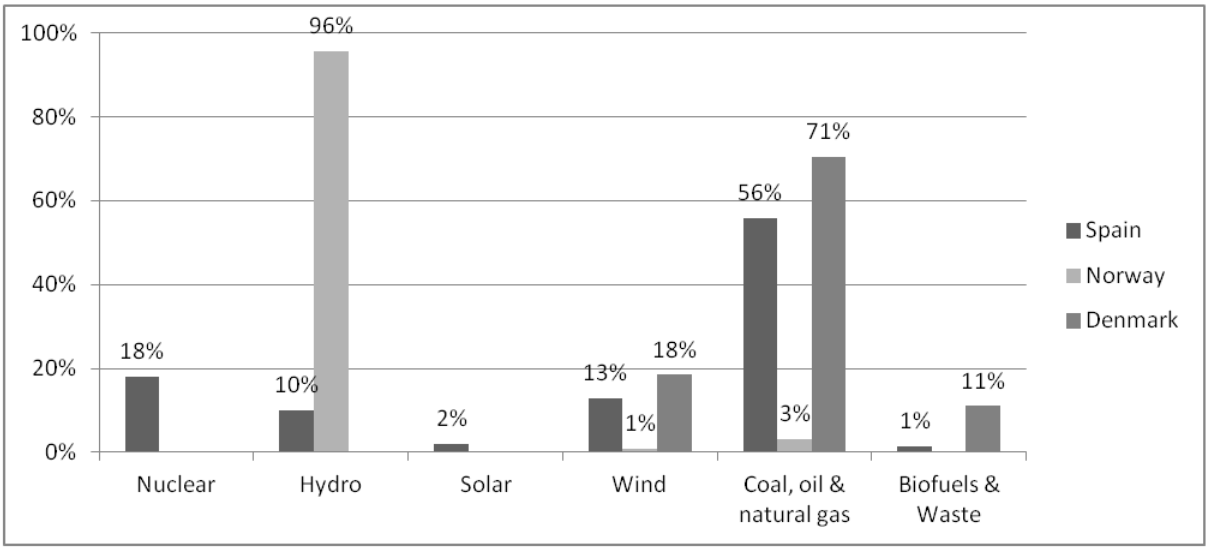


Figure 1. Distribution of 2009 electricity production (in per cent) by source of energy. *From Christensen et al., 2013b.*

Thus, Norwegian electricity production is almost entirely based on hydropower, while the electricity production is far more diversified in Denmark and Spain (2009 data); although in both countries more than half of the electricity is produced by coal, oil and natural gas (in Spain primarily natural gas and in Denmark primarily coal). Thus, the Spanish and particularly the Danish electricity systems are less flexible for short-term changes in electricity production from intermittent renewable energy resources than compared with the Norwegian system, which has a high share of flexible hydropower production. However, as a considerable part of the Spanish electricity production is based on relatively flexible natural gas-fired combined-cycle plants, and to some degree also flexible hydropower, these can work as a backup source for intermittent renewable energy.

The Danish combination of a high share of electricity production based on relatively inflexible condensing/CHP plants combined with a high share of intermittent wind power production is one of the major reasons for the particular focus on Demand-Side Management (load management) in the Danish smart grid discussion and R&D projects.

The survey also compared the load profiles (all sectors) of the three countries (Figure 2), which showed that while the Spanish and Danish load profiles have a similar two-peak shape with distinct morning and afternoon/evening peaks, the Norwegian load profile is more "smooth" with less distinct peaks. Actually, the highest "peak" is in the morning (and not in the afternoon/evening as in Denmark and Spain).

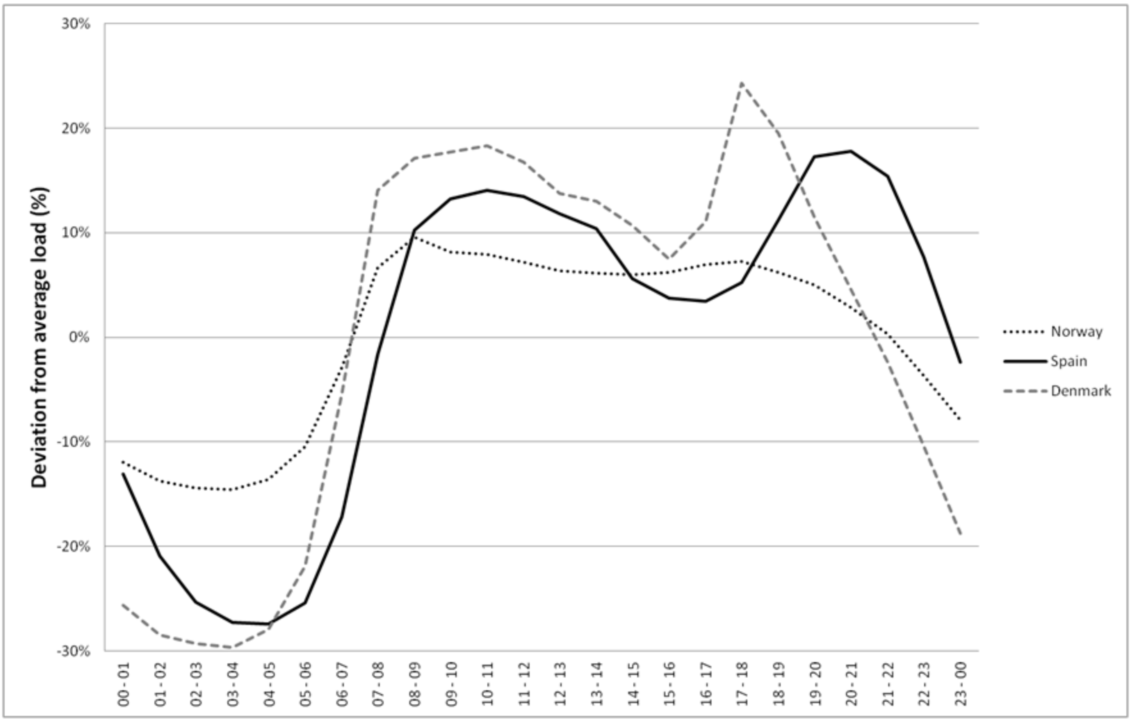


Figure 3. Comparison of load profiles for Norway, Spain and Denmark for week days in January 2012. The figure shows the hourly deviation for each country (in per cent) of the electricity consumption (all sectors) from the average consumption per hour during five weekdays in January (Monday 23 January to Friday 27 January 2012). The average consumption per hour (MWh/hour) is 19,227 (Norway), 32,970 (Spain) and 4,641 (Denmark). *From Christensen et al. 2013b.*

The smoother Norwegian load curve is presumably a result of about three quarters of the Norwegian electricity consumption being related to heating, which does not change as much in accordance with the rhythms of daily practices of the households as in the case of electricity consumption related to other activities like cooking or laundering.

Overall, the load profiles and the electricity production data indicate that balancing production and consumption is in general a smaller problem in Norway than is the case in Spain and (in particular) Denmark.

The survey of R&D and demonstration projects shows that Demand-Side Management (DSM) is a central theme for projects in all countries (but particularly in Denmark and Spain), with relatively few projects focusing on energy saving. The DSM projects differ in their conceptualisation of the household members; some emphasise the need for automated solutions (hiding the functionalities of load management by developing automated systems), while other projects aim deliberately at motivating users to change daily practices through information and price incentives (e.g. real-time dynamic pricing). Thus, there is a complexity with regard to the conceptualisation of the household members, even though the emphasis seems to be on automated solutions.

Even when household members are approached as potentially active participants in smart grid solutions, these solutions are generally based on an individualistic and simple rational-choice understanding of the household members' behaviour; economic incentives are in general believed to be the main driver of change of electricity consumption patterns. Thus, the projects in general lack a more nuanced understanding of the household members' practices as not just the result of individual choices, but as also being embedded in social-material structures and as collective practices shaped by many different elements. As a result, there is a risk of not recognizing possible negative (unintended) consequences of new smart grid solutions (e.g. if EVs increase the problems with peak-hour consumption, rather than help balancing production and consumption). Secondly, by not including nuanced understandings of everyday practices and the significance of the social context of households, the development of smart grid policies and solutions might fail to take advantage of the possible positive contribution from households and local communities in relation to the development of comprehensible solutions that *work in practice*.

Through the country-comparison and observations like those above, WP1 answered the questions related to the sub-goal no. 1 in section 1.4.

WP2: Interactions between systems/administrative rules and households

The overall goal of WP2 was to analyse the interaction between the overall electricity system, regulation efforts and households with a particular focus on how to achieve transitions from ordinary electricity grids to smart grids. WP2 was carried out by NTNU and the work package sought to contribute with knowledge about smart grid integration with the overall energy system, regulation efforts to achieve this, as well as how these systemic traits relate to the role of households. This was done through empirical studies of the Norwegian smart grid development. The goal was to identify major social, political and technological barriers to the implementation of smart grids, and to relate this to the role of the households both in existing and future smart grid systems.

In practice, this was achieved by conducting studies of different characters: First, the work of Norwegian policy makers and regulators involved in the production of smart grid related policies was studied, primarily the Norwegian advanced metering infrastructure regulation. Second, it was studied how Norwegian industry actors have worked as a response to the regulation and what kinds of work they engage in to transform visions from policy debates and regulation texts into real, working solutions. This also led the research in the direction of studying the work of technical smart grid experts more broadly, and their role as policy mediators, in shaping the future smart grid. Third, it was studied how the household users of the new technologies make sense of the situation, how they understand the new technologies and how they (potentially) make use of them.

Theoretically, WP2 study was anchored in Science and Technology Studies. Broadly speaking, this approach is concerned with the relationship between science, technology and society and how these arenas of development are mutually shaped and constructed. The perspective highlights that what happens in society feeds into technology development, and vice-versa, that new technology might pave the way for social change. Thus, it represents a critique of linear thinking about technology, where technology "diffusion" is the end of enquiry.

Empirically, WP2 mainly relied on qualitative methods such as participatory observation in the grid operator and electricity producer (Nord-Trøndelag E-verk, NTE), text analysis of documents related to the policy debate on smart meters in Norway (1998-2008) and interviews with implicated actors; interviews with key actors in four different smart grid demonstration projects across Norway as well as interviews with both prospective users and actual users in two demonstration projects *Demo Steinkjer* and *Demo Hvaler*. At Steinkjer, focus group interviews were also conducted.

In addition to the WP2 Report, the results of WP2 has been reported in a PhD thesis, two MA theses as well as a number of papers. See p. 6 in the WP2 Report (in Annex) for a full list of publications related to WP2.

On basis of a review of research literature on smart grids, three categories or narratives on the imagined role of the users were identified: economically rational users, technologically bypassed users and a social science critique of these perspectives. Through the empirical studies of the pilots, some of these narratives were found in play. The economic rationality narrative was proven faulty as users were found disinterested in the rather meagre potential for saving money, but the idea of monetary savings was nevertheless resilient among experts in the face of this experience. The technology bypass narrative was reinforced by a concretization of technological solutions to cater for the problem of missing economic incentives. Simply incentivising all consumers with the prospect of monetary savings will invariably fail to include everyone, and an incentive not reacted upon inverts to a penalty. This underlines the ubiquitous nature and therefore the heterogeneous kind of interdisciplinary action called for in scientific endeavours dealing with smart grids.

With regard to the role of regulation, a key observation from the Norwegian cases was that while the regulation (mandatory rollout of smart meters) served as an innovation "trigger", the experimentation in the demonstration projects grows out of local contexts and become highly different in character at the different sites. They encompass different technologies, different actor-constellations, have different goals, and conceptualize users and user rationalities in very different ways. In this way, the relatively open (and long-term) smart meter regulation creates space for the actors to try out and experiment with different ideas and solutions.

The analysis suggests that smart grids consist of *innovations in the making*, so we cannot predict which models will prevail. It seems, however, that the diversity in project configurations, goals and rationales for setting them up, do contain a policy lesson. It seems that when large-scale societal infrastructures are to be changed and innovation is sought, ample time is needed to experiment, to try out new solutions, and to find viable actor constellations and to ensure social learning. That there are both positive and negative experiences along the way is only to be expected.

The results show that network (grid) companies were not initially supportive of Advanced Metering Infrastructure (AMI) implementation in Norway. Rather, they were enrolled by the regulator, who created an obligatory passage point – the regulation – that established functional specifications designed to achieve socio-economic benefits. The regulator did not, in this case, have the expertise needed for the task at hand, and, as is common, the work was given to the real experts. This changed the landscape of network operators, forcing them into hitherto unknown territory. They responded with a sideways mobilization to establish upward influence.

Network companies were given a crucial role to play in the early days of Norwegian smart grid development. Consequently, because they oversee the infrastructure itself, they have become pivotal actors in smart grid development. As the future grid continues to take shape, understanding the complex role of network companies, their considerable agency as middle-out actors, and how they employ this agency to influence their surroundings will be of importance.

With regard to the involvement of users, the WP2 study shows that inviting users to some sort of venue within even a quite loose framework can produce results in the form of concrete articulations on which further informed smart grid work may be built. A strong presence of both pragmatic and enthusiastic sentiments among many consumers alongside the negative sentiments proves that there is ample opportunity for social learning to occur in bringing users (and their articulations) into smart grid technology and policy design. This is where progressive and useful enrolment of users becomes important in a practical sense.

More specific insights came from a study of nine households and their engagement with feedback technologies. Here, it was observed that the interaction with the technology usually unfolded through four distinct phases. A key challenge for developers of such technology seems to be that the technologies are largely designed for individuals, while household electricity consumption is largely a *collective activity*. Thus, while the technology in this case engaged one householder (typically the man), who mobilized the technology to make changes in the electricity consuming household infrastructure, it largely alienated and disengaged other inhabitants. The four phases illustrate this challenge:

First, was a phase of *initial learning* about the new technology and household electricity consumption. The users would begin interacting with the feedback technology, tinkering with their electricity consumption. Typically, one inhabitant (in most cases the man) in the household would take on a sort of lead role in this processes. This suggests that there are gendered dynamics to energy demand and management, which deserves closer scrutiny in future research.

Second, was a phase were respondents implemented *one-time measures* to decrease electricity consumption These included changing the physical infrastructure of the building through refurbishments or replacing old household appliances. The main feature of these measures was that once they had been implemented, they had no consequences for the routines and practices of the everyday life of the household members. Once the one-time measure was implemented, the feedback technology was used to confirm that the intended effect had been achieved.

In the first two phases it was sufficient to engage the man of the household. He conducted the household energy mapping exercises and one-time measures largely without the interference of other householders. In the third phase, many tried to establish *new operational rules*, which was not easy without the help of others. Typically, these rules would deal with the use of appliances. When could specific appliances be used, which appliances could be used simultaneously, etc.?

This also revealed an interesting division of labour in many of the households. While the man would be in charge of "technical stuff", and via this the energy and electricity infrastructure, it was the woman (in heterosexual relationships) who actually managed many of the situations where this infrastructure was vital. This included things like washing, cooking and cleaning, situations where energy-intensive appliances were at work. Thus, a clash of logics was often observed where the everyday needs (managed by women) were put against men's desire to be an energy manager.

In the fourth phase of using the feedback technology, it would *slip into the background* and become a normalized and un-exotic part of the householders' everyday lives. In this phase the technology did not provide any new learning about what occurred in terms of energy consumption in the building, nor on ways to reconfigure appliance set-ups.

Overall, the WP2 study highlighted the importance of seeing policy development, innovation strategies and the potential engagement of household users in the smart grid as related processes. The shaping of policies, markets and other framework conditions shapes the space that industry actors inhabit and provide tools that they can mobilize in innovation processes. The local peculiarities in which innovation unfolds lends itself to different formulations of what the smart grid is, what it might be, and what it should be. Household users, of course, engage with technologies, but their engagement is not only a matter of acceptance. Our analysis indicates that engagement with the energy system might take many forms, but similarly, that rendering too many voices mute and taking for granted what their preferred mode of engagement is, might alienate many and create resistance and opposition to the development.

There is reason to believe that these dynamics will be strengthened in the years ahead. Increasingly, users are not only expected to manage their own consumption of energy in new ways, but also produce their own energy through micro generation. In addition, we expect to see tighter integration of transport infrastructure and the electricity infrastructure, with electric vehicles serving as a bridge between the two, with its battery as a potential aggregated source of flexibility.

WP2 contributed to the overall aim of the IHSMAG project and, specifically, the sub-goal 2 in section 1.4.

WP3: Smart grid solutions in everyday life settings

The aim of WP3 was to contribute to a better understanding of the interplay between smart grid solutions and the daily electricity-consuming practices of households, including transport practices. As Demand-Side Management (DSM) has become one of the core objectives in smart grid development and visions, WP3 focused especially on the connection between the temporal organisation of households' everyday practices and the timing of the residential electricity consumption – and how smart grid solutions influence the temporal patterns of practices and electricity consumption. In addition, the study also analysed how families integrate electric vehicles (EVs) in their everyday life and hence included analysis of mobility intervention strategies associated with the dissemination and adoption of EVs.

Theoretically, WP3 was anchored within *social practice theories*. Practice theories represents an approach or "turn" in sociological thinking, which places social practices as the analytical unit for exploring the social. The practice theories approach seeks to overcome the structure-actor dualism regarding whether human behaviour is primarily determined by social structures or individual agency. Practices are not viewed as individual acts, but rather as collective actions where the individual can be viewed as a carrier (Reckwitz, 2002).

Another important observation from practice theories is that consumption of energy (and resources in more general terms) is the outcome of performing practices. Thus, everyday practices like cleaning, preparing food, doing the dishes, washing clothes, commuting and many entertainment activities (like watching television) all involve some sort 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.

Practices are configured by different and mutually dependent elements, including materials (e.g. smart grid technologies), meanings (e.g. understandings of what smart grid solutions are for) and competences (e.g. know-how related to how to operate technologies). Among the important features of practice theories, which separates this approach from psychological and many human-centred sociological and economic theories, are the focus on the role materiality plays in shaping practices and that it rejects the understanding of people's behaviours as a (simple) result of their (individual) attitudes and preferences.

Empirically, WP3 draws mainly on in-depth qualitative interviews and focus groups with Danish households participating in the EV demonstration project *Test an electric vehicle* ("Test en Elbil") and the static time-of-use pricing trial called *Dynamic Network Tariff* ("Dynamisk Nettarif"). In addition, the study also included participant observations as well as statistical analysis of hourly-based recordings of the electricity consumption of households participating in the *Dynamic Network Tariff* demo. WP3 was carried out in collaboration with the electricity provider and DSO *SE* (leading the *Dynamic Network Tariff* demo) and *Clever* (leading the *Test an EV* demo).

In addition to the WP3 Report, the results of WP3 has been reported in a PhD thesis and a number of papers. See p. 6 in the WP3 Report (also included in Annex) for a full list of publications related to WP3.

On basis of the introductory literature review and review of Danish smart grid projects involving households (part of WP1), WP3 confirmed that the "techno-economic" or "techno-rational regime" is still dominating the implementation of smart grid technologies targeted households. Within this regime, electrification of the current transportation system is seen as crucial, which implies that EVs are assigned a central role for the future energy system. The mainstream assumption is to accommodate the challenge of increasing fluctuations in the energy system from renewable sources by economic incentives and technological innovation. Following this, designs and strategies are often developed without duly acknowledgement of the complexity of people's everyday life and social practices.

The studied electric mobility intervention ("Test and EV") only partly acknowledges the complexity of the everyday life of the participating households, and the EV operator partly reproduced the widespread representation of EVs as a substitution for conventional combustion engine cars by underscoring the EV's ability to cover existing transportation needs. In addition, the intervention draws on the economic rationality by stressing the lower operation costs of EVs.

By demonstrating how everyday habits and routines are interwoven in socio-material systems of consumption, the WP3 study indicated that smart grid operators, and other key actors, should recognise the collective nature of daily practices and how these are interrelated in "systems of practices". Further, the study showed that the low uptake of EVs is not only about the lack of economic incentives (such as reduced taxes on EVs), but is also a result of the current infrastructure and systems of auto mobility being based on the combustion engine car. Auto mobility is a key example of a deeply complex and profoundly embedded socio-technical system, which requires fundamental transition that goes beyond mere technological changes in order to ensure a large-scale reduction in fossil fuel consumption. Employing a system of practices approach suggests interventions to intervene with (and challenge) the systems of practices in which car mobility is embedded. Instead of reproducing traditional approaches and understandings by focusing on technological "fixes" or trying to change people's individual behaviour through information campaigns, the results of WP3 implicates that reducing fossil fuels on the scale that appears to be necessary requires interventions to change the entire system of resource-intensive practices. "Unlocking" the current systems of practices requires interventions that take into account the path dependency of the present infrastructural systems of (mobility) practices and how they connect with other practices like working practices, grocery-shopping practices and leisure activities.

On a more specific level, the study revealed a number of unintended, negative consequences of the smart grid integration. Most alerting was that the EV test drivers participating in the focus groups (without a time-of-use pricing scheme) plugged-in their EVs when they came home from work. By doing this, the recharging of the EVs coincided with the critical evening load peak between 5 and 7 PM. This demonstrates the need to combine EVs with other measures/solutions (like time-of-use pricing) in order to avoid new or exacerbated peak loads and grid capacity problems. Moreover, several participants expressed that the EV increased the amount of driving trips during the trial and thus replaced bicycle rides and walking. These examples of unintended, negative consequences show exactly why it is so important to take the dynamics of everyday life and daily practices into account when planning and designing smart grid solutions and interventions.

The part of WP3 that focused on the static time-of-use pricing (the combined Test an EV and Dynamic Network Tariff trial) made a number of important observations regarding how time shifting of everyday practices (and their related electricity consumption) is highly dependent on the temporal rhythms (time patterns) of the daily life of the household and its members.

Most of the interviewed households time shifted their EV charging, laundry and dishwashing activities to low-tariff periods. The qualitative analysis showed that this was in particular due to the participating households' commitment and engagement with regard to following the operators' rules and the intentions of the trials. In comparison, economic incentives had a minor impact on developing the new practices. This shows that engagement, commitment and the experience of participating in collective action play a significant role in order to achieve time shifting.

Moreover, the study found that the reason why in particular the practices of dishwashing, laundering and EV charging was time shifted is that these practices involve the use of technologies that semi-automate some of the activities. Thus, the timing of electricity consumption and bodily involvement in practices are partly decoupled, which makes it easier to time shift the activities (e.g. postponing dishwashing to the night hours).

The temporality of everyday life and practices of households are pivotal for the households' flexibility of time shifting their electricity consumption. Time shifting routines and practices influences the synchronisations and interrelations between social practices and, by doing this, has a high impact on the flexibility.

The analysis of time shifting also demonstrates how social practices are interrelated and dependent on wider systems of practices partly shaped by collective and institutional rhythms and the temporalities of the households and their members. This also involves time constraints that make many everyday practices difficult to time shift (for instance the timing of dinner cooking and working hours). Hence, smart grid solutions and strategies should be aware of (and integrate) the temporalities of practices and households' everyday life (including differences between households).

On a practical level, the study of time shifting indicated that static time-of-use pricing (as in the Dynamic Network Tariff trial) has some impact on the timing of the households electricity consumption, whereas real-time pricing (following the market price on the Nord Pool power market) did not have any influence on the daily routines of the participating households. Thus, if the aim is to actively involve households in time shifting (DSM) their electricity consumption, simple schemes like static time-of-use pricing should be preferred for more "advanced" solutions like real-time pricing. The former makes it possible for households to adapt new routines that follows the time-of-use pricing, while the latter type of solutions are far too complex and involves too much day-to-day planning.

It is of course important to note that the results from our study of the Test an EV and Dynamic Network tariff trials are influenced by the deficiencies of the involved technologies. Both the EVs and the charging-boxes (for the remotely controlled charging of the EVs) represent first generation mass-produced versions. This has most likely influenced the results. In particular, the participants in the focus groups (who were EV test drivers in the wintertime) experienced the EV as too unsafe, uncomfortable, inconvenient and too expensive.

WP3 contributed to the overall aim of the IHSMAG project and, specifically, the sub-goal 2 in section 1.4.

WP4: Technological challenges and solutions at the household level

The aim of WP4 was to detect technological challenges related to the integration of households as an actor of the smart grid system. WP4 also focused on identifying intermediate steps that could be taken to progress in the process. Thus, WP4 had a more technology-oriented focus than the previous WP2 and WP3.

More specifically, it was chosen to develop a user interface, which monitored end-user consumption and provided them with recommendations aimed to change their consumption patterns. This interface, which was called *Home Display* runs on smart devices, such as smart phones and tablets, and was introduced as the key tool of a test pilot involving real households.

The test pilot involved households, electrical equipment manufacturers and distribution system operators and was done in Spain. In this way, assumptions and solutions suggested in this WP have been clarified through real users and equipment.

It has been considered that the smart grid system integrates an Advanced Metering Infrastructure composed by smart meters, metering data concentrators and a central dispatch at least. Although this entire infrastructure is provided by distribution system operators, the commercialization companies are in charge of end-user billing. So, the AMI is used to measure, price and in some cases control end-user consumptions.

Data concentrators and central dispatch are accessible through the internet via IP communications like TCP or GSM/GPRS/3G. This means, on the one hand, that end users could somehow reach the data stored in these systems through internet. On the other hand, using the existing smart grid equipment requires having advanced knowledge about the communication protocol used by the distribution system operator. And, what is more, it implies access to sensitive information related to customers' electricity consumption and related economic data. Therefore, it is mandatory to achieve secure communications, which will ensure a safe exchange of confidential data.

The technology selected through the specification phase of the Home Display tested in WP4 covers all the requirements mentioned above through a Web Services solution. Web Services technology is a method of communications between two electronic devices over the World Wide Web, with specific protocols related to how integrity and confidentiality can be enforced on messages.

Taking advance of the widespread access to internet, and fitting with existing communications standards, Web Services remains as a good choice to face Home Display communications with smart grid system.

Built on the premise that the Home Display must be a cost-effective solution, the previous mentioned facts have led to developing the Home Display as an app under open operating systems, which can run on the smart devices owned by the households (tablets or smart phones).

The visual interface was implemented as a separated module, which allows it being used on different operative system, such as Android or iOS. Moreover, the visual interface is independent of the communication module fulfilling data from smart grid system. These points ensure long-term flexibility for the Home Display application.

As part of the trial a dedicated server (demand management portal) to exchange data between metering recordings and users was set up in order to improve the speed of the data exchange. The current smart metering system is focused on billing consumption of end users and this fact has performance implications:

- Existing data concentrator devices gather consumption of meters only one time per day
- Communications are slow, because speed for retrieving consumption data is not critical, then only used for billing purposes

In this context, a dedicated server to exchange data with end users is necessary, in order to separate smart grid performance for pricing and performance for integrating households. For feedback to customers to be useful and effective, previous studies have shown that it is important to provide real-time (or as close to real-time as possible) data.

With regard to the programming language of the Home Display application, HTML5 was chosen since it was the last revision of core technology markup language used for structuring and presenting content for the World Wide Web. It is the best option to develop a flexible application to run on Smartphones or Tablets because it is applicable to multiple operative systems such as Windows, Android or iOS.

The data provided to the end users through the Home Display was:

- Hourly total consumption of electricity
- Daily total consumption of electricity
- Hourly disaggregated consumption of smart appliances
- Daily disaggregated consumption of smart appliances
- Daily average consumption
- Daily desired consumption curve (by the utility)
- Hourly qualitative recommendation with the aim of modifying consumption pattern
- Information about environmental impact of individual consumption

The following figures shows some of the features on the Home Display.

Figure 2: Home Display toolbar

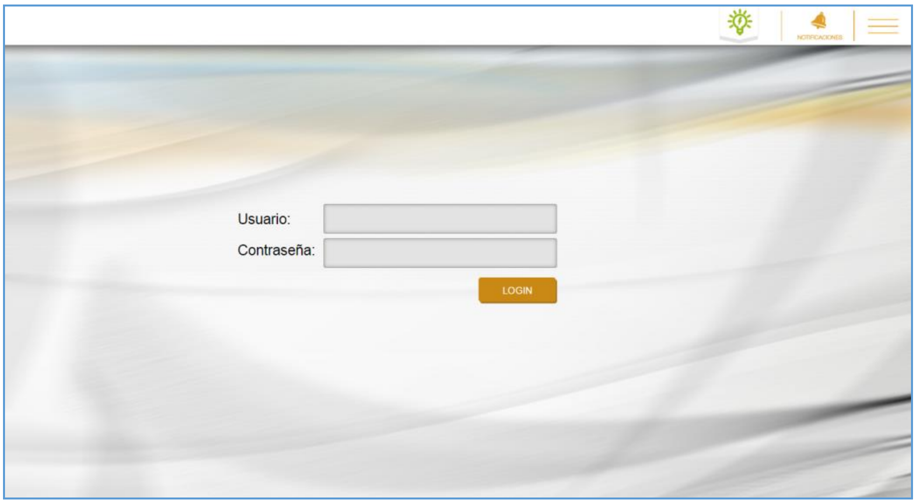
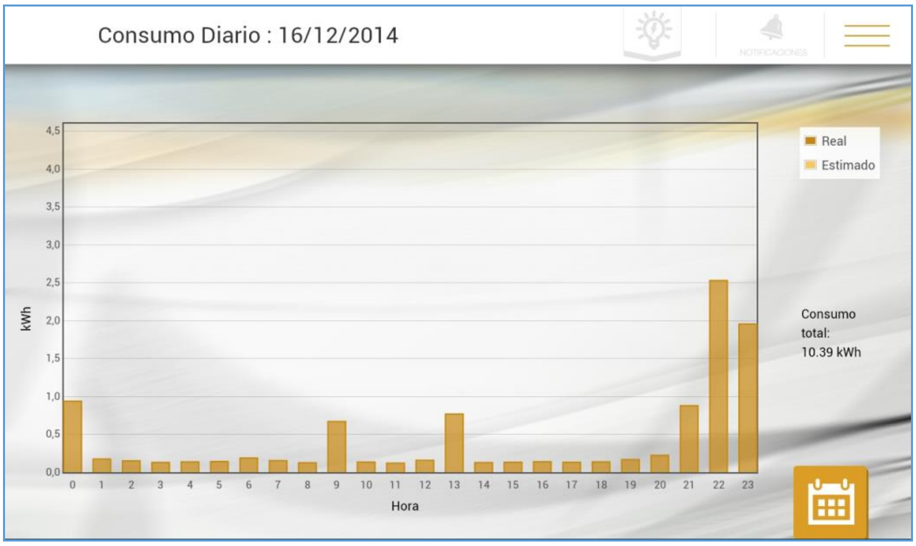


Figure 3: Login screen


Consumo Diario : 16/12/2014

Consumo total: 10.39 kWh

Figure 4: Daily consumption screen without Energy Box

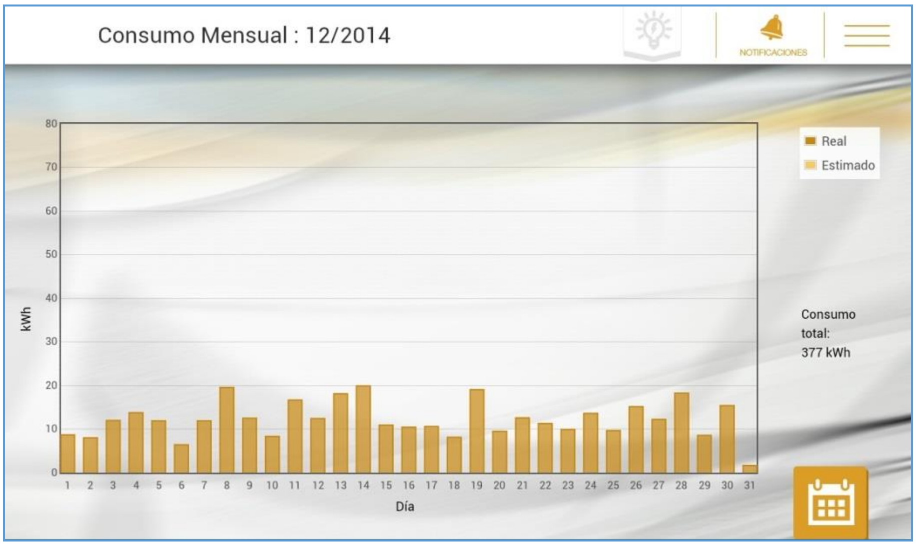


Figure 5: Monthly consumption screen without Energy Box

The test pilot took place from September 2014 to January 2015 at the Henares Corridor area, a residential and industrial area around the Henares River, which flows between the cities of Madrid and Guadalajara. The Henares Corridor area has more than 500,000 inhabitants.

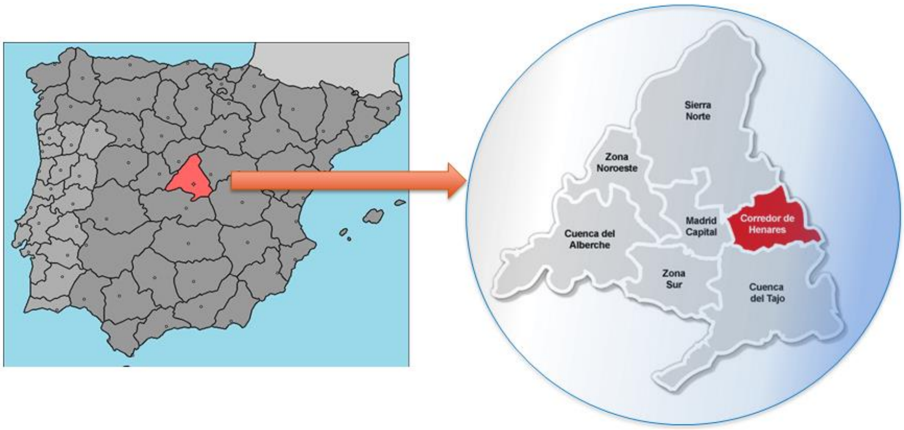


Figure 12: Henares Corridor area

The test pilot offered the opportunity of monitoring consumption to the Henares inhabitants, with the objective of knowing whether the displayed information was useful or not, and whether it helps to optimize the electrical consumption or not.

Massive mailing aimed to recruit volunteers for the test pilot was launched in August 2014. The ambition was to enrol about one thousand household. 8,000 letters were sent to Spanish utilities customers. In addition to the mailing, information campaigns took place at local entities such as universities and among the Advisory board members related to the Spanish part of IHSMAG.

The test pilot was aimed to increase user awareness among customers about their electricity consumption, providing data on daily and monthly consumption. Moreover, the users were given some recommendations to shift consumption towards suitable periods and they were even able to send comments about their consumption changes.

125 households signed up for the trial, but only 54% of them owned an Android Tablet (67 end-users). Finally, only 88% of them ever used the Home Display application. From the trial, the conclusions were (among others):

- Most of the participants (59%) used the application less than five days during the test pilot

- The interest of the households in the application decreases significantly with time. They are more engaged the days right after application download.

On basis of the trial a number of technological barriers were identified related to the availability of smart grid ready equipment, lack of interoperability, privacy issues and, finally, security, robustness and scalability. Further details about these barriers (and the Home Display trial in general) can be found in the WP4 Report (included in the Annex). The report also includes a number of recommendations, which fed into WP5.

WP4 contributed to the overall aim of the IHSMAG project and, specifically, the sub-goal 2 in section 1.4.

WP5: Design criteria for household smart grid solutions and policy recommendations

In WP5, the outcome of the three main work packages (WP2-4) was synthesised in order to develop a number of key lessons from the IHSMAG project regarding design criteria and policy recommendations on how to develop comprehensive and integrative smart grid solutions. I.e. solutions that take the technical, system-related and social/everyday life context of households into account. Or, in other words, answers the question: How to create smart grid solutions for households that work in practice?

WP5 resulted in two main groups of recommendations and design criteria: One group focusing on design criteria and recommendations for smart grid designers (i.e. persons involved in the specific designing of technical solutions related to households). The second focusing on recommendations for policy makers, planners and others involved in defining the conditions for the smart grid development or organising the design and development processes, like national energy agencies, politicians, planners within TSOs, DSOs etc. However, there are obvious overlaps between the two groups.

The results of WP5 are reported in the WP5 Report (included in Appendix). The work package related to the specific sub-goals 3-5 listed in section 1.4.

Below, we briefly summarize the recommendations and design criteria developed in WP5:

- **Do not focus on economic incentives only**: Even though economic incentives for participating in, for instance, DSM schemes such as time-of-use pricing seem to play a role, many other non-economic aspects or incentives play an even more important role for users' active engagement. These other aspects include more general environmental concerns, the possibility of contributing to an overall sustainable transition of the energy system, avoiding risks of blackout, contributing to energy security in times of crisis, avoiding expanding the grid capacity (and avoiding new power grid lines) or being part of a "collective movement" (the community-related aspect). Overall, it is important that participation in smart grid initiatives are experienced as *meaningful* activities by the households, which goes far beyond merely financial incentives like savings on the energy bill.
- **Ensure active (and wholehearted) involvement of users**: A more active involvement of users (customers) in the design and implementation of smart grid solutions seems to be a promising way forward. This could be done through community or neighbourhood initiatives. In relation to this, local "enthusiast" and grassroots can play a key role in pushing projects forward, manage the projects, secure that they meet their goals and making sure that all involved actors are able to formulate their interests and work towards a common goal. As part of this, facilitating learning over time (and avoiding a one-point-in-time intervention) seems important.
- **Remember the potentially unexpected actors**: Since successful design, and ultimately successful use, of smart grid solutions seem aided by embedding such solutions in local communities and regions, it is important to keep in mind that the involved group of users or households will not always be homogeneous. In IHSMAG, our focus was on households. Households, however, might be many things, and they are part of diverse networks with diverse interests. Thus, it is important to look beyond the obvious participants (electricity producers, grid companies and "users") when establishing smart grid

solutions. For instance, the Norwegian *Demo Lyse* project managed to build a quite successful demonstration project around the notion of welfare technology.

- **Look for positive synergies between smart grid solutions**: Trial and demonstration projects often aim to involve households in relation to one specific type of solution (e.g. energy feedback to consumers, energy efficiency or time shifting of electricity consumption). However, experience from the study of the Danish trials indicates that the combination of solutions (in this case time-of-use pricing and electric vehicles) implies potential synergies that can strengthen the effectiveness of otherwise separate solutions. The design of smart grid solutions should take into account and encourage these kinds of synergies and positive spill over effects.
- **Be aware of possible negative, unintended effects**: It is well known within the literature on energy saving that higher energy efficiency is often followed by increases in consumption, which partly offsets the achieved (technical) savings. This kind of unintended effect is known as the rebound effect. Similar examples of unintended, negative effects might be expected in relation to the implementation of smart grid solutions. One example from IHSMAG is how the "branding" of electric vehicles (EVs) as an energy efficient and environmentally friendly alternative to combustion engine cars made some participants feel more relaxed of using the car more often as it would not "make harm to the environment" and because of the cheaper operation costs. Another example could be if time-of-use pricing indirectly motivate households to increase their overall electricity consumption, as they would regard new (increased) electricity consumption as inexpensive as long as this happens at low-peak hours.
- **Data needs to be collected and made accessible to end-users without compromising data privacy**: Important questions regarding privacy and data security follow with the new opportunities for detailed monitoring and storing of households' consumption data. Thus, the question of data protection, privacy and data ownership has been identified as one of the main issues and challenges related to the smart grid development. Therefore, allowing users (or third parties) to access consumption data stored by the smart grid system implies the development of a safe and reliable protocol to minimize data leaks or misuse.
- **Make smart grid solutions easy to understand and use**: Smart grid solutions should be made easy to understand and use by the households. Users have varying levels of competences and knowledge about electricity-related parameters. Therefore, the provided data should be easily understandable. For example, information should be presented in graphs, which are easier to understand than numbers. This recommendation also relates to how DSM solutions are designed. For instance, the WP3 study indicated that the time shifting in electricity consumption was not so much depending on the actual cost savings (which were in general small), but rather depending on the fact that static time-of-use pricing conveyed a general and comprehensible information about at which hours it would be most suitable for the system and for the household economy to consume electricity.
- **Time shifting energy consumption – take into account the temporal rhythms of households and spatial qualities of homes**: The IHSMAG project shows that households are able to time shift some of their everyday consumption, but this most likely happens in relation to practices that involves *semi-automation* of daily practices. More specifically, practices such as dishwashing, laundering and charging EVs. However, time shifting has implications for the daily rhythms and temporality of the household members and can be a source of inconvenience (e.g., time shifting laundering to the night hours results in a new activity (habit) of hanging clothes to dry in the morning hours). Solutions aimed at influencing household members to shift the timing of their daily practices need to recognise the temporal complexity of the household members' everyday life and the meaningful social interaction within the home. Also, the materiality of the home and its spatial layout play an important role. For instance, noise from machines running during the night (e.g. dishwashers and washing machines) can interfere with other activities of the household members (like sleeping) and effectively hinder the time shifting of activities such as dishwashing and laundering. This can be a problem *within* the household, but also *between households* in apartment buildings where neighbours live close to each other.

- **Promote energy saving through comparisons with others**: Providing households with (visual) comparisons of the size of their own electricity consumption with the size of the consumption of their neighbours or households similar to themselves might be a way of increasing general awareness about own electricity consumption and motivate to save electricity. Obviously, data security and privacy issues have to be considered when implementing such measures. However, grouping users on basis of certain common characteristics and providing the average data of the group (who shares these characteristics) could be a way of avoiding privacy matters.
- **Feedback data should be real-time**: Feedback information to households should ideally be real-time. One example could be real-time notifications if a threshold consumption level defined by a user (daily or monthly) is exceeded. This could be an incentive for households to save energy. Also, real-time feedback supports the active participation of householders who can follow and monitor what impact their changes of daily habits have on the energy consumption.
- **Feedback data should be available on a non-aggregated level**: Efforts should be made in developing solutions that make it possible to provide households with consumption data on a non-aggregated level (i.e. an appliance-specific breakdown of the households' electricity consumption). Otherwise, the users will only be informed about their aggregated consumption, which gives no clear idea of when and where electricity has been consumed. Like real-time feedback, this would support active experimentation and learning processes regarding the household's use of electricity and possible ways of saving electricity.
- **Smart home appliances**: The technology in homes seems to be crucial in relation to providing non-aggregated consumption data. The development of mini-meters or smart plugs, which provides data on the electricity consumption of specific devices, is a key to increase awareness of users about their electricity consumption.
- **Flexibility and openness in policy important**: On the policy level, two overall recommendations can be inferred from IHSMAG. First, there should be *ample time* between the regulation is announced and its enforcement. In the Norwegian case, the authorities' intention to implement the technology through grid management regulations became known to the industry actors already in 2008 after some years of debating the issue already. Thus, political imaginaries of "what" the smart grid could become in the future was in the making, and network operators were forced to involve themselves in this process by the rollout being made mandatory by regulation. As the final wording of the regulation was not ready before 2013, this gave Norwegian stakeholders more than ten years to prepare for the massive infrastructure upgrade. In addition, it is important to make regulation that allows for, and perhaps stimulates, flexible solutions. Different localities, regions and countries consist of very different actor constellations and interest structures. This means that there are many different potential ways of mobilizing and designing smart meters and related technology. Second, it would strengthen the potential for innovation if the regulation of technology is relatively open-ended, with quite open standards so that it can be used for multiple purposes and be exploited by third parties. This would allow different actors to build new solutions "on top of" the technology.
- **Use intermediaries to engage the public**: Both in a physical and metaphorical sense, there is often a long distance between authorities and households in which the technologies are brought to use. The same can be said about the distance between the authorities and electricity sector companies. Thus, regulators should strive to enrol intermediary organizations or actors who can engage in active dialogue with implicated actors at different scales. In Norway, for instance, the non-profit industry organization Energy Norway, who represents about 270 companies involved in the production, distribution and trading of electricity, has been crucial for establishing arenas where actors from different industries and the policy and regulation sphere can exchange experiences and opinions about common problems and solutions. It has also served as an arena for negotiating the outcome of the smart grid efforts, made robust by broad support by the actors. This was necessary because of the infrastructural characteristic of the smart meter, and the need for it to be more or less uniform across the country, and indeed, across borders. Also, demonstration projects can often work as sites of public engagement and genuine dialogue between various actors. IHSMAG shows that it is possible to use demonstration

projects to mobilize a very positive political dialogue between local authorities, industry and market actors and citizens regarding issues such as sustainability, renewable energy and the smart, relevant uses of smart grid technologies.

Dissemination to non-academic actors

In addition to an extensive dissemination of the project results to academic audiences through PhD theses and journal/conference papers, IHSMAG also included a number of activities aimed at dissemination to non-academic audiences:

- National workshops with key actors within the smart grid field (e.g. DSOs, energy suppliers, regulators etc.) in the three countries. For example, the overall results of the IHSMAG project (the WP5 results) were presented at a Danish workshop in November 2015 with participation from Danish DSOs, the Danish Energy Agency, the Danish TSO and a Danish electric vehicle operator (in addition to a number of researchers). The workshop worked both as dissemination and as an opportunity for dialogue and getting input to our work with finalizing the overall recommendations and design criteria.
- Throughout the project, there has been continuous dialogue with the non-academic partners involved in the project and the studied demonstrations (in Denmark: SE and CLEVER).
- Results have been presented at national and international conferences and meetings. An example of an international conference, including also representatives from energy authorities and energy sector companies, is the ECEEE (European Council for an Energy Efficient Economy) summer study conference in France, where three papers have been presented (Christensen et al. 2013b; Friis & Gram-Hanssen 2013; Throndsen 2013).
- In addition, the results of IHSMAG have been presented to a broader audience through the following activities (done by SBi):
    - Gram-Hanssen, K.: *Consumers in the smart city*. TEchnoport Talks. 18 February 2013. Link to video: https://youtu.be/HW14qkgfMoQ
    - Friis, F.: *Integration af smart grid teknologier i et hverdagslivsperspektiv: Hvordan påvirker elbiler og dynamiske nettariffer husholdningernes hverdagsliv?* Presentation at CLEVER’s midway seminar at Trafikstyrelsen. 13 April 2013.
    - Christensen, T. H.: *Smart grid teknologier i husholdninger: Elbilen som eksempel*. Presentation at meeting in Smart City Netværket, Kalundborg, 15 May 2014.
    - Christensen, T. H.: *Fremtidens smart grid teknologier set fra et hverdagslivsperspektiv*. Presentation at Fremtidens Energi, Aarhus, 22 September 2014.
    - Christensen, T. H.: *Energiløsninger tilpasset brugernes hverdagspraksis*. Presentation at Green Cities Efterårskonference, Allerød, 23 October 2014.
    - Gram-Hanssen, K.: *Husholdningers rolle i smart grid – visioner og realiteter*. Presentation at meeting in Smart City Netværket, Kalundborg, 15 May 2014.
    - Christensen, T.H. (2015): *Energibesparelser hos borgerne – hvad og hvordan?* Presentation at Kommunernes Energinetværk, 3 February 2015, Nyborg.
    - Christensen, T.H. (2015): *Husholdningernes rolle i et ”intelligent energisystem”: Erfaringer fra IHSMAG projektet*. Presentation at Miljøstrategisk Årsmøde 2015, 16 November 2015, København.
- Finally, a website was developed early in the project period with general information about IHSMAG and access to the WP reports: http://sbi.dk/ihsmag

In addition to the above (primarily non-academic) dissemination, IHSMAG has also been involved in setting up two workshops at international (research) conferences with focus on energy transition-related issues. Here, results from IHSMAG were presented (along with presentations from other researchers). These two workshops (sessions) were:

1. The workshop *Sustainable consumption, practices and devices* in connection with the *Nordic Environmental Social Science (NESS) Conference 2015* June 9-11, 2015 in Trondheim. The workshop was organized in collaboration between Toke Haunstrup Christensen (SBi) and Tomas Moe Skjølsvold (NTNU). Papers based on both the Danish and Norwegian research in IHSMAG were presented at the workshop.

2. The workshop *A social practice perspective of the smart grid* was organised by Toke Haunstrup Christensen (in collaboration with Cecilia Katzeff og Annelise de Jong from *Interactive Institute Swedish ICT*) in connection with the *EnviroInfo & ICT4S 2015 Conference* September 6-9, 2015 in Copenhagen. The workshop was organised as an open discussion on basis of short presentations from all participants.

Project-related publications

Here follows a list of all the publications related to IHSMAG.

WP Reports

Christensen, Toke Haunstrup; Ascarza, Ainhoa; Throndsen, William (2013a): "Country-specific factors for the development of household smart grid solutions: Comparison of the electricity systems, energy policies and smart grid R&D and demonstration projects in Spain, Norway and Denmark." Danish Building Research Institute (Aalborg University), Tecnalia (Spain), Norwegian University of Science and Technology. (WP1 Report)

Skjølsvold, Tomas Moe; Ryghaug; Throndsen, William (2016): "Developing the smart grid: Perspectives on the integration with the electricity system, regulation aspects and households." Norwegian University of Science and Technology. (WP2 Report)

Friis, Freja; Christensen, Toke Haunstrup; Gram-Hanssen, Kirsten (2016): "Smart grid solutions in the everyday life of households: Electric vehicles and time-of-use pricing". Danish Building Research Institute (Aalborg University). (WP3 Report)

Riaño Fernandez, Sandra & Sanchez Perez, Eutimio (2015): "Technological challenges and solutions at the household level: Practical approach - development of user interface". Tecnalia (Spain). (WP4 Report).

Christensen, Toke Haunstrup; Friis, Freja; Ryghaug, Marianne; Skjølsvold, Tomas Moe; Throndsen, William; Riaño Fernandez, Sandra; Sanchez Perez, Eutimio (2016): "Recommendations and criteria for the design of smart grid solutions for households: Lessons learned for designers and policy makers from the IHSMAG project." Danish Building Research Institute (Aalborg University), Tecnalia (Spain), Norwegian University of Science and Technology. (WP5 Report)

PhD Theses

Friis, Freja (2016): *Integrating smart grid solutions within everyday life: A study of household practices in relation electric vehicles and time-of-use pricing*. PhD Thesis. Copenhagen: Danish Building Research Institute, Aalborg University. [To be defended in September 2016]

Throndsen, William (2016): *Response and Responsibility. Smart meters, end use, and the possibility of a green material public.* Doctoral thesis at Norwegian University of Science and Technology, 2016:17

Journal and conference papers (peer-reviewed)

Christensen, Toke Haunstrup; Ascarza, Ainhoa; Throndsen, William; Gram-Hanssen, Kirsten; Friis, Freja (2013b): The role of households in the smart grid: A comparative study. Paper for the *ECEEE 2013 Summer Study*, 3–8 June 2013, Belambra Presqu'île de Giens, France.

Christensen, Toke Haunstrup: Gram-Hanssen, Kirsten; Friis, Freja (2012): Households in the smart grid – existing knowledge and new approaches. Paper for the *2nd Nordic Conference on Consumer Research*, 30 May – 1 June 2012, Gothenburg, Sweden.

Christensen, Toke Haunstrup; Gram-Hanssen, Kirsten; Friis, Freja (2013c): Households in the smart grid – existing knowledge and new approaches. In: Hansson, L., Holmberg, U.,

Brembeck, H. (Eds.) Making Sense of Consumption. Selections from the 2^{nd} *Nordic Conference on Consumer Research* 2012, p. 333-348. Göteborg: University of Gothenburg.

Friis, Freja (submitted): Making sense of electric vehicle driving: Examining interventions in mobility practices.

Friis, Freja and Christensen, Toke Haunstrup (2016): The challenge of time shifting energy demand practices: Insights from Denmark. *Energy Research & Social Science* 19: 124-133.

Friis, Freja; Gram-Hanssen, Kirsten (2013): Integration of smart grid technologies in households - how electric vehicles and dynamic pricing change social practices in everyday life. Paper for the *ECEEE 2013 Summer Study*, 3–8 June 2013, Belambra Presqu'île de Giens, France.

Jørgensen, Susanne; Skjølsvold, Tomas Moe; Marianne Ryghaug (Forthcoming). Between empowerment and alienation. How feedback technologies can harm the prospects of successful energy transitions. *Energy Research & Social Science*.

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

Skjølsvold, Tomas Moe; Lindkvist, Carmel (2015): Ambivalence, designing users, and user imaginaries in the European smart grid: Insights from an interdisciplinary demonstration project. *Energy Research & Social Science* 9: 43-50.

Skjølsvold, Tomas Moe; Ryghaug, Marianne (2015): Embedding "smart" energy technology in built environments. A comparative study of four smart grid demonstration projects. *Indoor and Built Environment* 24(7): 878-890.

Skjølsvold, Tomas Moe; Ryghaug, Marianne; Berker, Thomas (2015): A traveller's guide to smart grids and the social sciences. *Energy Research & Social Science* 9 (September): 1-8.

Throndsen, William (2013): Constructing the Norwegian smart grids: To fix what is not broken? Paper for the *ECEEE 2013 Summer Study*, 3–8 June 2013, Belambra Presqu'île de Giens, France.

Throndsen, William (2016): What do experts talk about when they talk about users? Expectations and imagined users in the smart grid. *Energy Efficiency*. Online first: http://dx.doi.org/10.1007/s12053-016-9456-5

Throndsen, William; Ryghaug, Marianne Ryghaug (2015): Material participation and the smart grid: Exploring different modes of articulation. *Energy Research & Social Science* 9 (September): 157-165.

Journal and conference papers and master theses (not peer-reviewed)

Christensen, Toke Haunstrup (2014): The role of learning and social interaction for changing practices. Paper for the workshop "A Social Practice Perspective on the Smart Grid" at the *ICT for Sustainability ICT4S 2014 Conference*, 24-27 August 2014, Stockholm, Sweden.

Christensen, Toke Haunstrup; Friis, Freja (2016): Materiality and automation of household practices: Experiences from a Danish time shifting trial. Paper for the *DEMAND Centre Conference,* 13-15 April 2016, Lancaster, UK.

Frøysnes, Ane (2014): *Bare en jævla boks? En analyse av visjonsarbeidet knyttet til Avanserte måle- og styringssystemer (AMS)* ["Just a damn box? An analysis of visions work related to advanced metering"]. MA-thesis. Trondheim: Dept. of interdisciplinary studies of culture, NTNU.

Jørgensen, Susanne (2015): *Smart strøm – dumme kunder?* ["Smart electricity – stupid customers?"]. MA-thesis, Dept. of interdisciplinary studies of culture, NTNU

1.6 Utilization of project results

Due to the character of the results of IHSMAG, these are not going to feed directly into existing commercial or business activities as such (through patents or the like). But through the dissemination to both academic and non-academic audiences and the direct collaboration with the non-university partners of IHSMAG, the main findings, conclusions and recommendations of this project will become part of the "knowledge foundation" for commercial actors such as DSOs and energy suppliers (e.g. SE) and other smart grid operators (e.g. CLEVER). In this way, the results will contribute to the design of more comprehensive and successful smart grid solutions that are more likely to "work-in-practice".

Also, the results of IHSMAG will be an input for the policy-making and regulation within the electricity and smart grid area, which – hopefully – can contribute to set up the frames for a more efficient development of the smart grid area.

Results of IHSMAG will be used in teaching activities at both NTNU and SBi/AAU. At SBi/AAU, results have already been integrated in the international master *Sustainable Cities* at AAU-Copenhagen.

1.7 Project conclusion and perspective

It is, almost by definition, difficult to condense a multi-disciplinary study like IHSMAG, which aims to cover technical as well as everyday life and system-regulatory aspects, into a few, concluding sentences. In a way, the overall key observations and (policy) implications of IHSMAG have already been presented previously through the list of recommendations and design criteria developed in WP5, which synthesised the outcome of WP1-4.

Therefore, instead of repeating these recommendations – and the key learnings from WP1-4 described in section 1.5 – we will conclude the Final Report with some more overall observations and conclusions.

First of all, we believe that IHSMAG has demonstrated the strength of combining various perspectives and disciplines in a cross-country study. Through doing this, IHSMAG has been able to develop (we believe) robust insights and recommendations on basis of a detailed and nuanced analysis of the studied trials and demonstrations. The cross-country comparison also makes it possible to identify which dynamics or characteristics that are particular to a specific country (or even region) and which are of a more general/generic type. For example, we found that the focus on Demand-Side Management and time shifting of electricity consumption was more widespread in some countries (Denmark in particular) than in others (Norway in particular). This seems partly related to the differences in energy mix and sources between the countries. The recommendations developed in WP5 in particular focused on the key dynamics that were common across countries.

IHSMAG demonstrates that it is, indeed, a complicated and challenging task to develop and implement household smart grid solutions that are successful and work under "real-life conditions". Many trials and demonstrations have (partly) failed in doing this – even to some degree some of the studied trials and demos in IHSMAG – and the future will most likely bring many more examples of solutions and demonstrations with limited effect. At the same time, IHSMAG also demonstrates that there are real potentials for involving households in the "big energy transition". In some cases, households even appear to be much more willing and eager to getting involved than many smart grid designers and companies seem to believe. Some of the studied demonstrations illustrate this.

However, one of the main barriers here seems to be that smart grid designers and companies are primarily approaching the households on basis of rather simple understandings of the consumers as mainly driven by economic incentives. And sometimes also quite naïve understandings about how eager the households will be in detailed and minutious monitoring and optimisation of their own energy consumption etc. Rather, smart grid designers and companies should look at the households more like "energy citizens" than as "pure consumers" that are primarily driven by maximising their (individual) utility and financial gains. IHSMAG shows that household members are much more occupied by whether participating in a smart grid solution is a “meaningful activity” (for themselves, their family, their local community or the country and globe in general) than solely judging whether “there-is-something-in-it-for-me”. Widening the understanding of households (and how to involve and collaborate with them) would be an important first step towards designing solutions that will work in practice.

Annex

The following annex includes the five reports developed in relation to WP1-WP5:

- Country-specific factors for the development of household smart grid solutions (WP1)
- Developing the smart grid (WP2)
- Smart grid solutions in the everyday life of households (WP3)
- Technological challenges and solutions at the household level (WP4)
- Recommendations and criteria for the design of smart grid solutions for households (WP5)

The reports can also be downloaded as pdf’s from: http://sbi.dk/ihsmag/publications

Country-specific factors for the development of household smart grid solutions

Comparison of the electricity systems, energy policies and smart grid R&D and demonstration projects in Spain, Norway and Denmark

Toke Haunstrup Christensen
Danish Building Research Institute, Aalborg University

Ainhoa Ascarza
Tecnalia, Spain

William Throndsen
Norwegian University of Science and Technology

July 2013

Report from the ERA-Net SmartGrids project “Integrating households in the smart grid” (IHSMAG) – www.ihsmag.eu

Content

1. Introduction

This report is an outcome of the project *Integrating Households in the Smart Grid* (IHSMAG), which involves partners from Norway, Denmark and the Basque Country (Spain). The aim of IHSMAG is to contribute with knowledge of how to develop comprehensive designs of smart grid solutions that involve households in the smart grid. On the basis of experiences and results from a number of demonstration projects in Norway, Denmark and the Basque Country, the project explores how household smart grid solutions depend on household technologies, everyday practices and the overall electricity system and regulation. The IHSMAG project runs from January 2012 to December 2014 and is supported by the 2nd ERA-Net Smart Grid Joint Call.[1]

The aim of this report is to provide an overview of relevant country-specific factors in relation to understanding the context of the development of smart grid solutions in each of the three participating countries (e.g. main characteristics of the energy system) and to give an overview of the current status of activities in relation to smart grid solutions in households. In this way, the survey also serves as a common ground for the later synthesis of the country-specific results of the IHSMAG project (especially in relation to the development of design criteria for household smart grid solutions and policy recommendations). Understanding the differences and similarities between the three countries is important when evaluating whether the country-specific results and insights are “transferable” between the countries. The report is based on contributions from the Danish Building Research Institute (Aalborg University), Tecnalia in the Basque Country and Department of Interdisciplinary Studies of Culture (Norwegian University of Science and Technology).

Section 2 presents the main characteristics of the existing energy systems of the three countries (with a primary focus on the electricity system). This includes information about the share of renewable energy, the temporal pattern of electricity consumption and the roll-out of an advanced metering infrastructure (“smart meters”). Section 3 gives an overview of the national policies and regulation in relation to the electricity system and smart grid. Finally, section 4 presents a brief survey of the national smart grid research & development (R&D) and demonstration activities related to households in the three countries.

---

[1] For more information about the IHSMAG project, see the website: www.ihsmag.eu

2. The energy system – with particular focus on the electricity system

This section presents a number of characteristics of the energy systems – and particularly the electricity systems – of Denmark, Norway and Spain[2]. The presentation focuses mainly on statistics on the overall energy system, residential final electricity consumption, load profiles and electricity prices.

2.1 General overview and development within last 20 years

Overall energy system

Table 1 shows key figures on population, Gross Domestic Product, supply and consumption of energy and CO_2 emissions for 1990 and 2009 for Spain, Norway and Denmark.

Table 1: Key figures on population, GDP, energy supply & consumption and CO_2 emission for 1990 and 2009.

	Spain		**Norway**		**Denmark**	
	1990	2009	1990	2009	1990	2009
Population (millions)	39.0	45.9	4.2	4.8	5.1	5.5
Gross Domestic Product (billion 2000 USD)	441	713	117	196	124	168
Total primary energy supply TPES[1] (TWh)	1048	1471	244	328	202	216
TPES/population (kWh/capita)	26,865	31,983	57,569	68,036	39,309	39,193
Electricity generated[2] (TWh)	151.2	291.0	121.6	132.0	26.1	36.4
Net electricity import[3] (TWh)	-0.5	-8.1	-15.9	-9.0	7.1	0.4
Total final consumption TFC[4] (TWh) of energy	706	1073	203	231	153	165
Total final consumption (TFC) of electricity (TWh)	125.8	255.4	96.8	105.3	28.4	31.6
Electricity share of total final consumption – per cent	18%	24%	48%	46%	19%	19%
TFC electr./population (kWh/capita)	3,226	5,562	22,835	21,827	5,520	5,721
CO_2 emissions total[5] (Mt CO_2)	205.8	283.4	28.3	37.3	50.4	46.8
CO_2 emission/population (tons/capita)[5]	5.3	6.2	6.7	7.7	9.8	8.5
CO_2 emission/kWh, electr. and heat generation (g/kWh)[6]	427	299	3	17	477	303

[1] Total primary energy supply (TPES) is made up of the sum of domestic energy production and energy imports minus energy exports and international marine/aviation bunkers (the figure is also corrected for changes in stock of energy, e.g. oil). Notice that primary energy is the energy input *before* conversion/transformation to other energy forms (e.g. the input of embodied energy in coal used in power plants).
[2] Electricity generated is the gross production of electricity, excluding the amount of electricity produced in pumped storage plants
[3] Net electricity import is the total import of electricity minus total export. Negative figures represent net export of electricity (i.e. a situation with larger annual electricity export than annual import)
[4] Total final consumption (TFC) is the sum of consumption by the different end-use sectors.
[5] CO_2 emissions from fuel combustion (all sectors, including transport, industry etc.)
[6] The CO_2 emissions per kWh for electricity *and* heat generation
Sources: IEA 2011a: p. IV.250-IV.251 (Denmark), p. IV.538-539 (Norway) and p. IV.628-629 (Spain). On CO_2 emissions (total emissions and emissions/capita): IEA 2011b: xix, II.55, II.67.

[2] As the Spanish electricity system is an integrated system, we do not focus specifically on the Basque Country.

Table 1 shows that the **total primary energy supply** (TPES) has increased over the period 1990-2009 for all countries. The increase has been most significant for Spain (40%) and Norway (34%) and least for Denmark (7%). If **related to the size of the population** (TPES/population), Table 1 shows that for all countries, part of the increase can be explained by an increase in the population size. Thus, the increase in total primary energy supply *pr. capita* is 19% for Spain and 18% for Norway, i.e. about half of the increase in TPES. For these two countries, about half of the increase in TPES can be explained by the increased population. For Denmark, the per capita total primary energy supply has been more or less stable, which means that the (relative small) increase in the Danish TPES mainly can be ascribed to an increase in the population size. Furthermore, the increase in TPES might also relate to general increases in the level of consumption (including energy consumption) and production, which is reflected in the overall increase in the countries' **Gross Domestic Product** (GDP) over the period. Spain and Norway have had remarkable high GDP growth rates (62% and 68%, respectively), while the Danish GDP has shown a modest growth rate (35%).

There are also a number of other reasons why the Danish TPES has shown a less significant growth rate than the Norwegian and Spanish: First of all, there has been a general shift from electricity production based on traditional condensing power plants to combined heat and power (CHP) plants, which has increased the overall efficiency of the energy system due to the utilization of heat for district heating. Secondly, the share of electricity production based on wind power has increased markedly, which also contributes to lower primary energy supply (as the primary energy input equals the output of electricity for wind power). Other explanations include higher energy efficiency, lower energy consumption for industry and manufacturing etc. (Danish Energy Agency 2011)

The TPES/population figures furthermore show some interesting differences between the countries with regard to the **size of total primary energy supply pr. capita**: In 2009, the TPES per capita in Norway was twice the size of the TPES per capita for Spain (68 MWh versus 32 MWh) and also significant larger than the Danish TPES per capita (39 MWh). In relation to this, it is interesting to notice that even though the TPES/population is much lower in Spain than in Norway, the 1990-2009 increase in TPES/population of the two countries are nearly the same. Starting from a much higher level, one might have expected a lower increase for Norway than for Spain. However, as mentioned before, a significant share of the TPES/population increase in the two countries might be correlated with the remarkable high growth rates (compared to Denmark) in the Gross Domestic Product (GDP) over the period.

The **electricity generation** has been increasing in all countries. However, the increase has been most marked in Spain, where the electricity generation has almost doubled (92%), while the increase in Denmark has been 40% and in Norway only 9%. The increase in electricity generation in Spain has mainly been covered by increasing the natural gas-based electricity generation and, to a less extent, wind power generation. Also, the **total final consumption (TFC) of energy** has increased in all countries; most in Spain (52%) and least in Norway (14%) and Denmark (8%). Similarly, the **total final consumption (TFC) of electricity** has been increasing in all countries; again most markedly in Spain (103%) and with lower growth rates in Norway and Denmark (9% and 11%, respectively). However, worth of notice, the increase in the Spanish TFC of electricity actually peaked in 2007 and 2008 (reaching about 260 TWh/year), and the 2009-figure therefore represents a decline compared to 2007/2008. More details on the development in the countries' electricity consumption follow later in this section.

The **electricity share of the total final consumption (TFC) of energy** is significant higher in Norway (46% in 2009) as compared with Spain (24%) and Denmark (19%). This relates to the high availability of hydropower in Norway and, therefore, the historical focus on electricity as a primary energy source for households (e.g., electric heating is widespread in Norway). In 2009, nearly 96% of the electricity generated in Norway came from hydropower (see Table 3). The widespread use of electric heating is also an important part of the explanation why the **electricity consumption per capita** in Norway is almost four times that in Spain and Denmark. Furthermore, the hydropower-based electricity production of Norway explains the very low **CO_2 emission per kWh** for Norway as compared with Spain and Denmark. However, it is interesting to notice that if including *all* CO_2 emissions from fuel combustion (including transport, industry etc.), the Norwegian **CO_2 emission per capita** is actually not much different from the figures of Spain and Denmark (25% higher than in Spain and 9% lower than in Denmark). This is mainly due to a relative high emission related to energy industries (see Table 2), which represent about one quarter of the total Norwegian CO_2 emissions (Konkraft 2009).

While the CO_2 emission per capita has been increasing in both Spain and Norway (17% and 16%, respectively), it has decreased by 14% in Denmark from 1990 to 2009. This is mainly due to an increased share of wind power (from 2% in 1990 to 18% in 2009), which has replaced generation based on fossil fuels.

Table 2: CO_2 emission from fuel combustion by sectors in 2009 (Mt CO_2)

	Spain	**Norway**	**Denmark**
Total CO_2 emission from fuel combustion	283.4	37.3	46.8
- electricity and heat production	87.0 (31%)	2.4 (6%)	22.0 (47%)
- other energy industry own use[1]	17.5 (6%)	11.4 (31%)	2.4 (5%)
- manufacturing industries and construction	47.3 (17%)	6.6 (18%)	3.8 (8%)
- transport	100.5 (35%)	13.5 (36%)	13.1 (28%)
- other sectors	31.2 (11%)	3.4 (9%)	5.5 (12%)

[1] Includes emissions from fuel combustion in oil refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries

Source: IEA 2011b: p. II.25.

Table 2 shows great differences between the three countries with regard to the distribution of CO_2 emissions from fuel combustion by sectors. While the production of heat and electricity accounts for almost half of the total Danish CO_2 emissions, this accounts for only 6% in Norway and 31% in Spain. On the other hand, the share of CO_2 emissions from “other energy industry” is five times higher in Norway compared with Spain and Denmark (due to the extensive oil production in Norway). Furthermore, both transport and manufacturing industries/construction account for a smaller share in Denmark than in Spain and Norway.

These figures show that the three countries face different challenges in relation to reducing CO_2 emissions. While electricity/heat production and transport represent the major contributors to the Spanish and Danish CO_2 emissions, the major sources of CO_2 emissions in Norway are related to transport (as well) and other energy industry (oil production).

Energy sources for electricity generation

The countries differ much with regard to the sources of energy for electricity production, as shown by the following table and figure (Table 3 and Figure 1).

Table 3: Gross electricity production by source of primary energy (TWh).

	Spain			**Norway**			**Denmark**		
	1990	2000	2009	1990	2000	2009	1990	2000	2009
Gross production (TWh)	**151.9**	**224.5**	**293.8**	**121.8**	**140.1**	**132.8**	**26.0**	**36.1**	**36.4**
- nuclear	54.3	62.2	52.8	-	-	-	-	-	-
- hydro	26.2	31.8	29.2	121.4	139.4	127.1	0.0	0.0	0.0
- geothermal	-	-	-	-	-	-	-	-	-
- solar	0.0	0.0	6.0	-	-	-	-	-	-
- tide, wave , ocean	-	-	-	-	-	-	-	-	-
- wind	0.0	4.7	37.8	-	0.0	1.0	0.6	4.2	6.7
- combustible fuels	71.4	125.7	167.8	0.3	0.6	4.7	25.3	31.7	29.6
coal	*60.7*	*80.9*	*37.2*	*0.1*	*0.1*	*0.1*	*23.6*	*16.7*	*17.7*
oil	*8.6*	*22.6*	*19.0*	*0.0*	*0.0*	*0.0*	*0.9*	*4.4*	*1.2*
natural gas	*1.5*	*20.2*	*107.4*	-	*0.2*	*4.2*	*0.7*	*8.8*	*6.7*
biofuels & waste	*0.7*	*2.1*	*4.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.9*	*4.0*
- other (e.g. fuel cells)	-	-	0.3	0.1 e	0.1 e	0.1	-	0.0	-

Note: Gross electricity production is measured at the alternator terminals, and thus includes losses and own use of power in power stations and in transformers.
Source: IEA 2011a: p. IV.251 (Denmark), p. IV.539 (Norway) and p. IV.629 (Spain)

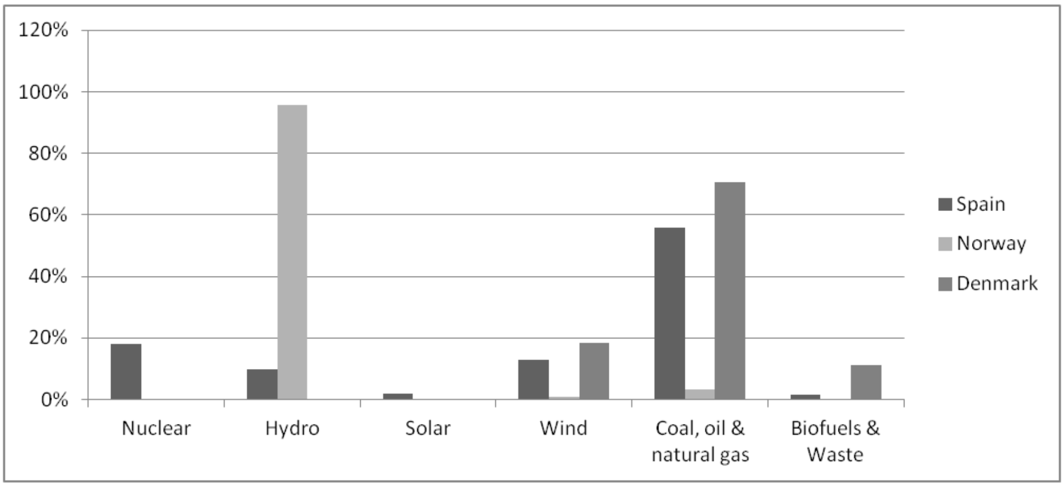


Figure 1: Distribution of 2009 electricity production by source of energy (based on data in Table 3)

The Norwegian electricity production is almost entirely based on hydropower (96%) and only a little share of wind power and fossil fuels. Compared to Norway, the electricity production is far more diversified in Denmark and (particularly) Spain. Thus, the Spanish electricity production includes all six categories of energy sources in Figure 1. A little more than half (56%) of the Spanish electricity production is based on coal, oil & natural gas, while nuclear power represents 18%, wind 13%, hydropower 10%, solar power 2% and biofuels/waste 1%. In Denmark, almost three quarters (71%) of the electricity is generated on the basis of coal, oil & natural gas. Wind power represents about 18% and biofuels & waste 11%.

With regard to how the electricity is produced, it should be noticed that in Denmark and Spain, a considerable part of the electricity production is based on either condensing power/combined heat and power plants or combined-cycle gas turbine plants (approx. 75% in Spain and approx. 82% in Denmark, while only approx. 3% in Norway). Electricity production based on condensing power/CHP plants is in general relatively inflexible for short-term changes (particularly for larger plants). Thus, the Spanish and particularly the Danish electricity systems are less flexible for short-term changes in electricity production from intermittent renewable energy resources compared with the Norwegian system, which has a high share of flexible hydropower production

However, as a considerable part of the Spanish electricity production is based on relatively flexible natural gas-fired combined-cycle plants, and to some degree also flexible hydropower, these can work as a backup source for intermittent renewable energy. In 2010, combined-cycle gas turbines represented 26% of the installed power capacity compared with 18% installed hydropower capacity (REE 2010). In general, the stop and start-up costs related to regulation of hydropower (and wind power) are lower compared to nuclear power and natural gas plants.

The Danish combination of a high share of electricity production based on relatively inflexible condensing/CHP plants and a high share of intermittent wind power production is one of the major reasons for the particular focus on load management in the Danish smart grid discussion and R&D projects (as showed later). Today, the Nordic electricity market Nord Pool Spot (which includes Denmark, Norway, Sweden, Finland, Estonia, Latvia and Lithuania) provides much of the regulating power needed to balance the consumption and generation side of the Danish electricity system (especially the exchange with Norway is important). However, with an increasing share of wind power, other supplementary solutions will be needed.

Final energy consumption by sectors

Table 4 and Figure 2 show the total final consumption (TFC) of energy by sectors.

Table 4: Total Final Consumption (TFC) of energy by sectors (Mtoe = Mega ton of oil equivalents)

	Spain			**Norway**			**Denmark**		
	1990	2000	2009	1990	2000	2009	1990	2000	2009
TFC (Mtoe)	60.74	85.48	92.29	17.44	19.80	19.85	13.17	14.23	14.22
- industry	19.39	24.72	23.35	6.03	6.94	5.59	2.69	2.94	2.33
- transport	21.28	30.21	34.44	3.41	4.06	4.65	3.45	4.03	4.41
- commercial & publ. serv.	3.41	6.70	9.11	2.04	2.12	2.57	1.72	1.83	1.97
- residential	9.15	11.88	14.89	3.60	3.82	3.99	4.00	4.16	4.40
- agriculture & fishing	1.66	2.56	2.54	0.51	0.77	0.79	0.99	0.96	0.85
- other	-	0.00	0.81	-	-	0.08	0.01	0.01	0.01
- non-energy use	5.84	9.40	7.15	1.84	2.08	2.17	0.30	0.30	0.25

1 Mtoe = 11.63 TWh = 41,868 TJ

Source: IEA 2011a: p. IV.259-260 (Denmark), IV.548 (Norway) and IV.636-637 (Spain).

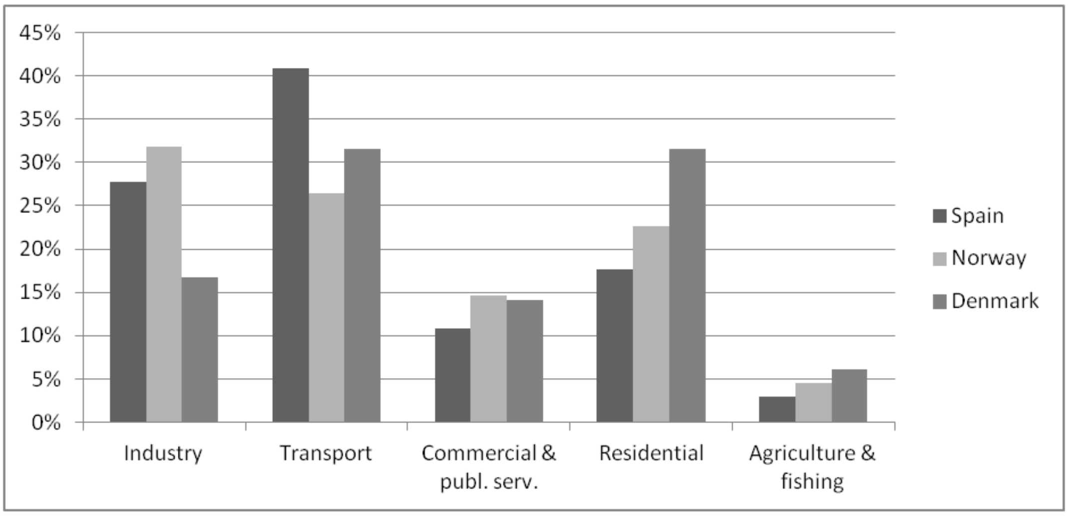


Figure 2: Distribution of 2009 Total Final Consumption (TFC) of energy by sectors (based on Table 4)
Note: “Other” and “Non-energy use” not included.

The distribution by sectors varies between the three countries, particularly with relation to industry, transport and the residential sector (notice that transport by households is included in “Transport” and not in “Residential”, which primarily includes electricity consumption and heating). The residential sector accounts for 32% of TFC in Denmark and only 18% in Spain (23% in Norway). More than 40% of TFC in Spain is related to transport, whereas the figure for Norway is only 26% (32% in Denmark). Finally, the industry sector accounts for 28-32% of TFC in Spain and Norway and only 17% in Denmark. The high share of energy consumption within the industry sector is among the reasons for a particular focus in Norway on implementing load management within the industry sector.

Turning focus to electricity consumption only, the following Table 5 and Figure 3 show the distribution of the total final electricity consumption by sectors.

Table 5: Total final electricity consumption by sectors (TWh)

	Spain			Norway			Denmark		
	1990	2000	2009	1990	2000	2009	1990	2000	2009
Total final electricity consumption (TWh)	125.8	188.5	255.4	96.8	109.5	105.3	28.4	32.5	31.6
Industry	63.3	85.6	94.3	45.8	51.6	42.1	8.4	10.0	8.5
Transport	3.7	4.2	3.1	0.7	0.6	0.7	0.2	0.3	0.4
Commercial & publ. serv.	25.1	50.0	79.9	19.4	20.6	24.1	8.3	9.9	10.7
Residential	30.2	43.6	69.5	30.3	34.6	36.4	9.7	10.2	10.1
Agriculture & fishing	3.5	5.0	5.7	0.7	2.1	2.1	1.7	1.9	1.9
Sector non specified	-	-	2.9	-	-	-	-	-	-

Source: IEA 2011a: p. IV.251 (Denmark), IV.539 (Norway) and IV.629 (Spain).

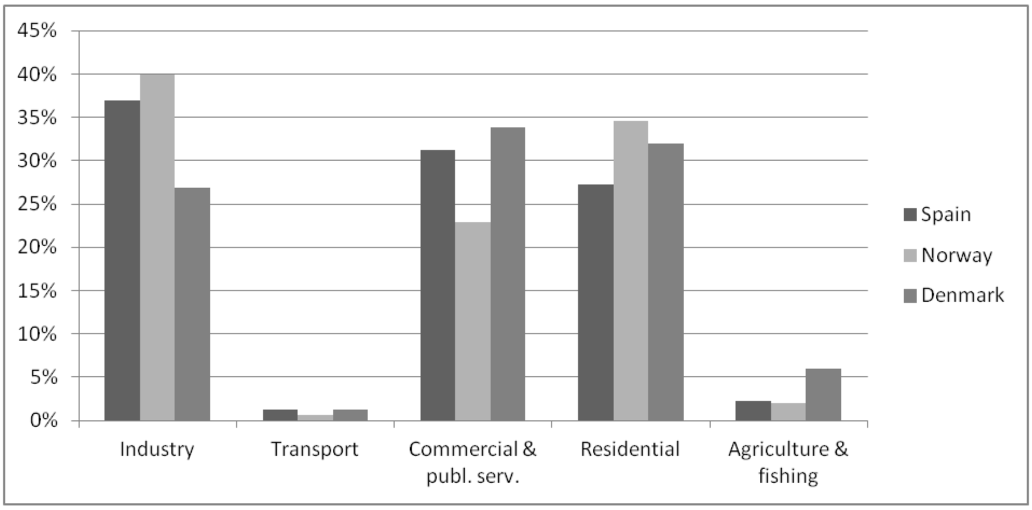


Figure 3: Distribution of 2009 total final electricity consumption by sectors (based on Table 5)

In Denmark, the industry sector accounts for only 27% of the final electricity consumption compared with 40% in Norway and 37% in Spain (2009-figures, cf. Figure 3). This probably reflects that industry and manufacturing have a less prominent role in the Danish economy than in Spain and Norway. For comparison, the commercial & public sector represents a higher share of the final electricity consumption in Denmark (34%) than in Spain (31%) and particularly Norway (23%). The same goes for agriculture & fishing.

With regard to the residential sector, this sector accounts for between 27% in Spain and 35% in Norway, with Denmark placed in the middle (32%).

As pointed out previously, the increase in the total final consumption of electricity for the period 1990-2009 has been particularly marked for Spain compared to Norway and Denmark. As shown in Table 5, the Spanish increase has been particularly marked within the commercial & public service sector (218% increase) and the residential sector (130% increase).

On the basis of the figures of the total final electricity consumption for the residential sector (Table 5), the total final consumption of electricity per capita can be calculated. Thus, in 2009, the average residential electricity consumption was 1,514 kWh/capita in Spain, 1,836 kWh/capita in Denmark and 7,583 kWh/capita in Norway. Interestingly, Spain and Denmark have more or less the same level of residential electricity consumption per capita, whereas the Norwegian consumption is about 4-5 times the Danish and Spanish consumption level. The primary reason for the high residential electricity consumption in Norway is the widespread use of electric heating in buildings and a high heating demand (see also next section).

Residential electricity consumption by final use

Table 6 shows the distribution of the residential final electricity consumption by final use categories for the three countries.

Table 6: Distribution of final residential electricity consumption by final use for Denmark, Norway and Spain.

	Denmark (2006)	**Norway** (2007)	**Spain** (2007)
Light	11%	9%	18%
Heating and power	59%	86%	64%
Cooking	8%	2%	15%
Heating (space and water)	18%	76%	18%
Fridge/freezer	18%	5%	18%
Laundry	15%	3%	10%
Air-conditioning	-	-	1%
Dishwasher	-	-	2%
Miscellaneous	30%	5%	18%
TV, video, stereo	12%	-	10%
PC	8%	2%	7%
Total	100%	100%	100%

Note (Danish figures): ”Laundry” includes dishwashers, washing machines and tumble dryers. Sources: Røpke et al. 2010 (Denmark) and Shandurkova 2011 based on results from the REMODECE project (Norway). Spanish data from “Practical guide: efficient energy consumption”, published by the Institute for Energy Savings and Diversification (IDAE), Ministry of Industry, Energy and Tourism.

As shown in Table 6, Norway has by far the highest percentage of residential final electricity consumption related to heating of space and water, which represents three quarters of the total electricity consumption. This is due to electric heating being the dominant heating form in Norwegian buildings. In comparison, the share of electricity used for heating is only 18% in Spain and Denmark.

When comparing the Norwegian percentages with the Danish and Spanish, it is important to bear in mind that the Norwegian final electricity consumption *per capita* is about four times higher than the Danish and five times higher than the Spanish. The difference is mainly due to the dominance of electric heating and the high heating demand due to the climatic conditions in Norway. Denmark has also a relatively high heating demand, but only 6% of Danish dwellings are heated by electricity (Statistics Denmark 2013). If heating is excluded from the Norwegian figures, the per capita electricity consumption is only about 1,800 kWh/capita, i.e. more or less the same level as in Denmark. But due to the differences in the per capita consumption, the Norwegian percentages for all other final uses (except heating) are relatively smaller than the Danish and Spanish figures.

The percentage of electricity related to lighting varies considerably between the countries, and if heating is excluded, the variations become even much higher: 13% for Denmark, 22% for Spain and 38% for Norway. This is interesting, as lighting is less suitable for load management compared with other final uses like heating or cooling.

Recognizing that some uses of electricity are more likely to be subject to load management than others, Table 6 can give an indication of the different potentials for load management in the three countries. By adding up the percentages of the final uses that might *potentially* be subject to time-shifting (in Table 6, this could be heating, cooling (fridge/freezer), laundering, air conditioning and dishwashing), the share of residential electricity consumption that could (ideally) be subject to some extent of load management would be: 51% for Denmark, 84% for Norway and 49% for Spain. Thus, Norway seems to have a higher potential for load management compared with Spain and Denmark, primarily due to the widespread use of electric heating. This also partly explains why, in Denmark, the smart grid debate with regard to load management focuses particularly on promoting the electrification of heating and transportation through households' increased use of heat pumps and electric vehicles. The aim of this is to increase the potential for load management.

Air conditioning represents a specific challenge in the case of Spain: Even though the electricity consumption for air conditioning is relatively low at the national level, the consumption in the southern regions is high and increasing. In regions with high penetration, it can represent 30% of the consumption during the summer peaks, which creates peak-capacity problems for the grid during warm periods. (Izquierdo et al. 2011)

Load profiles

Figure 4 shows a comparison of the electricity load profiles (all sectors) for Norway, Spain and Denmark on winter weekdays (Monday to Friday).

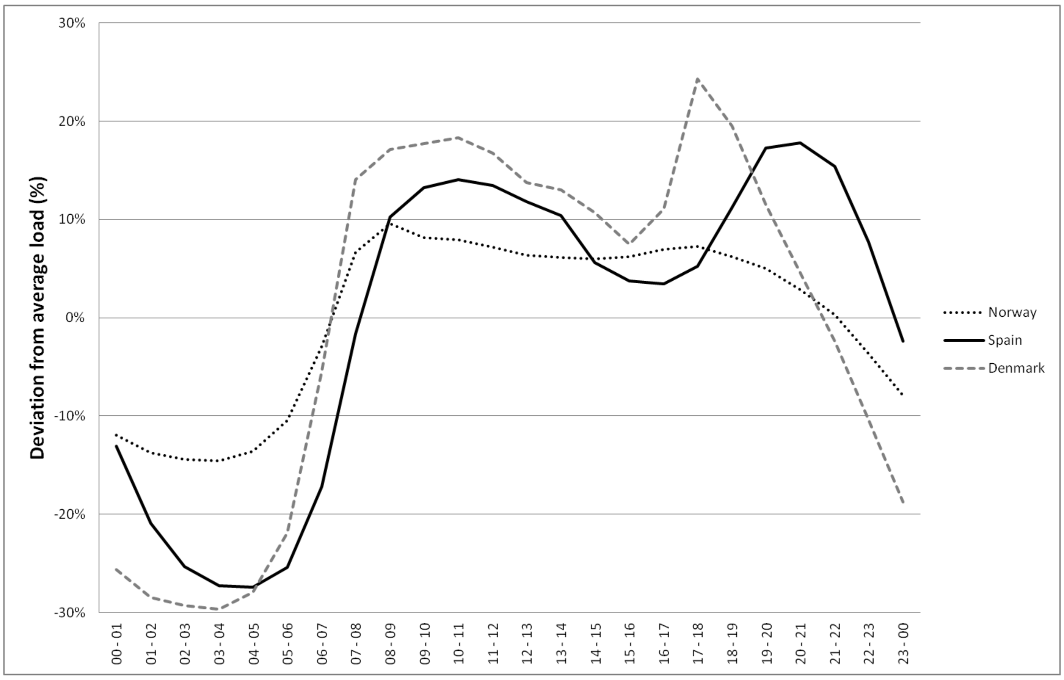


Figure 4: Comparison of load profiles for Norway, Spain and Denmark for weekdays in January 2012.

Note: For each country, the figure shows the hourly deviation (in per cent) of the electricity consumption (all sectors) from the average consumption per hour during five weekdays in January (Monday 23 January to Friday 27 January 2012). The average consumption per hour (MWh/hour) is 19,227 (Norway), 32,970 (Spain) and 4,641 (Denmark). Source: NordPool 2013 (Denmark and Norway) and REE 2013 (Spain).

Figure 4 shows a high degree of similarity between the Spanish and the Danish load profiles: Both follow a "two-peak pattern" during daytime and in both countries the difference between the peaks during daytime and the "dip" during the night is substantial. Thus, the maximum/minimum ratio of the energy consumption in Figure 4 is 1.62 for Spain and 1.77 for Denmark. In contrast, the Norwegian load profile is much more level and with less significant peaks during daytime; consequently, the difference between maximum and minimum is lower than for Spain and Denmark (the Norwegian maximum/minimum ratio is 1.28). This is mainly a result of about three quarters of the Norwegian electricity consumption being related to heating, which does not change as much in accordance with the daily practices of the households as in the case of electricity consumption related to other activities like cooking or laundering.

For comparison, Figure 5 shows the load profiles for summer weekdays (in June, a week before the summer holidays).

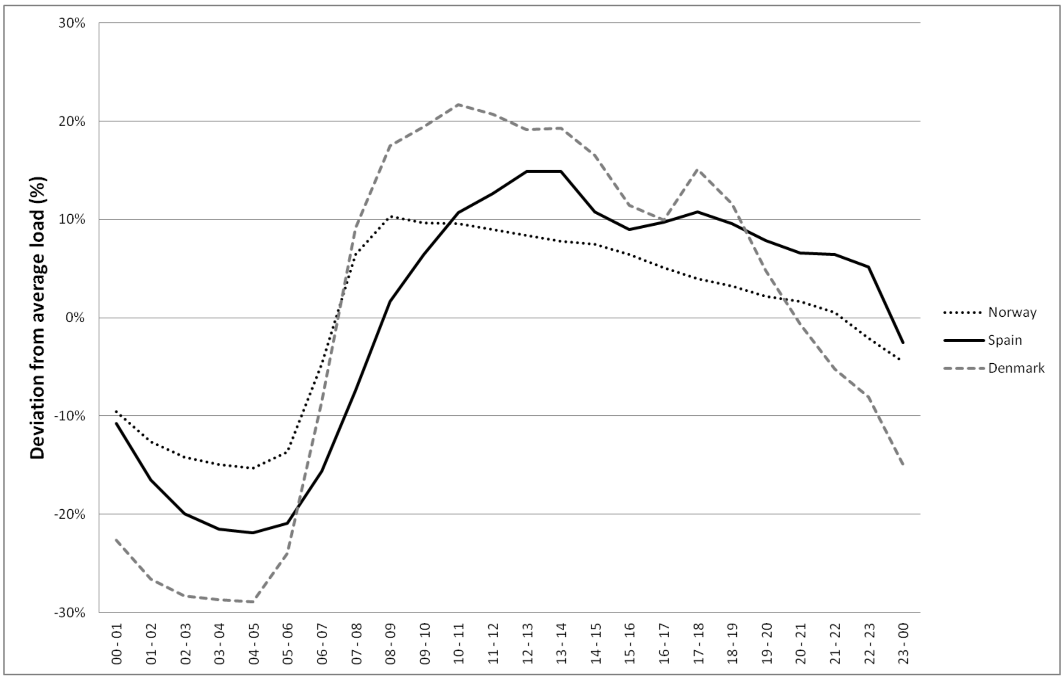


Figure 5: Comparison of load profiles for Norway, Spain and Denmark for weekdays in June 2012.

Note: The figure shows the hourly deviation for each country (in per cent) of the electricity consumption (all sectors) from the average consumption per hour during five weekdays in June (Monday 11 June to Friday 15 June 2012). The average consumption per hour (MWh/hour) is 12,082 (Norway), 29,351 (Spain) and 3,663 (Denmark).
Source: NordPool 2013 (Denmark and Norway) and REE 2013 (Spain).

Figure 4 and 5 show that the Danish and Spanish load profiles are more “smooth” during summer time compared to winter time. The Danish summer load profile still displays the two-peak pattern, but the late-afternoon peak is much less prominent in the summer load profile. In the case of Spain, the two-peak pattern is almost missing in the summer load profile. There is still a morning peak (which peaks a little later than during winter time), but the peak in the evening is much less significant. Also the Norwegian winter and summer profiles show some differences, but much less than in the case of Denmark and Spain.

While the average consumption per hour is only slightly lower during the summer for Denmark and Spain (21% lower for Denmark and 11% lower for Spain), the Norwegian summer average consumption per hour is more than one third lower than in the winter (37% lower). The great difference reflects the widespread use of electricity for heating during the winter.

In addition to Figure 4 and 5, Figure 6 shows the load profiles for weekdays during the *summer holidays*.

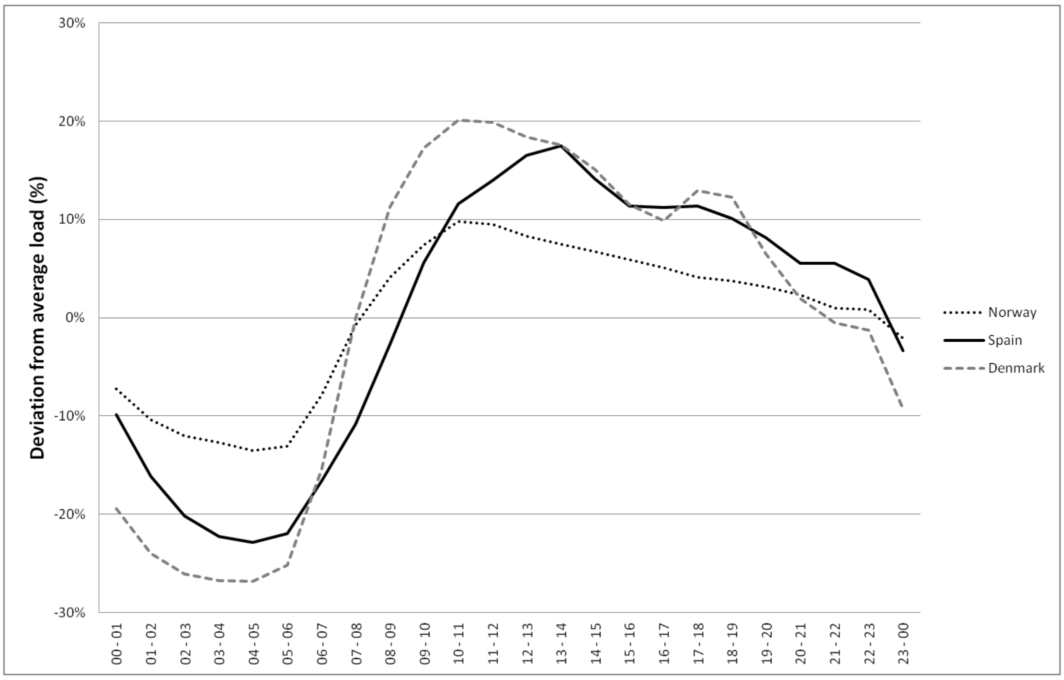


Figure 6: Comparison of load profiles for Norway, Spain and Denmark for weekdays in July 2012 (summer holidays)

Note: The figure shows the hourly deviation for each country (in per cent) of the electricity consumption (all sectors) from the average consumption per hour during five weekdays in July (Monday 23 July to Friday 27 July 2012). The average consumption per hour (MWh/hour) is 10,840 (Norway), 30,636 (Spain) and 3,175 (Denmark).
Source: NordPool 2013 (Denmark and Norway) and REE 2013 (Spain).

Figure 6 shows that during the summer holidays, the Danish and Spanish two-peak pattern is even less marked compared to ordinary summer weekdays (Figure 5); while there is still a peak in the morning (Denmark) or early afternoon (Spain), only the Danish profile shows a weak second peak in the late afternoon. But except from this, the differences between Figure 5 and 6 are not as marked as in the case of the differences between the winter and summer load profiles (Figure 4 and 5).

On a more general level, the above figures show the differences in relation to the challenges of load management, which appear to be greater for Denmark and Spain than for Norway. This is because a higher share of electricity consumption in Denmark and Spain is related to daily practices of morning or lunch activities or (in the case of the afternoon/evening peak) cooking practices and other activities related to coming home from work or educational activities. Thus, it seems difficult to change the timing of this consumption in Denmark and Spain as this would to a higher degree imply changes in the timing of daily routines than in the case of Norway, where a majority of the electricity consumption is related to heating, which has larger potentials for load management due to the thermal capacity of buildings. For the same reason, the Norwegian debate of load management in households mainly focuses on the potential for managing the heat demand, even though there is also some interest in possible future applications of load management that would arise from electrifying personal transport.

Electricity prices

Table 7 compares the retail (end-user) electricity prices for households. The prices include taxes and are from 2010 (2009 for Spain).

Table 7: End-user electricity prices for households in Spain, Norway and Denmark

	Spain	**Norway**	**Denmark**
Price (euro/kWh)	0.15	0.13	0.27
- of which tax	0.03	0.04	0.15

Source: IEA 2011a: IV.643 (Spain), IV.554 (Norway) and IV.266 (Denmark).

The table shows that Spain and Norway have almost the same price of electricity, while the electricity price in Denmark is about double. The main reason for this difference in price is the different taxation; taxes represent 56% of the electricity price in Denmark, but only 20% in Spain and 31% in Norway.

None of the three countries have a general roll-out of dynamic pricing schemes. In Denmark, it has for many years only been large customers (with an annual electricity consumption above 100,000 kWh) who have had the possibility of joining a dynamic pricing scheme. However, a smaller electricity supplier (SE) has recently started to offer their customers a dynamic pricing scheme based on the hourly electricity spot prices on the Nordpool market. Similarly, Spanish residential customers do not participate in the wholesale market, and – like in Denmark – the contracts between the residential customers and the suppliers are based on fixed tariffs.

In Norway, customers can in principle demand to be charged by spot prices, but not according to variations in consumption or load shifting, as billed consumption is based on average weekly consumption. Until 2009, it was possible to get somewhat cheaper net-tariffs if the customer agreed to let the electricity company curtail the customer’s electricity load for heating. However, this required that the customers had supplementary heating forms (e.g. like a combined electricity/oil boiler). This scheme is now closed.

2.2 Status of advanced metering infrastructure (smart meter roll-out)

The rollout of so-called “smart meters” is regarded as pivotal for the development of an advanced metering infrastructure that is expected to be the infrastructural backbone of the future smart grid. Smart meters are electrical meters that enable two-way communication between the meter and the supplier and recording electricity consumption in intervals of an hour or less. Smart meters are typically a technological prerequisite for feedback to customers about their electricity consumption and for load management. Furthermore, the remote reporting feature of smart meters is regarded by many Distribution System Operators as a more cost-effective alternative to the traditional meters that included considerable administrative costs in relation to the reading of the meters. In fact, this might hitherto have been a main driver for the investments in smart meters in Europe (Renner et al. 2011).

For the countries studied here, a specific driver for the smart meter roll-out is the need for finding solutions to increasing shares of intermittent electricity generation through load management. This applies particularly to Denmark, which faces the greatest challenges in this regard due to the goal of 50% wind power by 2020. Furthermore, load management is also promoted as a more cost-efficient way of solving present or future capacity problems of the electricity grid through peak-shaving. In Norway, this argument has been put forward by the Norwegian regulator in relation to capacity problems of the regional electricity grid (NVE 2011). In Denmark, on the other hand the main focus seems to be on future capacity problems of the local distribution network due to expectations of significant increases in households' use of heat pumps and EVs.

Finally, the legal framework of EU also works as a driver for the roll-out of smart meters; particularly the Directive on Internal Markets from 2009, which is part of the Third Energy Package. In order to promote energy efficiency, this directive demands member states or regulatory authorities to work for an optimisation of the use of electricity, e.g. through introducing intelligent metering systems. Before September 2012, all member states had to carry out a cost-benefit assessment for the rollout of smart metering. This assessment should also include a plan for the implementation of smart meters within the following maximum 10 years. The directive demands that in case the outcome of this cost-benefit assessment is positive, at least 80% of the national customers shall be equipped with intelligent metering systems by 2020. (Renner et al. 2011).

The present situation with regard to the roll-out of smart meters in Spain, Norway and Denmark is described briefly below.

Spain

According to the Spanish Energy Law, smart meters have to be installed for all consumers under 15 kW (i.e. most households) before the end of 2018. Minimum functional requirements include electronic meters with remote control, hourly metering and option for hourly tariff selection. Remote control should include possibilities for remote energy management. The overall aim of the Spanish meter substation plan is to support remote energy management systems (Renner et al. 2011).

By 2011, about 2 million smart meters have been installed (Renner et al. 2011), which represents app. 8% of the 26 million electricity customers in Spain.

Norway

In Norway, focus has primarily been on smart meters as a way to improve the efficiency of the electricity market (e.g. making it easier to change electricity supplier) and for better management of the electricity system. Hourly metering of electricity consumption is only obligatory for customers with an annual consumption larger than 100,000 kWh. As a result, only about 4% of the 2.5 million meters in Norway have hourly metering. Some DSO's have already replaced their customers' meters with smart meters, but these are mainly smaller DSOs (Renner et al. 2011).

In 2011, the Norwegian Water Resources and Energy Directorate decreed that all meters (app. 2.7 million) are to be replaced by advanced metering infrastructure (smart meters) within 2017. In conjunction with this, a regulatory guideline, created in concert with the directorate and all interested parties (mostly Norwegian DSOs), was issued. With respect to functionality, an extended debate ensued, resulting in Norwegian meter specifications looking much like other state-of-the art smart meters developed elsewhere and in the EU. The AMI must 1) measure in intervals of max-min 60-15 minutes, 2) use standardized UI based on open standards which may communicate with external units, 3) allow connectivity and communication with other types of meters, 4) boast data storage immune to power outage, 5) have kill-switch for remote curtailment included, 6) ability to send/receive price and tariff information in addition to service notifications in case of for instance earth faults, 7) include ample data and control security measurements, and 8) maintain registration of active and reactive power flow in both directions (NVE, 2011). However, due to the pressure from the Norwegian industries, the smart meter roll-out deadline was in the beginning of 2013 postponed to 2019 (Norwegian Ministry of Petroleum and Energy 2013a).

At this point each Norwegian DSOs have more or less started the process of procuring and rolling out new meters to the new specifications. Several demonstration and pilot projects have appeared, dealing first and foremost with communication infrastructures and meter data management issues. Later phases will include comprehensive tests of various display solutions for communicating with the end user, however this may need to include third party developers and market actors largely absent from the scene as of yet. The DSOs are all also working in concert with the Water Resources and Energy Directorate and Statnett, the Norwegian TSO, in creating a common ICT architecture for meter data management (Throndsen, 2013).

Denmark

The roll-out of smart meters to small customers (households) is not yet mandatory in Denmark. However, despite the lack of mandatory framework, many DSOs have already installed or plan to install smart meters in households. It is estimated that by 2011, about 50% of the app. 3 million customers had smart meters and remote reading installed (Renner et al. 2011). Thus, the DSOs represent in themselves the main actor behind the actual rollout of smart meters in Denmark. The rollout has particularly taken place in Jutland, on Funen and south-western Zealand (but not in Copenhagen and north Zealand, as the largest DSO, DONG Energy, has not yet decided a smart meter rollout among their about 1 million customers).

In April 2013, The Danish Government presented their proposal to a Smart Grid Strategy for Denmark. The strategy suggests a final roll-out of smart meters to all customers in Denmark by 2020. In relation to households, the smart meter roll-out is seen as an important prerequisite for ensuring energy savings (through more detailed data and feedback to households about their electricity consumption) and for the realization of the vision about flexible electricity consumption (load management) in households. The strategy also suggests that the smart meter roll-out is going to be combined with the introduction of flexible electricity pricing schemes on the retailer market (offered all customers, whether large or small) and the setting up of a central data hub for collecting and processing data from the smart meters. (Danish Government 2013)

3. National energy and smart grid policies

The following review of the national energy and smart grid policies of Spain, Norway and Denmark is primarily based on the country reviews of the International Energy Agency (IEA) supplemented with other sources.

3.1 Spain

Within recent years, the growth in electricity production has mainly been based on expanding the natural gas power production and (to a much less extent) extending wind power. From 2000 to 2007, gas-fired electricity generation increased with 101 TWh and represented 37% of the total electricity generation in 2009. According to the IEA 2009 country review of Spain (IEA 2009), the increase in electricity from combined-cycle gas turbines was in the beginning driven by a need for fast capacity extension (due to higher electricity consumption), but later also by the CO_2 reduction obligations related to the EU Emission Trading System (with gas replacing more carbon-intensive fossil fuels like coal and oil) and the need for backup power capacity for the growing wind power production. According to government projections, both gas-fired generation and wind-power generation are expected to increase from 2008-2016, while coal and oil-fired generation are expected to decrease further. (IEA 2009: 103-104)

All other electricity sources (except solar power and waste/biomass) have been in decline since 2000. With regard to nuclear power, the long-term goal is a phase out of nuclear energy. In 2008, fossil fuels represented 60% of the electricity consumption, while nuclear and renewable sources covered 20% each. (IEA 2009)

The overall aim of the Spanish energy policy is to “support sustainable development and ensure energy supply that allows for economic growth and competitiveness, while reducing the impact on the environment of energy production, transformation and end use” (IEA 2009: 18). According to the 2009 IEA country review of Spain (IEA 2009), policies in relation to supporting renewable energy are partly motivated by concerns related to security of supply (Spain imports about 80% of its energy supply):

> “The national government and the autonomous regions see renewable energy as both bringing environmental and energy security benefits, and enhancing local economic development and employment. Renewable energy technology development, especially wind and solar, is a focus area of Spain’s industrial policy.” (IEA 2009: 95)

Renewable energy development is generally supported through premiums and feed-in tariffs for power generation, investments subsidies (mostly for heat generation) and tax incentives for biofuels in transport (IEA 2009: 19).

Like in the other two countries, the Spanish energy policy is strongly influenced by the EU regulation, e.g. in relation to electricity and natural gas markets and with regard to energy efficiency in appliances and buildings such as the EU Energy Performance of Buildings Directive (IEA 2009). Another important EU regulation is the EU Climate and Energy package, which sets the so-called 20/20/20 targets for EU for 2020 (reduction in greenhouse gas emissions by at least 20% below 1990-level, 20% of energy consumption to come from renewable resources and 20% reduction in primary energy use compared with projected levels for 2020). The specific CO_2 reduction targets for Spain is 10% reduction in 2020 compared to 2005-level (EU 2009a) and the specific target in relation to renewable energy is to increase the share of energy from renewable sources in gross final consumption of energy to 20% in 2020 compared to 8.7% in 2005 (EU 2009b). At the time of writing, proposals for the Energy Efficiency Directive, which is going to set specific targets for each member state, is still being negotiated at EU level and by the EU leaders. In addition to the obligations in relation to the EU 20/20/20 targets, Spain – like other EU member states – has a binding target of covering 10% of the demand for transport fuel by renewable energy in 2020 (IEA 2009).

In relation to the Kyoto protocol, Spain's target (according to the EU Burden-Sharing Agreement) is to limit the greenhouse gas emissions to an average of 15% above the 1990 level for the period 2008-12. However, in 2007 emissions were 53% higher than in 1990. Thus, Spain will probably have to rely strongly on the Kyoto flexible mechanisms in order to fulfill its Kyoto targets (IEA 2009).

As previously mentioned, the wind power generation of Spain has increased fast in recent years. The larger share of intermittent wind power generation, combined with relatively low possibilities for cross-border electricity exchange with other countries, means that the variations in wind power generation to a large extent have to be dealt with within the Spanish electricity system. However, "Spain has successfully focused on developing a well-integrated system to balance these variations" (IEA 2009: 19), with natural gas being the most common backup option for wind power. In situations with high wind power production and low demand, it has also been necessary to cut wind turbines off in order to ensure system balance. The Spanish government, industry and the transmission system operator Red Eléctrica de España (REE) work on developing solutions that can handle an increased share of wind power in the future, including possible solutions like improved interconnections with France, using pumped storage for the surplus of wind power and charging electric vehicle batteries (IEA 2009: 108). The Spanish electricity system has relations to the electricity markets in Portugal (in particular) and France and (North) Africa. However, the Spanish electricity system (together with the Portuguese) in many respects works as an island system (the Iberian Peninsula).

In relation to handling intermittent renewable electricity production, the IEA 2009 country review points at a particular problem related to coincidences of high power demand and low wind power production that needs to be handled:

> "Power demand peaks at times of high use of air-conditioners or electric heaters, i.e. when temperatures rise or drop to their extremes. Normally, this is during high pressure and, therefore, when there is little wind. As a result, Spain needs expensive backup capacity, typically gas-fired, to make up for this unavailability of renewable energy. Peak demand could be reduced by more efficient heating and cooling appliances, by better insulating buildings and using light colours for roofs and pavements, as well as natural shading, to reduce the need for these appliances." (IEA 2009: 9)

3.2 Norway

The overall target of the Norwegian energy and climate policy is to reduce greenhouse gas emissions by 30% (compared with 1990) by 2020 and to be carbon-neutral in 2050 (taking into account the country's contribution to emission reductions abroad). The electricity supply and energy use in buildings are already more or less carbon neutral due to a high share of hydropower and as energy consumption in buildings is 70-80% based on electricity (Norwegian Ministry of the Environment, 2012). Thus, reductions in greenhouse gas emissions have largely to take place within other sectors than electricity and housing. For instance, the three largest contributors to the Norwegian CO_2 emissions were the transport sector, industry and petroleum industry, representing 69% of the total emissions in 2010 (Norwegian Ministry of the Environment, 2012). Through negotiations with the EU, Norway has pledged that 67.5% of its energy consumption will come from renewable energy by 2020 (compared with 62% in 2010). Even though Norway is not an EU member state, the country participates in the EU Emission Trading System (EU ETS). It is believed that Norway may play an important role in reducing emissions abroad by exporting renewable energy, but also by offering reductions from carbon capture solutions as they mature sufficiently (NOU, 2012).

The Norwegian electricity system is an integrated part of the Nordic wholesale market (Nord Pool Spot) and there is a high degree of exchange of electricity with Sweden, Denmark and Finland. As pointed out by the IEA 2011 country report (IEA 2011c), Norway has an important strategic role due to its high hydropower reservoir capacity, which can work as a backup (and storage) capacity for intermittent renewable electricity production in other countries. A large reservoir capacity provides flexibility, but it is still vulnerable to dry years (especially so in combination with cold weather and high heating demands).

Already today, the exchange of electricity between Norway and its neighboring countries (including the Netherlands) is significant (e.g., Denmark exports electricity to Norway at times with high wind power production and imports electricity from Norway at times with low wind). The Norwegian transmission system operator (Statnett) plans to build several new cross-border interconnections in order to strength the integration between the Norwegian electricity system (and thereby the Nordic electricity market) and the rest of Europe. This includes possible connections to Germany, UK and the Netherlands (IEA 2011c) as well as between its own regions (NOU, 2012).

In relation to electricity production based on fossil fuels, the Government does not allow the construction of any new gas-fired plants without carbon capture and storage (CCS) technology: “This effectively rules out the gas option until CCS becomes more competitive” (IEA 2011c: 8). However, 46 TWh of gas power was used in the offshore industry in 2010, and in 2012 there was 1,096 MW of thermal power installed on-shore, commissioned before the relatively new CCS-demands. Production rate in these plants is always dependent on the relation between high energy prices (a seldom occurring event) and cost of production (gas prices), and this often makes these plants a last resort. The last four years have seen on-shore thermal energy production in the range of 1-6 TWh (NOU, 2012), and the production facilities themselves are also sites for CCS-research. Technology Centre Mongstad, a CCS research facility dedicated to providing the decision basis for further realization no later than 2016, opens May 2012 (NOU, 2012).

Even though the domestic electricity production is almost entirely based on carbon-neutral hydropower, it is worth noticing that Norway import electricity from coal-fired plants (particularly in Denmark) and nuclear power (from Sweden and Finland) in situations of low hydropower availability in the Nordic market area and/or sudden and extreme peaks in domestic demand.

With regard to meeting the greenhouse gas targets for 2020 and 2050, measures employed in relation to reducing greenhouse gas emissions include: Increased public investments in research, development and deployment of clean energy technologies (including CCS and development of off-shore wind turbines), tightening the energy requirements for new buildings (with the passive house standard as the target level for the building codes by 2020), refurbishing old buildings at a rate of 3% per year, transitioning from fossil fuels in the transport sector to more electricity, bio and hydrogen fuel (including exemptions for EVs from toll road charges and other taxes, free public parking and infrastructure development funding) and plans for increasing use of rail in freight transport (IEA 2011c: 9-10). Norway has also adopted a strategy for development of offshore wind power and is planning to expand hydropower production by utilizing previously untapped hydropower potentials (IEA 2011c) and by refurbishing some older hydropower installations for increased effect. For instance, a new treaty with Sweden on green certificates aims at subsidizing 26.4 TWh of renewable production between the two countries (Norwegian Ministry of Petroleum and Energy 2013b). Furthermore, as around a quarter of Norwegian emissions stems from thermal energy production in the off-shore sector, it is estimated that a great deal of Norwegian emissions may be reduced by connecting the oil and gas production facilities with the mainland electricity grid (NOU 2012). This is, however, a complicated structural and political process, as creating large portions of demand off-shore must be seen in relation to the supply situation on the mainland.

There are, of course, many challenges in relation to exploiting the extensive renewable energy resources in Norway. Main obstacles include public acceptance issues and investment inertia due to immature technology and (relatively) low energy prices. A large focus is therefore also placed on efficiency improvements and load management solutions to preserve the flexibility of the system. It is thought that a smarter grid will allow for Europe as a whole to exploit the variations in the many distributed and intermittent resources better (NOU 2012). Thus, the idea of Norway as “the green battery of Europe” is prominent in the Norwegian debate. Because of this, and also to exploit its own flexibility potential better, the country's energy authorities (the Water Resources and Energy Directorate and the government-owned TSO) have demanded that all DSOs introduce AMS by 2017 (later postponed to 2019), and are now working in concert with the sector to create a robust and nation-wide smarter grid. However, the focus now, and at least for some time to come, is mainly on the transmission, distribution and metering side of the system; the market and consumer-oriented portion of smart grid developments are still in their infancy.

3.3 Denmark

As show previously, fossil fuels (mainly coal and natural gas) dominate the Danish electricity production as primary energy sources. Expanding the wind power production in order to mitigate climate change and improve energy sovereignty has been a main target of the Danish energy plans since the 1990s. In March 2012, all parties in the Danish parliament (except for one smaller party) agreed on a new Energy Plan with the overall aim of reducing the Danish CO_2 emissions by at least 34% in 2020 (compared to emissions in 1990). According to the plan, this will be achieved by reducing the total final energy consumption (transport not included) by 7% in 2020 (compared with 2010) and by increasing the share of renewable energy in the total energy system to 35% in 2020. With regard to the latter, this goal will be achieved first and foremost by doubling the wind power production to 49.5% of the Danish electricity production in 2020. Other major initiatives include increasing the use of biomass in combined heat and power production and increasing the production of biogas based on manure from farming and other biomass resources. Even though the measures of the Energy Plan only cover the period 2012-2020, the long-term goal is to build an energy system based on 100% renewable energy by 2050. (Energy Plan 2012)

Wind power being the main vehicle for achieving the renewable energy goals, the Energy Plan emphasises the importance of developing an “intelligent electricity system” (smart grid). However, the Energy Plan do not include specific measures in relation to the development of the smart grid, except that it prescribes the development of an overall smart grid strategy (a proposal for the smart grid strategy was presented by the Danish Government in April 2013) and making efforts for achieving a *voluntary* agreement with the Danish electricity distribution companies about the roll-out of smart meters. Also, the Energy Plan prescribes that a detailed analysis of the regulation of the Danish electricity system has to be carried out before 2015. The aim of this analysis is to ensure incentives for a “green transition”, cost-effectiveness, market competitiveness and consumer protection. Part of the analysis may focus on the taxation of electricity, including the discussion of a more dynamic taxation. (Energy Plan 2012)

The increasing share of fluctuating wind power in the electricity system results in new challenges in relation to balancing the input and output of the electricity grid. Already today, the wind power production exceeds the domestic electricity consumption at times with high wind speeds and low domestic consumption. These situations are partly handled through exchange of electricity with Norway, Sweden and Germany. In this way, Denmark has been able to take “advantage of hydropower resources in the rest of the Nordic market to balance its electricity system at short notice” (IEA 2011d: 32). However, as noted in the IEA country review (2011), the extent to which Norway also in the future can provide hydropower based balancing resources for the (increased) Danish wind power production will be dependent on the need for balancing resources in Norway itself as well as the Nordic market in general.

The growing challenges of balancing input and output and the visions of a dramatic increase in wind power production within the next decade have given rise to an interest among Danish Distribution System Operators (DSOs), the Danish Transmission System Operator (TSO) Energinet.dk and the Danish energy authorities in developing solutions to manage the consumption side through load management. Hitherto, the focus has particularly been on load management combined with electric vehicles and electric heating of buildings. However, most activities are still at a R&D or demonstration level, and a national strategy for the development of the smart grid has not yet been adopted.

4. Survey of national household smart grid activities

This section presents a survey of national household smart grid activities in Spain, Norway and Denmark. The survey is based on a study by the Joint Research Centre (2011) and our own review of existing projects or recently finished projects. Results of the survey have also been reported in Christensen et al. (2013a, 2013b).

A 2011 survey of European smart grid projects by the Joint Research Center (2011) shows that most of the EU smart grid R&D and demonstration projects are concentrated in a few countries. Denmark, Spain, Germany and the UK account for about half of the total number of projects (Denmark alone accounts for 22%). Thus, both Spain and Denmark have a high activity level with regard to development of the smart grid, but also Norway has a number of smart grid projects.

As the focus of the IHSMAG project is on smart grid solution related to *households*, only projects which include technologies or solutions related to households have been included in this survey. As part of the survey, each of the identified household smart grid projects was categorized according to the *type of smart grid activity* and the *household consumption area* that the project focused on. The following typologies were used for the categorization according to these two dimensions:

Type of smart grid activity

Electricity saving: Projects with the aim of achieving electricity savings in households through the use of smart grid solutions (e.g. smart meter-enabled feedback to household members about their electricity consumption)

Load management: Projects with a focus on load management in households (e.g. through test of dynamic pricing schemes, automated control of electricity consuming appliances such as heat pumps or the charging of EVs etc.).

Micro-generation: Projects with a focus on household-based generation of electricity from renewable energy sources (e.g. solar power or small wind turbines).

Other activities: Household smart grid projects with another activity focus than the above mentioned.

Type of household consumption area in focus

Heating (space and/or water) and air conditioning (e.g. heat pumps)
Cooling (freezers and refrigerators)
Laundering (washing machines and tumble dryers)
Cooking (e.g. electric cookers, dishwashers etc.)
Lighting & other electric appliances (including consumer electronics)
Transport (only if electricity is included, e.g. EV's)
Electricity consumption in general (no specific area in focus).
Other

Appendix 1 shows the distribution of the identified projects by type of smart grid activity and type of consumption area in focus. As it can be seen from Appendix 1, many of the R&D and demonstration projects address more than one type of smart grid activity and/or type of household consumption area.

In total, 18 household smart grid projects have been identified in Denmark, 5 in Spain and 3 in Norway. With regard to the distribution by type of smart grid activity in focus, Appendix 1 shows that most projects address load management or (to a less extent) electricity saving, while micro-generation seems to play a minor role in relation to household smart grid projects in the three countries. With regard to the household consumption area in focus, Appendix 1 shows that the identified projects tend to fall into two overall groups: *Either* they focus on (load management of) heating/air-conditioning or EV charging – *or* they do not focus on a specific consumption area, but address the household electricity consumption more generally.

In the following, the household smart grid projects of each country will be described in more detail (including similarities and differences between the countries).

4.1 Denmark

The Danish survey shows that load management is the area that attracts the most attention in relation to Danish R&D and demonstration projects (12 out of the 18 projects address this theme). The focus is particularly on the load management of electric heating (particularly heat pumps) and EV charging, despite the fact that heat pumps and EVs still have a very limited penetration in Danish households. This exemplifies how the development of new household smart grid solutions is to a high degree based on visions of future changes in the composition of the electricity consumption in households.

The load management projects differ with regard to their approach to and conceptualisation of the users. While some projects focus on automated remote management of appliances (implicating an understanding of the user as someone who should not be actively involved in performing the load management), other projects aim at motivating consumers to change their daily practices (e.g. defer their laundering) in response to spot prices and information about real-time electricity prices.

An example of active involvement of consumers are the eFlex project (by DONG Energy), which finished in 2012 and involved about 120 households (predominantly households with heat pumps). The test families were equipped with a home energy management system, which enabled feedback at appliance level, apps for smart phones and remote control of appliances. During the test period, the families were offered real-time dynamic prices. The project showed some potential for load management in relation to heat pumps, but also limitations to this potential such as in periods of extraordinarily cold weather.

While load management is a key area of the Danish projects, there are also a number of the reviewed projects (5) that address the potential for electricity saving. While the load management projects in general focus on specific consumption areas (like heating by heat pumps or charging of EVs), the projects addressing electricity saving tend to have a broader perspective on the electricity consumption of the household. Most of the projects develop and test solutions with general feedback information to the residents about their daily or hourly electricity consumption. These projects seem to be based on a general representation of the consumer as an informed, rational-choice agent, who will change his/her daily electricity consumption patterns on the basis of more detailed information about his/her electricity consumption. Interest in saving money or environmental concerns are usually assumed to be the primary driver for changing practices.

Electric vehicles are, as noted above, considered by many actors to play a particularly important role in the future Danish smart grid. The idea is that with the (expected) penetration of electric vehicles, these will represent considerable storage capacity for electricity. At times with high wind power production (due to high wind speeds), the electricity surplus (or some of it) can be stored in the batteries of electric vehicles through intelligent management of the charging. At the time of the COP15 summit in Copenhagen, two major electric vehicle demonstration projects were launched: “Better Place” and “Test-an-EV” (the latter run by CLEVER). Both projects aimed at introducing electric vehicles to the Danish market and promote sales, but they differed with regard to the basic battery charging design. While the “Test-an-EV” project made use of traditional electric vehicles, the “Better Place” project developed a design with switchable batteries; thus, depleted batteries could be replaced with new, fully-charged batteries at special-designed “battery switch stations”. However, Better Place went bankruptcy in May 2013 because of low car sales, while the “Test-an-EV” project is still running.

4.2 Spain

The Spanish survey includes five recently finished or ongoing smart grid projects in relation to households. The projects are: Smart City Malaga, MUGIELEC (Development of infrastructures and energy management systems related to the EV), PROYECTO GAD (active demand management), BIDELEK and ADDRESS (Active distribution networks with full integration of demand and distributed energy resources).

Like in Denmark, load management constitutes the main focus of the household smart grid projects; all five projects address load management, although to varying degrees. Two of the projects (BIDELEK and MUGIELEC) focus primarily on the potential of EVs, while the remaining projects have a more general focus on the potential of household electricity consumption for demand management (e.g. heating/air conditioning and laundering). The Smart City Malaga project is somewhat different from the other projects (and also the Danish projects) as this has a system perspective of the city instead of focusing on specific sectors like households or large customers. Also, some of the projects mainly focus on developing the infrastructural hardware and software for smart grid solutions (MUGIELEC and BIDELEK).

Energy saving is not a prevalent theme in the surveyed Spanish projects. Thus, like in Denmark, the focus on load management dominates the household smart grid projects in Spain. Furthermore, the development and testing of new hardware and software solutions (and to some degree also new business models, e.g. the ADDRESS project that develops models for aggregators of small customers offering load management services for the electricity market) are the primary focus of the projects, while studying users’ perception and developing new approaches to the active involvement of users (households) in general seems to be underrepresented.

4.3 Norway

The Norwegian survey includes three projects: Demo Steinkjer, Smart Energy Hvaler and Demo Lyse. The Demo Steinkjer and Smart Energy Hvaler projects have a broad focus on different smart grid solutions (electricity saving, load management, micro-generation and power balancing capacity) as well as different areas of household consumption. Both projects, which are still in their initial phases, are characterised by being based within a specific geographical area (the town of Hvaler and the area of Trøndelag) and have a specific focus on smart meters and their potential use for developing smart grid solutions. Demo Steinkjer and Smart Energy Hvaler are subprojects of the DeVID (Demonstration and Verification of Intelligent Distribution grids) project, which is a demonstration project with the aim of providing knowledge and experience for the planning of the coming roll-out of smart meters in Norway.

The third project, Demo Lyse, focuses on the potential for combining smart meters with new ICT infrastructures like fiber optics and new devices like tablets etc. Energy-related aspects like load management or energy saving are not the primary focus of this project, which instead focuses on the potential of new technologies for home automation (like controlling appliances or heating and lighting) and developing new welfare services like tele-medicine. Thus, this project exemplifies the diversity of ideas and solutions that is often associated with the smart grid concept.

5. References

Christensen, T. H.; Ascarza, A.; Throndsen, W.; Gram-Hanssen, K.; Friis, F. (2013a): *The role of households in the smart grid: A comparative study*. ECEEE 2013 Summer Study, 3–8 June 2013. Belambra Presqu'île de Giens, France.

Christensen, T.H.; Gram-Hanssen, K.; F. Friis (2013b) "Households in the smart grid – existing knowledge and new approaches". In: Hansson, L.; Holmberg, U.; Brembeck, H. (Eds.) *Making Sense of Consumption. Selections from the 2nd Nordic Conference on Consumer Research 2012*. Göteborg: University of Gothenburg

Danish Energy Agency (2011): *Energy Statistics 2010*. Copenhagen: Danish Energy Agency.

Danish Government (2013): *Smart Grid-Strategi – fremtidens intelligente energisystem*. Copenhagen: Danish Ministry of Climate, Energy and Building & Danish Government. URL: http://www.kemin.dk/da-DK/NyhederOgPresse/pressemeddelelser/2013/Documents/smart%20grid-strategi%20web%20opslag.pdf

Energy Plan (2012): *Aftale mellem regeringen (Socialdemokraterne, Det Radikale Venstre, Socialistisk Folkeparti) og Venstre, Dansk Folkeparti, Enhedslisten og De Konservative Folkeparti om dansk energipolitik 2012-2020*. Danish Government. URL: http://www.kemin.dk/Documents/Presse/2012/Energiaftale/Aftale%2022-03-2012%20FINAL.doc.pdf

EU (2009a): *DECISION No 406/2009/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020*. The European Parliament and the Council of the European Union.

EU (2009b): *DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. The European Parliament and the Council of the European Union.

IEA (2009): *Energy Policies of IEA Countries: Spain 2009 Review*. Paris: International Energy Agency

IEA (2011a): *Electricity Information 2011.* Paris: International Energy Agency

IEA (2011b): *CO_2 Emissions from Fuel Combustion 2011*. Paris: International Energy Agency.

IEA (2011c): *Energy Policies of IEA Countries: Norway 2011 Review*. Paris: International Energy Agency.

IEA (2011d): *Energy Policies of IEA Countries: Denmark 2011 Review*. Paris: International Energy Agency.

Izquierdo, M., Moreno-Rodriguez, A., Gonzalez-Gil, A. and N. Garcia-Hernando (2011) 'Air conditioning in the region of Madrid, Spain: An approach to electricity consumption, economics and CO2 emissions'. *Energy* 36(3): 1630-1639.

Joint Research Centre (2011), *Smart Grid projects in Europe: lessons learned and current developments*, Luxembourg: Joint Research Centre and European Union.

KonKraft (2009): *Petroleumsnæringen og Klimaspørsmål. KonKraft-rapport 5*. Oslo: KonKraft. URL: http://www.konkraft.no/postmann/dbase/bilder/KonKraft%20rapport%205%20Petroleumsn%C3%A6ringen%20og%20klimasp%C3%B8rsm%C3%A5l%20Lavoppl%C3%B8selig%20siste%20versjon.pdf

Nordpool (2013) Retrieval from the Nordpool Spot website. URL: http://www.nordpoolspot.com/Market-data1/Power-system-data/Consumption1/Consumption/ALL/Hourly1/ (Accessed 22-02-2013)

Norwegian Ministry of Petroleum and Energy (2013a) *Utsatt frist for utrulling av AMS*. Oslo: Norwegian Ministry of Petroleum and Energy.

Norwegian Ministry of Petroleum and Energy (2013b) *Elsertifikatordningen*. Oslo: Norwegian Ministry of Petroleum and Energy. URL: http://www.regjeringen.no/nb/dep/oed/tema/fornybar-energi/hva-er-gronne-sertifikater.html?id=517462 (accessed 25-02-2013)

NOU (2012) *Energiutredningen – verdiskaping, forsyningssikkerhet og miljø*. Official Norwegian Reports. Oslo: Departementenes servicesenter, Informasjonsforvaltning.

REE (2010) *The Spanish electricity system – Summary*. Madrid: RED Eléctrica de España.

REE (2013) Retrieval from the RED Eléctrica de España website. URL: http://www.ree.es/ingles/home.asp (accessed 22-02-2013).

Røpke, I., T. H. Christensen and J. O. Jensen (2010): Information and Communication Technologies –A new round of household electrification. Energy Policy 38 (2010) 1764–1773.

Shandurkova, Iliana (2011): *Thinking smart about electricity usage. How can advanced demand response programs affect consumption of electricity?* Master thesis. Norwegian University of Life Sciences. Department of Economics and Resource Management.

Statistics Denmark (2013) *Dwellings by county, type of resident, type of dwelling, year of construction, heating, toilet facilities, bath facilities and kitchen facilities*. Copenhagen: Statistics Denmark. URL: http://www.statistikbanken.dk/statbank5a/default.asp?w=1600 (accessed 21-02-2013)

Throndsen, W. (2013): *Constructing the Norwegian Smart Grids: To fix what is not broken?* ECEEE 2013 Summer Study, 3–8 June 2013. Belambra Presqu'île de Giens, France.

Appendix 1: Household smart grid projects by type of smart grid activity and consumption area (Denmark, Spain and Norway)

	Electricity saving	Load management	Micro-generation	Other
Heating/air cond.		DK: Price-sensitive electricity cons. in households DK: EcoGrid EU DK: eFlex DK: Intelligent remote control of heat pumps DK: Trials with heat pumps on spot agreements ES: ADDRESS		
Cooling		ES: ADDRESS		
Laundering		ES: ADDRESS		
Cooking				
Lighting & other appliances				
Transport		DK: EDISON DK: EcoGrid EU DK: eFlex DK: Intelligent charge stands DK: Test en elbil ES: MUGIELEC		DK: Test en elbil DK: Better Place DK: Etrans
Household electr. cons. in general (excl. transport)	DK: ConsumerWeb DK: EcoGrid EU DK: Intelligent home DK: EnergyFlexHouse DK: Feedback-motivated energy savings DK: Several “feedback light” solutions in relation to smart meters (provided by DSOs) NO: Demo Steinkjer NO: Smart Energy Hvaler ES: Smart City Malaga ES: BIDELEK	DK: eFlex DK: iPower DK: Energy Forecast DK: FlexPower DK: EnergyFlexHouse NO: Demo Steinkjer NO: Smart Energy Hvaler ES: Smart City Malaga ES: PROYECTO GAD ES: BIDELEK	DK: EnergyFlexHouse NO: Smart Energy Hvaler	DK: IMPROSUME NO: Demo Lyse
Other				DK: Innovation Fur

Developing the smart grid

Perspectives on integration with the electricity system, regulation aspects and households

Tomas Moe Skjølsvold
Dept. of interdisciplinary studies of culture, Norwegian university of Science and Technology

Marianne Ryghaug
Dept. of interdisciplinary studies of culture, Norwegian university of Science and Technology

William Throndsen
Dept. of interdisciplinary studies of culture, Norwegian university of Science and Technology

This report presents the outcome of work package two, "Interactions between systems/administrative rules and households", of the ERA-Net SmartGrids project "Integrating households in the smart grid" (IHSMAG)

SmartGrids ERA-Net

ZIV a Group Company

DANISH BUILDING RESEARCH INSTITUTE
AALBORG UNIVERSITY COPENHAGEN

tecnalia Inspiring Business

NTNU – Trondheim
Norwegian University of Science and Technology

Date of publication: 01.07.2016

This report is published as part of the ERA-Net SmartGrids project “Integrating households in the smart grid” (IHSMAG). See www.ihsmag.eu for further information.

CONTENT

1. Introduction

This report is an outcome of work package 2 “Interactions between systems/administrative rules and households” of the project *Integrating Households in the Smart Grid* (IHSMAG). The project involved partners from Norway, Denmark and the Basque Country (Spain). The overall aim of the IHSMAG project was to contribute with knowledge on how to develop comprehensive designs of smart grid solutions that involve households in the smart grid.[3] The overall goal of WP2 was to analyse the interaction between the overall electrical system, regulation efforts and households with a particular focus on how to achieve transitions from ordinary electricity grids to smart grids. WP2 has sought to contribute with knowledge about smart grid integration with the overall energy system, regulation efforts to achieve this, as well as how these systemic traits related to the role of households through empirical studies of the Norwegian smart grid development. The goal was to identify major social, political and technological challenges to the implementation of smart grids, and to relate this to the role of the households both in existing and future smart grid systems.

In practice we have achieved this by conducting studies of different character: First, we have studied the work of Norwegian policy makers and regulators involved in the production of smart grid related policy, primarily the Norwegian advanced metering infrastructure regulation. Second, we have studied how Norwegian industry actors have worked as a response to the regulation and identified what kinds of work they engage in to transform visions from policy debates and regulation texts into real, working solutions. This also led us in the direction of studying the work of technical smart grid experts more broadly, and their role as policy mediators, shaping the future smart grid. Third, we have studied how the household users of the new technologies make sense of the situation, how they understand the new technologies and how they (potentially) make use of them.

Theoretically, the WP2 study has been anchored in Science and Technology Studies (STS) (Pinch and Bijker 1984, Latour 1987). Broadly speaking, this literature is concerned with the relationship between science, technology and society and how these arenas of development are mutually shaped and constructed. In other words, the perspective highlights that what happens in society feeds into technology development, and vice-versa, that new technology might pave the way for social change. Thus, it represents a critique of linear thinking about technology, where technology “diffusion” is an end point of enquiry. Instead, links between policy processes, technology development processes and processes of technology use are emphasised, stressing that they are mutually dependent and emerging processes where technology and society are co-produced (e.g. Jasanoff 2004).

Empirically, we have mainly relied on qualitative methods such as participatory observation in the grid operator and electricity producer (Nord-Trøndelag E-verk, NTE), text analysis of documents related to the policy debate on smart meters in Norway (1998-2008) and interviews with implicated actors, interviews with key actors in four different smart grid demonstration projects across Norway, as well as interviews with both prospective users and actual users in two demonstration projects, *Demo Steinkjer* and *Demo Hvaler.* At Steinkjer we also conducted focus group interviews with end users of smart meters.

---

[3] For more information about the IHSMAG project, see the website: www.ihsmag.eu

The findings of WP2 have been reported through a number of publications, most of these in well-known and peer reviewed international journals. Two master students have produced their MA theses addressing IHSMAG WP2 issues, and a PhD has been produced and defended (Throndsen 2016a). In addition to these papers and theses, we have disseminated the results from our work at many international conferences, as well as through national media outlets. This report, provides an overview of the background and theoretical approach of the study, the research design and methods, the analytical findings and conclusions. It has not been the aim to provide an exhaustive presentation of the project activities and results in this report, as this has already been done in several publications. Instead, the goal is to provide an overall description of the outcome of the study.

In addition to this, the WP2 results have – along with the other IHSMAG work packages – contributed to the design recommendations for technology developers, grid operators, policy makers and others presented in the report *Recommendations and criteria for the design of smart grid solutions for households* (Christensen et al. 2016).

Publications related to WP2

Frøysnes, Ane Storhaug (2014) Bare en jævla boks? En analyse av visjonsarbeidet knyttet til avanserte måle- og styringssystemer (AMS) MA thesis, dept. of interdisciplinary studies of culture, NTNU

Jørgensen, S. (2015). Smart strøm - smarte kunder? En studie av norske husholdningers domestisering av smarte strømmålere og styringsteknologier. MA thesis, dept. of interdisciplinary studies of culture, NTNU

Skjølsvold, T.M., Jørgensen, S., & Ryghaug, M. (Forthcoming, 2016). Between empowerment and alienation in the Norwegian smart grid. The role of feedback technologies in energy transitions. *Energy research and social science*.

Skjølsvold, T. M. (2014). Back to the futures: Retrospecting the prospects of smart grid technology. *Futures, 63*, 26-36.

Skjølsvold, T. M., & Lindkvist, C. M. (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, T. M., & Ryghaug, M. (2015). Embedding smart energy technology in built environments. A comparative study of four smart grid demonstration projects *Indoor & Built environment*. doi:10.1177/1420326X15596210

Skjølsvold, T. M., Ryghaug, M., & Berker, T. (2015). A traveler's guide to smart grids and the social sciences. *Energy Research & Social Science, 9*, 1-8. doi:http://dx.doi.org/10.1016/j.erss.2015.08.017

Throndsen, W. (2013a). Constructing the Norwegian smart grids: To fix what is not broken? *ECEEE SUMMER STUDY PROCEEDINGS*, 1831-1840.

Throndsen, W., & Ryghaug, M. (2015). Material participation and the smart grid: Exploring different modes of articulation. *Energy Research & Social Science*.

Throndsen, W. (2016b). What do experts talk about when they talk about users? Expectations and imagined users in the smart grid. *Energy efficiency*, 1-15. doi:10.1007/s12053-016-9456-5

Throndsen, W. (2016c) Response and Responsibility. Smart meters, end use and the possibility of a green material public. Doctoral thesis, NTNU 2016: 17

Throndsen, W. & Berker T. (submitted) Planning story lines in smart grid road maps (2010-2014). Three types of maps for coordinated time travel

2. Theoretical approaches

The theoretical departure point of WP2 was anchored in Science and Technology Studies (STS). Historically, STS scholars 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 seen an autonomous force, unilaterally affecting social affairs. Thus, STS has asked how social processes influence technological development, and in turn, how this development feeds into social processes (Pinch and Bijker 1984, Russell and Williams 2002). In Actor-network theory (Callon 1986, Latour 1987, Law 1987) this argument 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 and Lie 1996, 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 overarching STS-perspectives have been instructive to the project. For instance, we have studied innovation and technology development in the smart grid field through the mobilization of theories about the social construction of technologies (SCOT). This line of thought describes how technology development takes place under specific local, social and historical contexts, and underscores that it is never given a priori if a technology will be successful, how it will be interpreted, understood or used in practice. Instead, SCOT stresses that technologies are subject to *interpretative flexibility*. This means that different social groups involved in the technology development process can have radically different understandings of what the same technological artefact is, what it can do and how it should be used. Advanced electricity meters, for example, can take on different meanings for different social groups such as policy makers, electricity grid companies, the building industry and the households. A practical outcome is that different smart grid development projects situated in different Norwegian locations look very different from one another. They have different goals, build on different technological set ups and different actor constellations are involved.

Working on the how the future smart grid potentially could be integrated with the electricity system, the role of the regulatory aspects and the households made theories that describe the performative character of imaginaries instructive. Since the smart grid is an emerging system, it is surrounded by actors who have different ideas about what it is, what it should be, and what it could become in the future. This is particularly well addressed by the “sociology of expectations” literature, examining the role of future visions, expectations and imaginaries as a tool for contemporary navigation (Brown and Michael 2003, Borup et al. 2006, van Lente 2012). An example of the performativity of future expectations can be found in stock markets, where visions of brilliant future performances can send stocks to the clouds. Similarly, sinister expectations of a pandemic tends to influence the economy, politics and individual behaviors (Nerlich and Halliday 2007). In the context of the smart grid, expectations for technology outcomes are tightly linked to expectations about how future users will interact with the technologies. This means that we can analyze how future use is configured (Woolgar 1990), or how experts imagine smart grid users or smart grid publics (Maranta et al. 2003, Barnett et al. 2012, Skjølsvold 2012). To give a practical example of the relevance of such an exercise, we can consider the task of developing an in-home display meant to give feedback to electricity consumers, and to stimulate behavior changes. If the designer believes that future users are predominantly utility maximising and economically rationally motivated individuals, this will lend itself to the design of a different kind of product, then that of a designer who considers users to be eco-oriented and prone to sharing. Similarly, policymakers will most likely pursue quite different strategies, depending on whether or not they believe that various publics are in favor of - or against desired developments. We will discuss empirical examples of such dynamics where imaginaries (futures and/or publics) come into play later in this report.

The focus on the relationship between technologies and publics, as well as on the relationship between experts and publics has been followed up in the analysis. On the one hand we have studied the relationship between experts and users through the notions of technology scripting (Akrich 1987, 1992) or user configuration (Woolgar 1990, 1991), and on the other, the way that such scripted objects have been appropriated, or domesticated (Sørensen 1994). Engineers design technologies to work and to be used in certain ways. This implies that technologies from the outset contain prescriptive guides, or “instructions” that users’ needs to follow if the technology is to work as the technology developer has planned. Often, however, users find alternative ways of engaging with the technologies, they domesticate them differently, or create what some scholars have called anti-programs (Latour 1990) to work around the instructions and find new ways of use.

A more recent strand of politically oriented STS interested in users and their relationship to the new technologies (Marres 2012) talk of materialized publics, as the introduction of smart energy technologies such as smart meters, in-home displays etc. are arguably a way of making household energy practices, once viewed as belonging to the private sphere, re-introduced in such a manner that they are granted influence on matters of public concern, such as climate change or energy security. When household consumption of energy becomes a public concern, it follows that energy technologies such as smart meters are a way of locating political engagement in everyday practices and thus *materializing* public participation in such concerns (Marres and Lezaun 2011). Such an object-oriented perspective provides “a way of attending to the variability of enactments of engagement afforded by everyday material devices – as something that is crucial to the politics of participation these technologies enable”. Thus, it flips the argument often used about social acceptance of technologies on its head: people do not need to “accept” ready-made technologies into fixed routines, but rather, technologies present opportunities for engaging politically as an agent of change in the world, and these opportunities can be examined qualitatively. In short, citizens are expected to be able to express their material engagement discursively while being deliberately, politically engaged with that materiality. One implication of this is that it challenges the classic understanding of the public sphere as the primary political one, and that the private, materially messy sphere, cannot accommodate deliberate political action. We will come back to how these theoretical perspectives have informed the analysis in the following, but first a short note on methods.

3. Methods

The overall goal of WP2 was to analyse the interaction between the overall electrical system, regulation efforts and households with a particular focus on how to achieve transitions from ordinary electricity grids to smart grids. Our theoretical perspectives (see section two), brings focus to the relationship between actors and technologies, the assemblages they construct, and the issues that are formed in these constellations.

In this section of the report we will discuss the key methods employed, and illustrate how the IHSMAG project has enabled constructive, yet critical cooperation with the involved industries, policy makers, and users. We have done this through active participation and research in several arenas. This highlights the importance of research-industry relations, but also suggests that it is important to retain and fund research that asks somewhat different questions than the industry would have formulated on their own.

To achieve this, much of our research has been conducted as a sort of shadowing, or following of, key actors; either through text and documents they have produced and officiated, through their day-to-day operations, or through interviews. Thus, we have always stayed close to the industry and policy arenas, and we have allowed ourselves to be inspired by their challenges, while not fully adopting their perspectives. Arguably, our methods provide rich insights into three levels of engagement with the smart grid and their integration: a level of discursive production of understanding and policy production, an industrial level of technology development and innovation, and a level of technology use and engagement with new technologies at the household level.

3.1 The arenas of study: research design and methods.

3.1.1 Studying smart grid policy development

One of the key interests of this study was to look at the role of the smart grid and its various components in the Norwegian policy discourse. Norway was one of the first countries to decide on a nation-wide mandatory roll-out of smart meters, which make it a particularly interesting case for policy studies.

Norwegian policy documents and expert interviews

One data source for smart grid policy studies was policy documents. The study of the integration of smart energy solutions in the Norwegian energy system has mainly been focussed on the political discussions that culminated in the formulation of a regulation, demanding that all Norwegian households should have advanced electricity meters installed by 2019. Debates about this technology were followed through deliberation in 11 official documents. The first of these was the relatively general 1998 White Paper on energy policy. The final document was an official summary of an official hearing that had been conducted based on a draft regulation text in 2008.

The documents written early in the period did not have discussions about a specific regulation as a backdrop, but constitute essential elements to understand the introduction of the concept of “smart” energy technologies in Norwegian policy discourse. Once the corpus of text had been analysed in detail, a few key publications stood out. Specifically, we were interested in three reports published by the Norwegian Water Resources and Energy Directorate (NVE), who are the regulating body in this case. The three reports were published in 2004, 2006 and 2007, and they all discussed the feasibility of making a roll-out of smart meters' mandatory. The first two reports were authored by NVE employees, while the latter was commissioned and written by an external consultancy firm. These reports were particularly interesting, because they represent a break in the expectations for the future smart grid. While the first two reports indicated that rolling out smart meters would not be socio-economically feasible, the latter report indicated that it would be. Thus, we were interested in interviewing the involved authors, to learn about the process behind the writing of these reports. It proved to be somewhat difficult to get access to people at the Norwegian Water Resources and Energy Directorate that had been involved in the issue and the writing of the reports. However, we managed to get an interview with a senior staff member who had been involved in the process, but not in the actual writing and deliberations concerning the reports. The consultancy firm who wrote the final report were very interested in discussing the process, and all three authors were interviewed as experts, and gave interesting insights about the discussions about smart meters at the time of writing the report. These interviews also illuminated much of the thinking around smart meters which was muted or not visible to detect in the actual reports.

In the initial phase of trying to understand the Norwegian discourse around smart meters, we also conducted interviews with three actors who were considered key to the Norwegian expert-policy nexus on the issue:

- Tord Lien (then employed in the energy company Trønderenergi, now Norwegian minister of oil and energy)
- Jan Onarheim, then leader of the Norwegian Smart grid centre (employed by NTNU)
- Kjell Sand, a leading technical expert on smart grid issues in Norway (then employed in SINTEF, now NTNU and one of the leaders of a newly funded national centre of excellence on the smart grid).

These interviews provided vital detail on what industrial, research and policy actors considered to be the key challenges and opportunities associated with the smart grid in the Norwegian context, as well as how the envisioned the development in the years ahead.

The role of roadmaps in policy navigation

Adding to the understanding of the way smart energy policy is produced more broadly, a study of planning documents called "roadmaps" was conducted. These roadmaps were used as an innovation guidance tool in large technology development processes, like the one detailed in this project. The study included 13 smart grid roadmaps, each from a different country, written between 2010 and 2014 (Berker & Throndsen, forthcoming). In the European context, the road maps of the UK, Germany, Denmark and Ireland were selected, along with the road map of the European Electricity Grid Initiative (EEGI). In the US context, the National Institute of Science and Technology road map was selected (federal level), as were those of the states of California, Kentucky and New York. The road map of the Standards Council of Canada was also included here. On the international level, the road maps of the International Energy Agency (IEA) and the International Electrotechnical Commission (IEC) were selected. To represent Asia, we included the smart grid road map of China. All the documents were subjected to a quantitative word correspondence analysis, which produced three distinct categories according to the common base vocabulary of all documents.

Road map	Gov-ernment	Reg-ulator	Utility	University	Industry	Interest organisation	Legislative body
UK	xxx	xx	-	x	x	-	-
Germany	x	xxx	-	-	-	xxx	xx
Denmark	x	x	-	xxx	x	xx	x
Ireland	xxx	-	-	-	-	x	-
European Electricity Grid Initiative (EEGI)	-	-	-	xx	xxx	x	-
US National Institute of Science and Technology	-	-	-	-	xx	xxx	xxx
State of California	-	xxx	-	-	x	x	x
State of Kentucky	x	x	x	xxx	x	-	-
State of New York	xxx	-	-	-	xxx	-	xxx
Canada	xxx	-	x	-	x	xxx	-
International Energy Agency (IEA)	xxx	-	-	-	xxx	-	-
International Electrotechnical Commission	xxx	-	-	-	xxx	x	-
China	xxx	-	xxx	-	x	-	-

Table 1. Distribution of involved actors in road map authorship. More x's denote heavier involvement.

The 13 road maps consist primarily of continuous text, which lends itself to a qualitative data analysis. In addition to the qualitative analysis, we conducted a quantitative assessment in which, in line with the research questions described in the previous section, the documents were grouped according to their base vocabulary. The text corpus was then fed to a correspondence analysis using the software R (using the TM package) to create a representation of both related road map documents and their vocabularies. The qualitative analysis was based on a close reading of all 13 documents, the summary of which has been reduced to the table above, which highlights who are drawing roadmaps. The qualitative analysis of the three documents that were selected to represent the three approaches discovered in the findings of the correspondence analysis is discussed in section 4.

3.1.2 Studying smart grid development in practice

An important aspect of understanding the development of smart grids relates to the links between policy development, the development of imaginaries or expectations with respect to smart grids, and the actual smart energy technology implementation. To grasp this leap from words and ideas to actual technology, we have conducted three exercises. First, we have studied the role of different kinds of experts in shaping the understanding of what the smart grid could be, as an important group of mediators. Further we have studied how the idea of the smart grid is picked up, understood and translated into actual technology development in four different smart grid demonstration projects. Finally, we have conducted an in-depth field study of the activities in a Norwegian network operator.

Experts as policy mediators

This project sought to gain insight into how policy ambitions find their way into expert development projects. One way to look at this is how smart grid policy about energy end use has been shaped. However, that would overlook the crucial aspect of scientific expertise which also enters into these processes. In order to look closer at this, we produced a literature review of smart grid research on end users, and compared its narratives with the content of the self-representation of ERA-Net funded smart grid demo projects, as reviewed in Prüggler et al (2014). In short, this approach sought to examine to what extent expert knowledge may have performative influence on demo projects. The following will give a brief summary of this relationship.

127 research papers gathered from a database search of Science Direct and the (former) ISI Web of Knowledge in the spring of 2013 were initially retrieved using the search parameters 'smart grid + smart meter' and 'user'. Subsequently, 40 relevant papers were extracted based on a close reading of abstracts to single out those which contained keywords such as users, consumers, customers, practices, behavior, households, everyday practices, residential, active demand, demand (side) response, privacy, etc. Text analysis was undertaken by close reading of all 40 papers Papers were then categorized in the following categories; papers focusing on a) economic theories or incentives, b) technological issues and solutions, or c) a critique of these two approaches as well as soliciting cultural, social or "everyday" emphasis.

The second part of this study examined the question of how, and in what form, user representations found within the research papers actually informed smart grid implementations. It looks at some prominent European smart grid demonstration projects belonging to the ERA-Net funding programme under the European Research Framework Programmes 6 and 7. A report issued by ERA-Net (Prüggler et al. 2014) which provides snapshots of 34 key projects was utilised as an index for further inquiry. This part of our project studied the self-representations, reports and documents disseminated by these projects, accessible online during the autumn of 2014, with specific regard to how they incorporate the user within their project frameworks.

In accordance with the theoretical framework presented above we studied what visions, designs and expert's expectations about technology could tell us about the future role of the smart grids within households. Different expectations about technology and imagined users/publics were identified in the research literature, making it possible to examine to which extent they reappeared within the operational context of piloting. This was read as an indication of how expectations and prescriptions of science literature may have performative potential, and in which instances they did not. This exercise also provided an overview of the solutions which are brought out of the pilot context, which problems prevail, and finally, which parts of the future visions we may expect have performative influence on current smart grid developments.

Innovation in smart grid demonstration projects

To grasp how Norwegian actors work to integrate smart meters and associated technologies and solutions, we conducted studies of the four main Norwegian smart grid demonstration projects, spread out across the country. They all involve users at household level. Our aim was to investigate how the smart grid developed in different localities and contexts, and to study smart grid development as done by different actors, with different goals, rationales and understandings of the smart grid. Figure 1 illustrates the location of the four demonstration sites in Norway. We originally also intended to study a fifth project, Dyrøy Microgrid, located in the north of Norway. This was however not feasible as the project did not begin its operations before our fieldwork period ended.

Figure 1: Map of Norwegian smart grid pilots studied in IHMSAG

To achieve our goals, we visited the four sites in question. We identified the key personnel involved in the demonstrations, and also tried to identify those who had been involved during the start-up of the projects. We carried out initial interviews and preliminary discussions via e-mail and phone, before we conducted ten on-site in-depth interviews. Several of these were group interviews, where different actors involved in the projects could discuss and elaborate on their experiences. In total we interviewed 16 persons. To add to these interviews, we were given quite extensive guided tours to the sites in question, in order to experience some of the involved technology and to better grasp both problems and opportunities involved. In sum, this exercise provides with a rich understanding and an informative snapshot of the diversity of contemporary Norwegian smart grid development.

Participatory observation + interviews

The project also provides insight into the process of regulatory and technological implementation using a more in-depth case study of a Norwegian network operator. This part of the project draws on empirical evidence from 120 hours of participatory observation undertaken at a medium-sized (80,000 connections) network company in mid-Norway from November 2011, the beginning of their AMI (Advanced Metering Infrastructure) project, to the summer of 2012, when the final metering regulation draft was completed. Additional data were collected in four 1.5 hour interviews with key AMI project members.

The case study was a fortuitous start for a research project on smart grids, as it granted access to the heart of an ongoing technological controversy and translation process regarding the role of smart metering in Norway, where smart grids and smart grid competency were being developed more or less from scratch. It was invaluable for getting an insider's take on how engineers understand the smart grid and the reasons they support having it implemented in the first place. It was also useful for getting to know relevant smart grid stakeholders and learning about smart grids in general, thus establishing what might be termed a "vulgar competence" about the technical issues of the smart grid (Crabtree, Hemmings, and Rodden 2001)

Observation continued in the fall of 2011 and intensified during the two first quarters of 2012, where regular visits were made to the offices of Nord-Trøndelag Energy's resident smart meter project team, with participation in planning meetings and general discussions. Getting to know the experts was useful for retaining access to information about relevant planning documents and industry white papers, as much of the work that went on in this case was related to regulatory text and interpretation. Precisely for this reason, it became evident that upon drawing the observation to a close in the summer of 2012, the inquiry would benefit from undertaking strategic interviews with some of the relevant personnel. Simply "shadowing the object", the smart meter, during the observation (Czarniawska-Joerges 2007) was not always possible, as many details were either not discussed or were handled largely through computer terminals and e-mail correspondence, thus proving hard to capture by participatory observation alone.

This resulted in four 1.5-hour interviews with 4 central project leaders and participants which acted as important supplements to the observations . As much of the work that went on at the network company was, by its nature, performed in unobservable realms, and much of the knowledge that went into smart grid construction was related to abstract phenomena that were embedded in unspoken or regulatory aspects.

3.1.3 Studying household integration

A final element of the WP2 study included studies of the relationship between ordinary households and new smart energy technologies. To study this, we conducted focus group interviews and individual interviews.

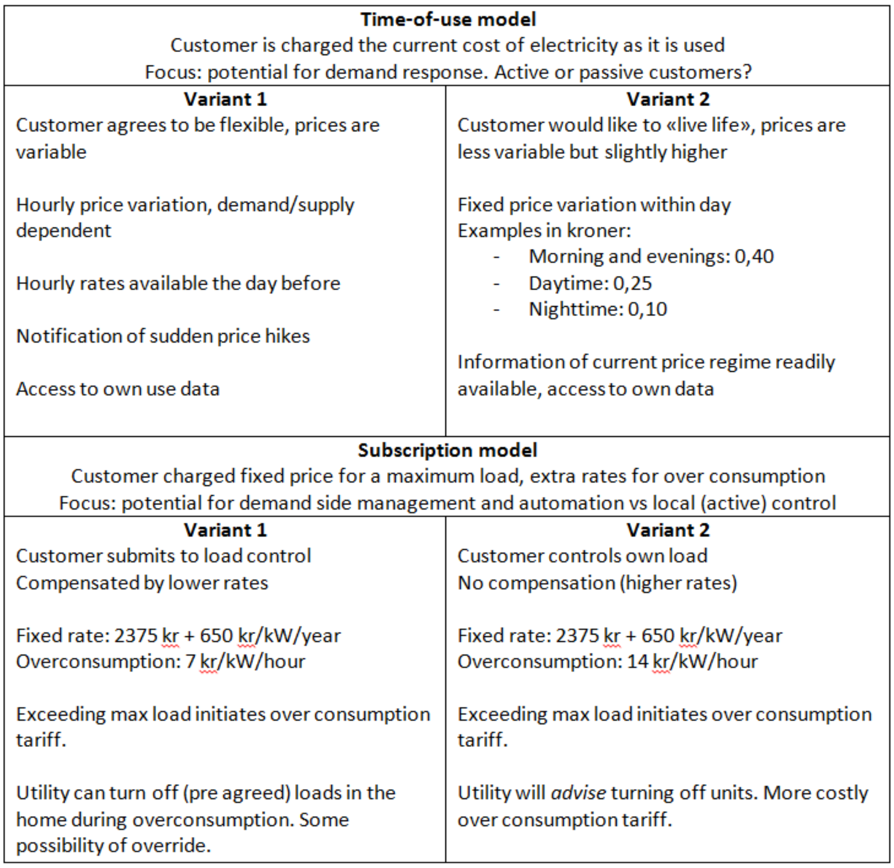
Focus groups

A closer look at actual end users and their relationship with smart metering was included in the final stages of the project. This study also employed the interview method, albeit under different circumstances. Here, the focus group variant was chosen, as it was considered beneficial to produce a discussion about smart grids in general among the participants rather than relying on individual accounts of their (non-)relationship with smart meters. 104 respondents were initially contacted, out of which 26 respondents recruited themselves. These were given two date options per meeting (two in total for each respondent), and final number of unique respondents was 14, with a total attendance of 22 across all four sessions. Participants were recruited by Demo Steinkjer, a smart grid pilot project located in mid-Norway. Created in 2011 and headed by Nord-Trøndelag Energy (NTE), the pilot project had enrolled approximately 1,000 customers with smart meters, most of which were households, and 300 of which had voluntarily enrolled as "research households." The ages of the respondents varied from early forties to late seventies, and there were two women in the entire group. Subjects were chosen among individuals who had already spent over a year in the smart grid pilot, and as such, they were well acquainted with what their presupposed role in the smart grid.

The four sessions were both part of a framework developed and undertaken in collaboration with (then) SINTEF researcher Erica Löfström. The sessions were designed to cover two topics: novel price models and the prospect of users relating to something other than economic incentives when making energy use decisions. Thus, this framework provided insight into two of the most central issues regarding Demand Response and Demand Side Management.

The interviews were modeled such that the first session introduced the consumers to various scenarios and pricing models. Each pricing model had two variations. The first "basic model" was a real-time pricing model, where the customer would pay the real-time cost of energy at the time of consumption. This basic model had two variants. The first variant offered a volatile pricing scheme, where prices would vary every hour according to market supply and demand. The second variant offered fixed variation in prices. In both examples, meter data for consumption and cost would be provided. The main focus in this model, and the insinuated topic for discussion, was the articulations of active and passive consumers.

The other price model, which was intended to explore articulations of another possible smart meter enactment, was a power subscription model where the customer is charged according to a fixed power limit for the household. Exceeding the power threshold triggers an over-consumption fee that initiates a cumulative "counting" of kWh consumed above the threshold, which are added to the bill at a fixed unit price. The two models here were somewhat similar because they both had the same fixed price. The first model had a less expensive over-consumption fee of 7 kr/kWh, but the "catch" was that the customer would have to allow the utility company to remotely shut down appliances when "need be." The other model entailed a more expensive fixed price of 14 kr/kWh, but the sole intervention from the utility company would be a simple request for the householders to shut down some appliances.



<table>
<tr><td colspan="2">Time-of-use model
Customer is charged the current cost of electricity as it is used
Focus: potential for demand response. Active or passive customers?</td></tr>
<tr><td>Variant 1
Customer agrees to be flexible, prices are variable

Hourly price variation, demand/supply dependent

Hourly rates available the day before

Notification of sudden price hikes

Access to own use data</td><td>Variant 2
Customer would like to «live life», prices are less variable but slightly higher

Fixed price variation within day
Examples in kroner:
- Morning and evenings: 0,40
- Daytime: 0,25
- Nighttime: 0,10

Information of current price regime readily available, access to own data</td></tr>
<tr><td colspan="2">Subscription model
Customer charged fixed price for a maximum load, extra rates for over consumption
Focus: potential for demand side management and automation vs local (active) control</td></tr>
<tr><td>Variant 1
Customer submits to load control
Compensated by lower rates

Fixed rate: 2375 kr + 650 kr/kW/year
Overconsumption: 7 kr/kW/hour

Exceeding max load initiates over consumption tariff.

Utility can turn off (pre agreed) loads in the home during overconsumption. Some possibility of override.</td><td>Variant 2
Customer controls own load
No compensation (higher rates)

Fixed rate: 2375 kr + 650 kr/kW/year
Overconsumption: 14 kr/kW/hour

Exceeding max load initiates over consumption tariff.

Utility will <i>advise</i> turning off units. More costly over consumption tariff.</td></tr>
</table>

Table 1: The price models showcased for the focus groups. At the time of writing 10 kroner equaled about 1€. In the case of the subscription model, it can be held that a common Norwegian dwelling operates at a power threshold of about 5 kW, requiring a normal household to pay a tariff of 2375 kr + (650x5) per year. Price examples were provided by NTE.

In the second session, the goal was to widen the scope and attempt to "jolt" informants into thinking differently about their efforts to change energy consumption practices, which, partly due to cheap electricity, is difficult for Norwegians. The scenarios created for this second session explored hypothetical — but realistic — examples of the types of information with which more active users may be expected to interact with when using smart meter technologies in the near future (i.e., the content of interaction, not the mode). The session problematized access to electricity by relating this idea to natural disasters that had recently occurred in Scandinavia, including weather storms that damaged infrastructure, disrupting services and sparking a catastrophic fire in the Norwegian town of Lærdal in the winter of 2013-2014. Images and news clippings were displayed with a projector to initiate discussions of these scenarios and their impact on energy security. The session also focused on the possibility of providing customers with information beyond simply the cost of energy, testing the viability of appealing to an interest other than an economic incentive. For instance, the session sought to explore consumer interest in linking consumption data to other "values" such as the environment, the dependability of the grid, or the security of the energy supply for the community. The findings from this study are presented in section 4.2.

Household video interviews

To add to the understanding of user engagement with the new technologies, we did nine in-depth qualitative video interviews with participants in two Norwegian smart grid demonstration projects. The interviews were set up as relatively lengthy and videotaped "guided tours" of the respondents' households, where the purpose was to "walk and talk" through the use of electricity on an average week-day. This allowed householders to practically enact and demonstrate familiar everyday situations, also mobilizing and demonstrating the many material elements that were part of their daily routines. Compared to ordinary audio interviews, this method has been argued to be particularly well-suited "to determine how routines work, on which logic they are based" (e.g. Jelsma 2003, 114).

The interviewees were recruited out of a pool of participants who were volunteers in two smart grid demonstration projects. We were assisted in this process by the operators of the demonstration projects. The households participated in *Demo Steinkjer* (six participants)*,* and *Demo Hvaler* (three participants). At the time of the interviews, both these demonstration projects combined smart electricity meters with different solutions providing feedback to the users about their own consumption. In Demo Steinkjer, the smart meter was combined three or four special electricity plugs that were connected to a chosen household appliance. Users could access the consumption data from these appliances, as well as the total household consumption data through an online portal. Demo Steinkjer also contained an element of control, as the special plugs could be turned on and off via the online portal. The goal of the trials was first to reduce the overall electricity consumption, particularly during peak hours. This, however, was only seen as a first stepping stone in a project that would eventually produce "*active, conscious and flexible users of electricity in Steinkjer*"[4].

Users in Demo Hvaler received electricity consumption feedback from a portable in-home display, an "e-Wave" and through an app for smart phones, but had no options for control. The system provided hourly readings of the households' entire electricity consumption, and aggregated consumption on a weekly and monthly basis. The users at Hvaler also had an over consumption tariff, meaning that prices of electricity would increase once a threshold had been reached. The goal of the project owners was both to reduce overall electricity consumption, and to distribute the consumption more evenly during the day. The project is located on an Island, which has a quite limited electricity grid distribution capacity. Table one gives an overview of who participated in our interviews, and displays the dynamics of the household in question. The interviewees have been given pseudonyms for the sake of privacy. All users in demo Steinkjer were given pseudonyms starting with "S", while all users in demo Hvaler were given pseudonyms starting with "H".

Demo Steinkjer	**Age**	**Household composition**
Stig	40s	two adults, two children (2 and 4 years)
Sigbjørn and Solfrid	70s	two retired persons
Svein	40s	two adults, two children (12 and 16 years)

---

[4] Citation taken from interview with director of strategy and business development at the time of the project start-up. See http://smartgrids.no/demo-steinkjer/

Sverre	40s	two adults, one child (ca 10 years)
Ståle and Signe	40s	two adults, one child (13 years)
Steinar and Sunniva	40s	two adults, two children (12 and 18 years)
Demo Hvaler		
Håkon	50s	two adults, three children (14, 18 and 21 år)
Henry and Helga	70s	two retired adults
Hermann	40s	two adults, three children (unknown age)

4. Results and analysis

The analysis and results from WP2 have been reported in a number of research papers, a PhD thesis and two MA-theses (see list of publications in Section 1). In this section, we will summarize the main results and analyses from these studies (with references to papers). Combined, the WP2 analysis paints a rich description of the smart grid development in Norway (and elsewhere), where the efforts of experts, policy makers, bureaucrats, industry actors, and technology users are all involved in shaping the current systemic development.

4.1 Expectations and policy development

Expectations and Norwegian policy development

Arguably, the most important Norwegian smart grid related policy is the AMI regulation, stating that all analogous electricity meters should be replaced by advanced meters by 2019. We have studied the ten-year long debate and process, which led to the formulation of this policy. This study illustrates the difficulty of obtaining political agreement about how to change fundamental societal infrastructures. This is particularly true for a technology which is rapidly developing while it is being debated. This means that those who debate have to learn while they debate, and they have to come to terms with what they think the potential is, how users will react, what the economic consequences are.

The study of this process (Skjølsvold 2014, Frøysnes 2014) illustrates how the understanding of what a future with smart meters would entail shifted over time, and that this shift in understanding was instrumental for the formulation of the regulation. At the beginning of the period, smart meters were considered to be a two-way communication device, which would provide improved information to consumers, and in turn lead to more rational consumption. As one of the reports stated: "*Two-way communication has little value beyond precise reading and through this, precise billing*" (Tjeldflåt and Vingås 2004, 39). In other words, it was regarded an incremental innovation, which the authorities did not want to enforce. Towards the mid-2000s, the idea of smart meters allowed for the formulations of visions similar to what we currently call the smart grid. As a report stated in 2006:

> *"services that can be delivered through infrastructure for two-way-communication […] include: alarm, health and security services; load management; energy consultancy services; broadband; IP-telephony; various types of entertainment"* (Tjeldflåt and Kolbeinstveit 2006, 14).

Thus, the technology changed – but only in text. Theoretically, this has led to the development of a new concept, namely that of a virtual domestication trajectory, which describes how imagined meanings, practices and future learning is ascribed to technologies that are not yet in use (Skjølsvold 2014). The analysis illustrates how the production of favorable futures for smart grid technologies and non-favorable futures without them, as well as gaining a strong network of support for such narratives are essential for the production of new policies.

In our view, the experiences of the lengthy deliberation, is that a reflexive and truly deliberative policy process has served the cause quite well. It has shed light on potential problems and benefits, while encouraging social and technological learning on many levels: what can be expected from the technology? What can be expected from the human-technology interaction? How will the technology influence existing energy related practices? What is it really that policy actors want to achieve through the introduction of smart grids and AMI? In a time where the pressure to make quick political decisions is high, this case points towards the virtues of incremental change and gradual learning processes.

The role of roadmaps

The roadmaps analysis provided insight into how planning documents, and indeed the process of producing and maintaining such documents, play an important role in modern system building (Throndsen and Berker forthcoming). We now know individual system builders, so important for development of the early modern world, have been long gone. They have been replaced by complex relational activities that involve many actors, such as supranational organizations, governments, regulators, research institutions and universities, legal bodies, and industry organizations. Although the efforts are heterogeneous, they are not isolated from each other. Rather, they overlap both in terms of topic and geography, as they are undertaken at levels above, below and beyond the nation-state.

Overall, the analysis of the results of this activity, which sought to keep track of innovation processes with the help of roadmaps, revealed that the creation and maintenance of the roadmap becomes a valuable practice unto itself. The roadmap was in this case found to cater for three different kinds of planning, from "standardization as due process" in the case of the U.S., to "top-down deterministic technology cataloguing" in the case of China, via "political regulation of markets" in the case of the U.K.

The latter genre of roadmaps hardly focuses on technology as such and tells the innovation story as one of political regulation for market success. This approach summons regulations and market actors (including consumers) as the main personage and takes for granted that the technology will be developed by market actors accordingly. This is in contrast to the US and Chinese type road maps, which are first and foremost about a specific aspect of technology development: technological standardization. The main actors presented here are experts involved in the standardization process, which in the U.S. case more explicitly includes experts from private businesses than in the Chinese case. These experts are brought together to ensure interoperability and, in the Chinese phrasing, the "unity" of development. Markets and politics, in turn, are largely absent in these documents. Instead, good standards are seen as facilitating eventual market success and the subsequent realization of the other benefits promised by smart grids.

Technology and its evolution towards smart grids (and beyond) are thus taken to be a determining force, which makes this progress a question merely of technological expertise. Standardization seen in this light is an expert task of creating a catalog of the best possible standards—which is basically what the Chinese road map does. In the U.S. case, standardization is an expert task as well. However, it is more about defining a good process in which good results are produced with the help of good tools. From the U.S. perspective, the certainty of smart grids as part of the future is not based on their technological necessity; rather, it is assumed that the U.S. way of standardizing will also prevail in the future, a characteristic similar of the other roadmaps of this particular style (for instance, the German one). These findings indicate that in order to ensure a viable smart grid development process, it helps to employ a roadmap – but in turn, roadmaps themselves require much work in order to become viable. In short, they will need to include the relevant actors, in order to forcibly shape events, but they also need to cater for a strong supportive framework which has itself in focus almost as much as its technological goals.

4.2. Smart grid development: from imaginaries to reality

The imagined users of experts, and the corresponding strategies

We argue that technology design may configure users, and that expectations of technology and its imagined use may have performative influence on technology design. This has allowed us to evaluate expectations and imagined users in actual demo projects and in which way they may be different from the more abstract, theoretical deliberations found within research literature (Throndsen 2016b). Initially, expectations and imaginaries within the research literature on smart grids were found to fall into three categories, or narratives; those of economically rational users, technologically bypassed users, and a social science critique of these perspectives.

The pilot context saw these same narratives recurring, but the reality of testing conditions was brought to bear on them as well. This caused a need for experts to reiterate either their technological solutions or their expectations of users. The economic rationality narrative was proven faulty as users were found disinterested in the rather meagre potential for saving money, but the idea of monetary savings was nevertheless resilient among experts in the face of this experience. The technology bypass narrative was reinforced by a concretization of technological solutions to cater for the problem of missing economic incentives. In line with recommendations from social science critique, some projects also showcased comprehensive approaches to enrolling actual users (i.e. enrolment programs).

The analysis suggests that the process of expectations exerting performativity on pilot projects is not entirely straight forward. For instance, when real users were found less interested in saving money than the experts had previously imagined, the idea of the economic incentive as important, even though it clearly lost the argument with reality, prevailed. Even so, users are not always required by experts to be active for economic and technical expectations to be met. Unresponsive users within an economically rational narrative will be taxed and the value of flexibility obtained regardless. In a technical focus, “irrational” users, potentially imagined as obstacles within a technological expectation, may simply get bypassed by automation.

It is in these aspects we see some evidence of performativity at work. In the first case, expectations are performative even in the face of severe hindrances (i.e. economic incentives remains central even though they are found to be weak). In the case of technology bypass, expectations were maintained but their basis modified, or the rules were changed.

We also saw some examples where what we call “hard enrolment” was employed and actual users were meticulously brought on board the pilot projects. But importantly, even if a smart grid project does employ a hefty user focus, it may still be a strictly top-down project in reality; this was made evident by widespread use of ideographs in some instances. For instance, many projects extol smart grids as empowering users. However, far from being provided more control by real time pricing or demand response management, it is quite possible to argue that what users would in fact be doing within a demand response framework is to relinquish control over their energy consumption to market mechanisms. Stating the case for empowerment without addressing the ways in which it will come about is only getting half the job done – unless indeed the intention is to posit ideographic jargon as a rallying cry in what has been called “strategic game” (Geels and Smit 2000).

Importantly, even though we critically highlight that smart grids may not “empower” users but instead have them relinquish their energy control, this is not to say that this necessarily has to be a negative outcome. We could attempt at opening up for an understanding of the opportunities in the smart grid for a shared workload between users and what we call the “stochastic man”, meaning that the lion’s share of demand response flexibility is provided by automation and algorithm. Arguably a reduction, such a result would still be based on work that deals very seriously with users. Conversely, simply incentivising all consumers with the prospect of monetary savings will invariably fail to include everyone, and an incentive not reacted upon inverts to a penalty. This underlines the ubiquitous nature and therefore the heterogeneous kind of interdisciplinary action called for in scientific endeavours dealing with smart grids.

Finally, as social sciences are becoming more and more important in smart grid development, we register that instead of just instrumentally helping engineers to include households in the smart grid, they could also help them realise the realistic extent of such involvement.

The social construction of smart grid demonstration projects

As a means of moving from the imagined to real technologies, we studied four Norwegian smart grid demonstration projects who all try to engage the household level. The rationale was quite simple, we wanted to understand how and why they responded to the demand that smart meters should be rolled out, and how they prepared for the AMI roll out (Skjølsvold and Ryghaug 2015).

The study has several interesting results. First, it suggests that Norwegian authorities have been on target when they assessed that a mandatory roll-out would be generative in terms of innovation endeavors. While the motivation and goals of the project participants involved in the four case studies differ, they all stressed that they would not be involved in smart grid activities if it were not for the regulation. While the regulation was implemented in 2011, Norwegian electricity grid companies have known about the regulation plans since 2008. Thus, they have been given sufficient time to experiment, and learn from these experiments. To us, the diversity of the case studies illustrate that ample time is needed, both to find potential benefits and business solutions, feasible ways to embed the technology locally, and to come to terms with potential technological obstacles.

A key result from this study is that while the regulation served as an innovation “trigger”, the experimentation in the demonstration projects grows out of local contexts and become highly different in character at the different sites. They encompass different technologies, different actor-constellations, have different goals, and conceptualize users and user rationalities in four very different ways. These four constellations point both to new opportunities for integration of different industries, technologies and actor-constellations, but also points towards some potential obstacles.

The health-electricity alliance:

Demo Lyse combined an interest in welfare technology with “ordinary” electricity consumers. This focus on health and welfare emerged from specific regional challenges such as a senior boom, and from good relations with the healthcare sector. These links influenced the perception of what technology users needed, and what they were capable of. As well as what constituted good smart technology design. The interviewees highlighted that most people were not really interested in smart energy technologies; people just wanted simple, comfortable lives. This led the project towards a focus not only on flashy gadgets such as in-home displays and apps, but also on the development of very simple solutions.

Thus, Demo Lyse became anchored in an implicit criticism of what was seen as common sense in much of the smart grid discourse, namely the degree to which technology users would be interested in engaging new technologies actively – and thereby changing their energy consumption practices

The construction-electricity alliance:

In the case of demo Skarpnes, the interest in experimenting with smart energy technologies emerged from an alliance of a different kind, between the electricity producers/grid operators and the construction industry. The background for their interest was that the construction company Skanska was building a new neighborhood of energy plus-houses. This was considered a pioneering project, partly conducted for the potential learning involved, but these houses were also to be sold on the ordinary retail market for a considerable premium price, targeting early adopters of new "green" technology. The houses should qualify as passive houses and they were equipped with solar panels, to allow for production of electricity for self-consumption and to sell electricity to the grid. Geothermal boreholes and solar collectors produced hot water for space heating and showering, as well to be used in in hot-fill washing machines and dishwashers. The houses were also equipped with smart meters and smart home technology, and state of the art ventilation systems. This was a very uncommon and novel technical setup for a Norwegian neighborhood, which means that it could eventually serve as a real-life "laboratory" or a sort of natural experiment where the relationship between new technologies and energy related practices were explored. The grid operator was interested in exploring this, because it might influence their future way of operating.

The intricate set-up became an arena to explore how the combination of renewables with fluctuating production, new construction practices and smart grid technology would influence electricity demand peaks, distinctly different from the focus on user simplicity and welfare technology found in the previously mentioned case, Demo Lyse.

A research-municipal and industry alliance

The Hvaler demo project illustrates how regional authorities could play an important role in crafting smart grid strategies. Here, the municipality has been central to the project development. Further, Hvaler is known as a summer vacation paradise for many people in Norway. Therefore, it also contains a special kind of built environment consisting of many second homes (so-called hytter) for the development of smart grids. The second homes are typically used most intensively during the summer months. Another specifically regional trait of Hvaler is that it can be very cold during a few days in the winter. Thus, there is usually great pressure on the electricity grid in a few intense periods of the year. The island also has favorable conditions for small scale and (distributed) local renewable energy production, both for small-scale solar and small-scale wind power.

The three main participants in this demo had different, but complementary goals. Hvaler municipality wanted the benefits from a green reputation, but they also welcomed new forms of commerce and economic activity. Further, as they learned more about the technology they also saw opportunities in the production of services, such as health and welfare technology, quite similar to what we found in the Demo Lyse project. Fredrikstad energy was primarily interested in the distribution grid, but in the short run, this meant a focus on users. Finally, NCE smart energy was primarily focused on the users. Since the actors could interpret the technologies into their own frames of reference and use them as means to pursue different individual goals, the implementation of smart grid solutions for households in this setting was relatively successful.

Research-industry links and organizational challenges

The final case study, demo Steinkjer, is illustrative of the importance of organizational issues in smart grid development activities. In this case, the electricity grid company, NTE originally had quite modest ambitions, they wanted to do some tests with smart meters to gain some experience. A group of university researchers convinced the NTE leadership to significantly up-scale and increase the ambition of the project. Thus, the dynamics and conditions for technology embedding in this case were quite different from the other three cases and many employees did not identify with the development strategy produced by the external actor. Thus, the demonstration activities beyond the initial smart metering tests were established as a holding company outside the other departments of NTE. This means that where other demos had emerged as grid companies responded to local socio-technical particularities, and found ways to grow “out of” the electricity grid and production companies, this demo had to find a way to grow “into” the organization. The demo was established based on the interest from university researchers. It created an initial buzz, but many in the electricity grid company felt alienated from the project according to our interviewees. As the company economy tightened, funding to the smart grid demonstration project was more or less cut-off, and the project crumbled. The Demo Steinkjer project was eventually re-started, but now in a more cautious manner.

The generative capacity of diverse localities

As this case demonstrates, the technology might be ready-made and simple enough. However, its interpretation and possible stabilization, as well as the embedding and socialization of the technology is not a trivial matter. In this case, many in the electricity grid company saw the smart grid demonstration as a spearhead in what was also a disciplinary and organizational battle. Taken together, the four cases demonstrate how, technology appropriation is a complex and political process that is influenced by the initial roles, commitments, identities, knowledge and expectations of a range of groups and individuals. Success requires interactions across different divides in work environments: management and workforce, professional and occupational groups, functional divisions in an organization and often across different organizations

In Norway, all electricity grid companies must roll out smart meters by 2019. In itself, this is not a big challenge, but getting the most out of the situation is. User engagement seems to be the ultimate target, and developing suitable technology and organizational platforms in relation to the smart meters is deemed essential. As we have seen, there are different ways of doing this, but focusing on individual economic incentives alone to achieve engagement is probably not enough. Instead, we believe that the technologies introduced through smart grid roll-outs hold significant potential for different types of social and political engagement, for instance through new modes of social organization and collective production of renewable energy, as in the Demo Hvaler case. The different ways that user-technology interaction has been set-up in the projects might also pave the way for different modes of what we can call material participation (see section 4.2), and political engagement. In other ways, modes of engagement that incorporate values, ideas and rationalities beyond the economic. How this will pan out, however, is still an open and empirical question.

In sum, the analysis s suggests that smart grids consist of innovations in the making, so we cannot predict which models will prevail. It seems, however, that the diversity in project configurations, goals and rationale for setting them up, do contain a policy lesson. It seems that when large scale societal infrastructures are to be changed and innovation is sought, ample time is needed to experiment, to try out new solutions, and to find viable actor constellations and to ensure social learning. That there are both positive and negative experiences along the way is only to be expected.

From regulation to smart technology? Participatory observation

Digging deeper into the matter of what goes on in the electricity industry as a response to the new regulation are the results from the study conducted by participatory observation. The results from this exercise demonstrated that Norwegian grid companies have been understood as liable to make sub-optimal choices, and that a future without mandatory regulation was thought to lead to uncoordinated implementation. This provided the regulator with the impetus to make smart metering an energy policy issue affecting the socio-economic well-being of the entire grid. The regulation asserted that network companies' main goal in implementing smart meters was to achieve efficiency benefits in their regular operation for the greater good of the nation. But even though the regulation included functional specifications it was completely left up to the network companies to make expert decisions about how to technically achieve these functionalities.

Because the charge the network companies had been given also stated that they must consider larger socio-economic benefits, the companies were more or less intrinsically motivated by this particular problematization to work together. This implies that mandatory implementation according to regulation in the hands of grid operators seem like a relatively effective way of treating a smart meter roll-out. The ensuing collaboration between grid actors signals the prominence of sideways activity within this framework for the success of the individual network companies. The results indicate that sideways mobilization (Janda and Parag 2013) was considered necessary to progress, and acting alone was sure to result in inevitable failure.

At the time of the study, the main argument from the regulator for network companies to internalise the smart grid ambition of the regulation was that they should focus on realising potential opportunities for efficiency gains for themselves. This strategy was not very effective. The network companies were given the initial impression that unless they all had a solution that fulfilled the regulation requirements equally well and maintained the possibility of future interoperability they would struggle to realize benefits for themselves later on. The problematization of socio-economic benefits and the creation of the regulation as an obligatory passage point (Callon 1986) for every network company thus ensured that these companies would act as expected and create a solution that benefited the entire network first and themselves only second.

As it was up to network companies to solve the regulation technically in order to achieve socio-economic benefits alongside their own, the regulation also intrinsically forced the network operators to ensure they would not close themselves (or other potential actors in the grid) off from future possibilities. This cleverly internalized the motivation to implement smart meters within most of the network companies, even though the impetus was largely interpreted as external (imposed by the regulation). The regulator viewed its argument as a carrot, but it was nevertheless received as a stick. Again, because no one knew what type of actors would want to create new business models within this network in the future, it was a stated goal that opportunities should be kept open for potential latecomers.

However effective the gradually successful enrolment of network companies into the regulatory passage point were, the process of enrolment was not clear cut or straightforward. In the sideways mobilization observed, the network operators did not simply accept the will of a top-down impetus but worked to create a space within which they could manoeuvre. This clearly established the network companies in a significantly influential middle-out position in the Norwegian smart grid constellation, outlining the importance of middle-out activities in defining such innovation outcomes, even in processes that may seem very top-down driven. The incentive structures already in place for governing the spending of network companies was a significant obstacle to the efficacy of the initial idea of local (meaning at the site of the network actors) efficiency gains. It was suspected that it would also be detrimental to enrolment because many companies could theoretically gain by allowing most of the hard work to be done by their competitors, thus leaving the cost to them. This is because there is little room within the tariff finance structure for loosely defined R&D efforts. Finally, however, to accommodate further enrolment, the incentive structures became more malleable as a result of this process, proving—as did the many deadline extensions since the regulation first saw the light of day in 2008—the presence in this scenario of considerable upstream influence.

Others (Inderberg 2015) have argued that AMI implementation in Norway transpired largely because of pressures from within the industry itself. Our project, adopting a more granular approach, has told a different story. The results show that network companies were not initially supportive of AMI implementation in Norway. Rather, they were enrolled by the regulator, who created an obligatory passage point—the regulation—that established functional specifications designed to achieve socio-economic benefits. The regulator did not, in this case, have the expertise needed for the task at hand, and, as is common, the work was given to the real experts. This changed the landscape of network operators, forcing them into hitherto unknown territory. They responded with a sideways mobilization to establish upward influence.

Network companies were given a crucial role to play in the early days of Norwegian smart grid development. Consequently, because they oversee the infrastructure itself, they have become pivotal actors in smart grid development. As the future grid continues to take shape, understanding the complex role of network companies, their considerable agency as middle-out actors, and how they employ this agency to influence their surroundings will be of importance.

4.3 The role of users in the new, smart reality

Once policies have been made, and technologies have been rolled out, the encounter with actual users stands as a tremendous test of how well the work has been done. In this project, we have studied users in two ways. First, through focus groups where interviewees discuss hypothetical, but realistic examples of what they can expect to meet in the future, and then through studies of how users engage with feedback technologies.

Material participation?

When providing the users with examples of future price models and scenarios, this study solicited several varied articulated user enactments of smart grid technology. As we have stated in the theoretical framework above, this inquiry was, among other things, aimed at uncovering the possibilities of developing materialised public engagement (Marres 2014). This study revealed three types of smart grid articulations among pilot participants. We found both enthusiasts and pragmatics, but that wide spread scepticism was prevalent as well (Throndsen and Ryghaug 2015).

Smart grid research often showcases two different specific co-articulations of how smart grid participation may materialize in the household. The type of user participation that is perhaps most desired from the perspective of the experts is what we call “articulations of activation”. In this mode of articulation, the installation of the smart meter translates into a range of social, material and technical transformations and effects. Users are meant to produce these effects by enthusiastically procuring, interacting with, and responding to the smart meter (price signals) and its complementary technologies and actively shift consumption and practices such as cooking and washing to hours of the day with less demand (and cheaper electricity prices). This kind of active and enthusiastic user was present in our analysis, however, only marginally so.

Other studies have portrayed ideal engagement with smart meters as minimal engagement, where participation is mostly delegated to the technology or device itself. In such “articulations of automation,” the technology would optimize the “smartness” of the house according to the principle of picking the low-hanging fruits first. For example, freezers or water heaters could be automatically controlled as long as the automation does not interfere with the activities of the household. This specific mode of participation resembles Marres' “involvement made easy,” where environmental participation through material practices aims at minimal effort, cost, and disruption. This mode seeks to enact the “change of no change” where the practices in the home can continue in the same way as before and there is “no change in the state of things, settings or stuff involved” (Marres 2011, 517). We find this kind of setup discussed as pragmatic articulations of the smart grid by some of the participants in our data.

Both of these modes of articulation frame public engagement with the green political economy in terms of material enactment through the smart meter, and each approach invokes a certain material public. We also found traces however, of scepticism in our data. Such sceptical articulations could of course potentially manifest themselves as anti-programs (Latour 1990) to the smart grid and causing users to resist future invitations of engagement with smart grid technology. This type of anti-programs of dis-engagement can be political in nature. This stand is articulated by the energy citizen that has accepted the premise of the green political economy that relocates private energy consumption into the public domain, but is disgruntled by what is perceived as a lack of real possibilities of engagement by citizens and possibilities to adopt this responsibility in a meaningful way. This contribution is critical and constructive, which makes it a particularly relevant articulation of smart meter enactments and an indication that serious material publics are in fact invoked by smart meters, where they are also coupled by some basic information about what is expected of the user.

This suggests that strong seeds of possible material publics can quite easily be planted by enrolling users in demo projects, and that these can later produce relevant co-articulations of smart meter enactments. These different articulations at this point give insight into what may constitute eventual input for a political discourse of smart grid enactment. The analysis shows that some people realise the greater political potential of energy technology such as smart meters. What does this mean? Many arguments of a possible user-public in relation to the smart grid evidently already exist in the population and are ready to be mobilized in the face of controversy. Claims that users will not engage with the smart grid on any meaningful level can therefore safely be refuted. Several of our early users widely recognized the political role of this particular artefact.

End users clearly conceive of smart grid technology as a technology with morals and politics, and they expect the issue to be treated accordingly by the authorities and market actors. We believe that this implies that various negative articulations are already poised and ready to be used and that attempts to sub-politicize (Marres 2012) the role of the smart meter (for instance, by invasive automation and few ways except economic demand response measures for users to react to them) could cause resistance by already sceptical users. This has also been the case in several sites and countries where smart grids have been implemented with little or no regard to consumers (See Darby 2010 for how the smart grid has been operationalized in different contexts).

As our analysis shows, inviting users to some sort of venue within even a quite loose framework can produce results in the form of concrete articulations on which further informed smart grid work may be built. A strong presence of both pragmatic and enthusiastic sentiments among many consumers alongside the negative sentiments proves that there is ample opportunity for social learning to occur in bringing users (and their articulations) into smart grid technology and policy design. This is where progressive and useful enrolment of users becomes important in a practical sense (c.f. section 4.2.1). The workability of sustainable community participation itself has been exemplified, for instance, by Burchell et al. (2014) in their

Smart Communities Project. Consequently, the potential for the creation of an object-oriented public among smart meter users may be a way to allow positive articulations rather than negative sentiments to be strengthened in the future.

Finally, by engaging households in smart grid projects, the “hidden costs” of the smart grid are brought into the limelight and thereby problematized. Further development and implementation of the smart grid cannot expect easy engagement, and our results hint at various reasons of why individual attempts at energy reduction are likely to become more costly in practice than anticipated. Similarly, Marres’ (2011) framework reveals that issues will be more constrained in terms of their geographic location, financial situation and access to information and services. We also notice that engaging early users in discussions around their role in the smart grid have a performative effect, in which the question of wide societal distribution of the “costs” of developing and participating in the smart grid development is publicly raised. This calls for more discussion on the politics of redistribution and the allocation of energy and climate responsibility that goes beyond the household level and which is seldom a part of the public discourse. In this way, we may conclude that the smart grid and the smart meter have a certain promise as a technology of participation in that these could be engaging devices that act as vehicles of democratization, at least in a discursive form.

Use of feedback in diverse households

Through a study of nine households and their engagement with feedback technologies, we observed that the interaction with the technology usually unfolded through four distinct phases (Jørgensen 2015, Skjølsvold, Jørgensen, and Ryghaug Forthcoming). A key challenge for developers of such technology in the future seems to be that the technologies are largely designed for individuals, while household electricity consumption is largely a collective endeavor. Thus, while the technology in our data engaged one householder (typically the man), who mobilized the technology to make changes in the electricity consuming household infrastructure, it largely alienated and disengaged other inhabitants. The four phases illustrate this challenge.

First, was a phase of initial learning about the new technology and household electricity consumption. The users would begin interacting with the feedback technology, tinkering with their electricity consumption. In this way, they were familiarized and sensitized to their own consumption. Typically, one inhabitant in the household would take on a sort of lead role in this processes, and in most instances, the man took this role. This suggests that there are gendered dynamics to energy demand, which deserves closer scrutiny in future research.

Most users reported that they actively engaged the feedback technology immediately after having it installed. They would play around with the gadget during an initial period, and tinker with appliances in the household to see how this affected the overall consumption.

Second, was a phase were respondents implemented one-time measures to decrease electricity consumption These included changing the physical infrastructure of the building through refurbishments, or replacing old household appliances. The main feature of these measures was that once they had been implemented, they had no consequences for the routines and practices of the everyday-life of the household members. Once the one-time measure was implemented, the feedback technology was used to confirm that the intended effect had been achieved.
In the first two phases it was sufficient to engage the man of the household. He conducted the household energy mapping exercises and one-time measures largely without the interference of other householders. In the third phase, many tried to establish new operational rules, which was not easy without the help of others. Typically, these rules would deal with the use of appliances. When could specific appliances be used, which appliances could be used simultaneously, etc?

This also revealed interesting division of labor in many of the households. While the man would be in charge of “technical stuff”, and via this the energy and electricity infrastructure, it was the women who actually managed many of the situations where this infrastructure was vital. This included things like washing, cooking and cleaning, situations where energy intensive appliances were at work. Thus, we could often observe a clash of logics, where the everyday needs (managed by women) were pit against the man’s desire to be an energy manager.

In the fourth phase of using the feedback technology, it would slip into the background, and become a normalized and un-exotic part of the householders’ everyday lives. In this phase the technology did not provide any new learning about what occurred in terms of energy consumption in the building, nor on ways to reconfigure appliance set-ups. It would typically be checked from time to time, and a response would be given only if some problem was detected

For other respondents, this was more or less interpreted as an end-point for their smart energy technology trial adventure. While it had been interesting, they had “done their chores”, made some changes to the built environment and infrastructure, and through this they were saving energy. Why continue to look at an in-home display?

The implications of the study are that it might be time to re-think the design of feedback technology quite radically. The design at hand appears to be exclusive, and with the words of gender oriented technology analysts, we could say that one of the key challenges in the smart energy technology field over the coming years is to enable more inclusive modes of technology design (e.g. Sørensen, Faulkner, and Rommes 2011). The question is: how can this be achieved?

Our recommendation to technology developers is to move away from a paradigm of what we can call “design for individual resource management” towards a paradigm of “design for collective practice. This implies that:

- If the goal is to change electricity consumption, begin by trying to understand how electricity is currently used.
- Understand current motivations and needs for electricity consumption; do not see them as “barriers” for implementation of new, improved behavior.
- Focus on the entire household. Technologies must appeal to, and be relevant to all potential householders. Use the different rationalities, practices and understandings actively in the design to strengthen potential changes.

6. Recommendations for future research

The IHSMAG WP2 study has highlighted the importance of seeing policy development, innovation strategies and the potential engagement of household users in the smart grid as related processes. The shaping of policies, markets and other framework conditions shapes the space that industry actors inhabit, and provide tools that they can mobilize in innovation processes. The local peculiarities in which innovation unfolds lends itself to different formulations of what the smart grid is, what it might be, and what it should be. Household users, of course, engage with technologies, but their engagement is not only a matter of acceptance. Our analysis indicates that engagement with the energy system might take many forms, but similarly, that rendering too many voices mute and taking for granted what their preferred mode of engagement is, might alienate many and create resistance and opposition to the development.

There is reason to believe that these dynamics will be strengthened in the years ahead. Increasingly, users are not only expected to manage their own consumption of energy in new ways, but also produce their own energy through micro generation installation. In addition, we expect to see tighter integration of transport infrastructure and the electricity infrastructure, with electric vehicles serving as a bridge between the two, with its battery as a potential aggregated source of flexibility.

At any rate, an increased participation of households on the traditional “demand side” will be desired, but increasing complexity will not make the situation easier. In sum, this points to the need for new strand of research focusing on:

- How micro generation technologies in combination with other smart energy technologies on the demand side might cater for material participation in a broad spectrum of social and political issues.
- How the emerging links between smart energy system and mobility infrastructure for households feed into and influence a) the way we consume electricity in our households, and b) the way we transport to and from our households.
- What policies and regulations stimulate diverse modes of innovation in these technology fields.
- How new technologies and new modes of social organization emerge in tandem.

This WP and the IHSMAG project in general has also produced a set of design and policy recommendations. Read the publication *Recommendations and criteria for the design of smart grid solutions for households* (Christensen et al., 2016) for further policy and design recommendations developed on basis of WP3 (as well as the other WPs in IHSMAG).

7. Literature

Akrich, Madeleine. 1987. "Comment décrire les objets techniques?" *Techniques & culture* (9):49-64.

Akrich, Madeleine. 1992. "The de-scription of technical objects." *Shaping technology/building society*:205-224.

Barnett, Julie, Kate Burningham, Gordon Walker, and Noel Cass. 2012. "Imagined publics and engagement around renewable energy technologies in the UK." *Public Understanding of Science* 21 (1):36-50. doi: 10.1177/0963662510365663.

Borup, Mads, Nik Brown, Kornelia Konrad, and Harro Van Lente. 2006. "The sociology of expectations in science and technology." *Technology analysis & strategic management* 18 (3-4):285-298.

Brown, Nik, and Mike Michael. 2003. "A sociology of expectations: retrospecting prospects and prospecting retrospects." *Technology Analysis & Strategic Management* 15 (1):3-18.

Burchell, Kevin, Ruth Rettie, and Tom Roberts. 2014. "Community, the very idea!: perspectives of participants in a demand-side community energy project." *People, Place and Policy* 8 (3):168-179.

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

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”*.

Crabtree, Andy, Terry Hemmings, and Tom Rodden. 2001. "Domestic legacy and design."

Czarniawska-Joerges, Barbara. 2007. *Shadowing: and other techniques for doing fieldwork in modern societies*: Copenhagen Business School Press DK.

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

Frøysnes, Ane S. 2014. "Bare en jævla boks? En analyse av visjonsarbeidet knyttet til Avanserte måle- og styringssystemer (AMS)." MA, Dept. of interdisciplinary studies of culture, NTNU.

Geels, Frank W, and Wim A Smit. 2000. "Failed technology futures: pitfalls and lessons from a historical survey." *Futures* 32 (9):867-885.

Inderberg, Tor Håkon. 2015. "Advanced metering policy development and influence structures: The case of Norway." *Energy Policy* 81:98-105.

Janda, Kathryn B, and Yael Parag. 2013. "A middle-out approach for improving energy performance in buildings." *Building Research & Information* 41 (1):39-50.

Jasanoff, Sheila. 2004. *States of knowledge: the co-production of science and the social order*: Routledge.

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

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

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

Latour, Bruno. 1990. "Technology is society made durable." *The Sociological Review* 38 (S1):103-131.

Law, John. 1987. "Technology and heterogeneous engineering: the case of Portuguese expansion." *The social construction of technological systems: New directions in the sociology and history of technology*:1-134.

Maranta, Alessandro, Michael Guggenheim, Priska Gisler, and Christian Pohl. 2003. "The reality of experts and the imagined lay person." *Acta Sociologica* 46 (2):150-165.

Marres, Noortje. 2011. "The costs of public involvement: everyday devices of carbon accounting and the materialization of participation." *Economy and society* 40 (4):510-533.

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

Marres, Noortje. 2014. "The environmental teapot and other loaded household objects." *Objects and materials: A Routledge companion*:260.

Marres, Noortje, and Javier Lezaun. 2011. "Materials and devices of the public: An introduction." *Economy and society* 40 (4):489-509.

Nerlich, Brigitte, and Christopher Halliday. 2007. "Avian flu: the creation of expectations in the interplay between science and the media." *Sociology of health & illness* 29 (1):46-65.

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.

Prüggler , N., Verboven, P., Hübner, M. 2014. "Collection of regional and national key projects as a starting point for the establish-ment of ERA-Net Smart Grids Plus Smart Grids Demo Snapshots 2013/2014. Smart Grids ERA-Net Deliverable D 4A.4.1."

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.

Skjølsvold, Tomas Moe. 2012. "Publics in the Pipeline. On Bioenergy and its Imagined Publics in Norway and Sweden." In *Past and present energy societies*. Bielefeld: Transcript Verlag.

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

Skjølsvold, Tomas Moe, Susanne Jørgensen, and Marianne Ryghaug. Forthcoming. "Between empowerment and alienation in the Norwegian smart grid. The role of feedback technologies in energy transitions " *Energy research and social science*.

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.

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

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

Sørensen, Knut Holtan, and Merete Lie. 1996. *Making technology our own?: domesticating technology into everyday life*. Oslo: Scandinavian University Press.

Throndsen, William. 2016a. "Response and responsibility. Smart meters, end use and the possibility of a green material public." Ph.d, Department of interdisciplinary studies of culture, NTNU.

Throndsen, William. 2016b. "What do experts talk about when they talk about users? Expectations and imagined users in the smart grid." *Energy Efficiency*:1-15. doi: 10.1007/s12053-016-9456-5.

Throndsen, William, and Thomas Berker. forthcoming. "Planning story lines in smart grid road maps (2010-2014). Three types of maps for coordinated time travel ".

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

Tjeldflåt, A., and O. Kolbeinstveit. 2006. Automatisk måleravlesning og toveiskommunikasjon. Styringsinstrument eller avlesningsautomat. Oslo: Norges vassdrags- og Energidirektorat.

Tjeldflåt, Asle, and Lisbeth Vingås. 2004. Toveiskommunikasjon i det norske kraftmarkedet. Er det hensiktsmessig med tiltak fra myndighetene for å fremskynde en utbygging? In *NVE Rapport*. Oslo: Norges vassdrags- og Energidirektorat.

van Lente, Harro. 2012. "Navigating foresight in a sea of expectations: lessons from the sociology of expectations." *Technology Analysis & Strategic Management* 24 (8):769-782.

Woolgar, Steve. 1990. "Configuring the user: the case of usability trials." *The Sociological Review* 38 (S1):58-99.

Woolgar, Steve. 1991. "The Turn to Technology in Social Studies of Science." *Science, Technology & Human Values* 16 (1):20-50. doi: 10.1177/016224399101600102.

Smart grid solutions in the everyday life of households

Electric vehicles and time-of-use pricing

Freja Friis
Danish Building Research Institute, Aalborg University

Toke Haunstrup Christensen
Danish Building Research Institute, Aalborg University

Kirsten Gram-Hanssen
Danish Building Research Institute, Aalborg University

This report presents the outcome of work package 3 SMART GRID SOLUTIONS IN EVERYDAY LIFE SETTINGS of the ERA-Net SmartGrids project "Integrating households in the smart grid" (IHSMAG)

SmartGrids ERA-Net

ZIV a Group Company

DANISH BUILDING RESEARCH INSTITUTE
AALBORG UNIVERSITY COPENHAGEN

tecnalia Inspiring Business

NTNU – Trondheim
Norwegian University of Science and Technology

Date of publication: 07.06.2016

This report is published as part of the ERA-Net SmartGrids project “Integrating households in the smart grid” (IHSMAG). See www.ihsmag.eu for further information.

CONTENT

1. Introduction

This report is an outcome of work package 3 “Smart grid solutions in everyday life settings” of the project *Integrating Households in the Smart Grid* (IHSMAG), which involved partners from Norway, Denmark and the Basque Country (Spain). The aim of IHSMAG was to contribute with knowledge on how to develop comprehensive designs of smart grid solutions that involve households in the smart grid.[5]

The aim of WP3 was to contribute to a better understanding of the interplay between smart grid solutions and the daily electricity-consuming practices of households, including transport practices. As demand-side management (flexible energy demand) has become one of the core objectives in smart grid development and visions, WP3 focused especially on the connection between the temporal organisation of households’ everyday practices and the timing of the residential electricity consumption – and how smart grid solutions influence the temporal patterns of practices and electricity consumption. In addition, the study also analysed how families integrate electric vehicles (EVs) in their everyday life and hence includes analysis of mobility intervention strategies associated with the dissemination and adoption of EVs.

Theoretically, the WP3 study was anchored within social practice theories, but it has also included other theoretical approaches. Empirically, the study draws mainly on in-depth qualitative interviews and focus groups with households participating in the EV demonstration project *Test an electric vehicle* (“Test en Elbil”) and the static time-of-use pricing trial called *Dynamic Network Tariff* (“Dynamisk Nettarif”). In addition, the study also included participant observations as well as statistical analysis of hourly-based recordings of the electricity consumption of households participating in the *Dynamic Network Tariff* demo.

WP3 was carried out in collaboration with the electricity provider and DSO *SE* (leading the *Dynamic Network Tariff* demo) and *Clever* (leading the *Test an EV* demo).

The findings of WP3 are reported in a number of publications (several peer-reviewed), which are listed at the end of this chapter. In this report, we provide an overview of the background and theoretical approach of the study, the research design and methods as well as the analytical findings and conclusions. It has not been the aim to provide an exhaustive presentation of the project activities and results in this report, as this has already been done in previous publications and the PhD Thesis (Friis, 2016), which was the core activity of the work package. Instead, the aim is to provide an overall description of the outcome of the study.

The findings from WP3 have – along with the other IHSMAG work packages – also contributed to the design recommendations for technology developers, grid operators, policy makers and others presented in the report *Recommendations and criteria for the design of smart grid solutions for households* (Christensen et al., 2016).

---

[5] For more information about the IHSMAG project, see the website: www.ihsmag.eu

Publications related to WP3

Christensen, Toke Haunstrup (2014): "The role of learning and social interaction for changing practices". Paper for the workshop "A Social Practice Perspective on the Smart Grid" at the *ICT for Sustainability, ICT4S 2014 Conference*, 24-27 August 2014, Stockholm, Sweden.

Christensen, Toke Haunstrup; Friis, Freja (2016): “Materiality and automation of household practices: Experiences from a Danish time shifting trial”. Paper for the *DEMAND Centre Conference*, 13-15 April 2016, Lancaster, UK.

Christensen, Toke Haunstrup: Gram-Hanssen, Kirsten; Friis, Freja (2012): ”Households in the smart grid – existing knowledge and new approaches”. Paper for the *2nd Nordic Conference on Consumer Research*, 30 May – 1 June 2012, Göteborg, Sweden.

Christensen, Toke Haunstrup; Gram-Hanssen, Kirsten; Friis, Freja (2013): “Households in the smart grid – existing knowledge and new approaches”. In: Hansson, L., Holmberg, U., Brembeck, H. (Eds.) *Making Sense of Consumption. Selections from the 2nd Nordic Conference on Consumer Research 2012*, p. 333-348. Göteborg: University of Gothenburg.

Friis, Freja (2016): “Integrating smart grid solutions within everyday life: A study of household practices in relation electric vehicles and time-of-use pricing”. PhD Thesis. Copenhagen: Danish Building Research Institute, Aalborg University.

Friis, Freja (submitted): “Making sense of electric vehicle driving: Examining interventions in mobility practices”.

Friis, Freja; Gram-Hanssen, Kirsten (2013): "Integration of smart grid technologies in households – how electric vehicles and dynamic pricing change social practices in everyday life." *ECEEE 2013 Summer Study*, 3-8 June 2013, Belambra Presqu’île de Giens, France.

Friis, Freja; Christensen, Toke Haunstrup (2016): “The challenge of time shifting energy demand practices: Insights from Denmark”. *Energy Research & Social Science* 19: 124-133.

2. Theoretical approach

The theoretical outset of the WP3 study is “social practice theories”. Practice theories are not a new or common agreed upon, unified theory, but rather an approach or “turn” in sociological thinking (Gram-Hanssen, 2011; Schatzki et al., 2001). The idea of social practices being the analytical unit for exploring the social was (re-)introduced within the social sciences by Theodore Schatzki and Andreas Reckwitz (Schatzki, 1996; Reckwitz, 2002). Both re-interpreted and synthesized theoretical elements based on work from sociologists and philosophers such as Giddens (1984), Bourdieu (1990), Butler (1990), Foucault (1978) and Latour (1993).

To get an overview, Halkier & Jensen (2008) divide the range of practice-aligned approaches into two positions. On one side, the scholars who attempt to systematise and position social practice theories on a general theoretical level by distinguishing it from other sociological theories (e.g. Reckwitz, 2002; Schatzki, 1996; Schatzki et al. 2001). On the other side, the more operational and empirically based approaches, particularly within the area of consumption research (e.g. Shove & Pantzar, 2005; Shove et al., 2007; Warde, 2005), environmental and sustainability research (e.g. Burgess et al., 2003; Shove, 2003; Southerton et al., 2004; Spaargaren & Van Vliet, 2000) and in socio-technological research (e.g. Christensen & Røpke, 2005). Further, recent contributions also attempt to meet the critical challenges of sustainable change by integrating elements from system-based transition theories. Contributions to developing such “system of practices” approaches include Watson (2012), Spurling and McMeekin (2014), and Shove et al. (2015).

The practice theories approach seeks to overcome the structure-actor dualism regarding whether human behaviour is primarily determined by social structures or individual agency. Practices are not viewed as individual acts, but rather as collective actions where the individual can be viewed as a carrier (Reckwitz, 2002). This understanding of practitioners as “carriers of practices” can be aligned with the concept of “habitus” from Bourdieu (1998). Habitus describes the embodiment of practices and dispositions and thus explains why we tend unconsciously to repeat structures and collective practices based on what we have learned and been exposed to during our lifetime, from childhood to adulthood.

Another important observation from practice theories is that consumption of energy (and resources in more general terms) 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 like 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 (as is also explored in this study).

As an effect of the heterogeneous approaches within theories of practice, the elements configuring social practices have been variously interpreted (Gram-Hanssen, 2011). Schatzki defines a practice as a “temporally unfolding and spatially dispersed nexus of doings and sayings” hold together by three elements: 1) shared understandings, 2) explicit rules and 3) teleo-affective structures (the latter is described as the “ends, projects and tasks” associated with moods and emotions) (Schatzki, 1996:80,89). These blocks or patterns of activity are filled out and enacted by practitioners that through their performances of doings reproduce, transform and perpetuate the practices they carry. 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” (Reckwitz, 2002:249).

Shove and Pantzar (2005) simplify the number of elements constituting practices to three elements: competences, meanings and products. Shove et al. (2012) write that “practices are defined by interdependent relations between materials, competences and meanings” (Shove et al., 2012:24). The elements are further 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.” (Shove et al., 2012:14). Using 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 et al., 2012:8).

The conceptualization of the elements originally developed by Shove and Pantzar (2005) has proven useful in many empirical studies. However, the same can be said about the conceptualization developed by Gram-Hanssen (2011), who distinguishes between four different types of elements: Know-how and embodied habits (unconscious and embodied habits and routines, e.g. learned through childhood), institutionalized knowledge and explicit rules (including e.g. technical knowledge and information provided through campaigns etc.), engagement (refers to the ends people are seeking to achieve) and technologies (e.g. washing machines, computers, cars etc.) (Gram-Hanssen, 2011). As it can be seen, there are many similarities between the conceptualizations of elements by Gram-Hanssen and Shove & Pantzar, except that Gram-Hanssen distinguishes explicitly between know-how/embodied habits and institutionalized knowledge/explicit rules, which Shove & Pantzar combines in the element of competences.

Across the different conceptualisations of practices and their constituting elements, it is in particular the emphasis of including material elements in our understanding of how social practices are produced and reproduced that makes social practice theories different from other social and cultural theories. The emphasis of the material as a significant dimension in practices to a high degree reflect the impetus from the Actor Network Theory tradition (with Latour, Akrich and Callon among the influential contributors).

Overall, social practice theories depart from the dominating human-centred psychological and economic theories often applied within consumption and (environmental) behaviour studies. Shove (2010) has termed these dominating theories the “Attitudes, Behaviour, Choice” (ABC) model. The dominant ABC paradigm relates to the typically restricted modes and concepts of social change embedded in contemporary, established policy approaches, which primarily frames human action as a matter of individual choices and an outcome of individual attitudes. Through confronting and criticising the limitations of this assumption and its lack of success in obtaining long-lasting transformations and reductions in energy consumption, social practice theories are positioned as an alternative approach to inform intervention and sustainable transition (Hargreaves, 2011; Shove, 2010; Shove et al., 2012; Strengers & Maller, 2014; Watson, 2012).

How (consumption and energy within) practices are reconfigured and changed over time and space is a theme for continuous discussion and exploration within practice theories. Reflecting the energy transition and smart grid discussion, practice theorists underpin that households are more than consumers, and thus rather should be considered as “practitioners” or co-managers who are implicated in the routine functioning of the system as a whole (Shove & Chappells, 2001:57). Thus, sustainable consumption interventions and smart grid development have to recognise that innovation should be embedded in the daily life (Shove et al., 2007).

The discussion of how practices are reconfigured and changed over time and space has become a central theme within more recent practice theoretical studies. Some of these have been inspired by the Multi-Level Perspective (MLP) developed by Geels (2010) and have attempted to argue of valuable potentials of intersections and crossovers between social practice theory and MLP (Gram-Hanssen, 2011; Hargreaves et al. 2013; McMeekin & Southerton, 2012). For instance, Hargreaves et al. argued through empirical analysis of two different case studies of sustainability innovation that “intersection between regimes and practices offers vital insights into processes that can serve to hinder (or potentially help) sustainability transitions” (Hargreaves et al., 2013:403). Their conceptual framework does not suggest an integration of the individual, distinctive strengths of practice theory and MLP, but rather to retain the distinction between regimes and practices and explore how they intersect.

Another dimension related to change of practices and governance is the role of power and power relations. Thus, on basis of the empirical example of resource-intensive personal mobility, Watson (2012) argues that current patterns of mobility are constituted and reproduced by travellers’ practice performances, but also embedded in systems of power and interest. These aspects related to power and governance, and how this relates to continuity and change of practices over time, has also been one of the key interests for the WP3 study.

3. Method

In this section, we will first describe the two demonstration projects that were studied in WP3 (Test-an-EV and Dynamic Network Tariff). Then follows a presentation of the research design and methods applied in relation to the studies of the two demonstration projects.

3.1 The demonstration projects

3.1.1 Test-an-EV (TEV)

The Test-an-EV (TEV) demonstration was carried out by the Danish mobility operator Clever (partner in the IHSMAG project), and the aim was to gather knowledge and experience about EV-driving by testing first generation mass-produced electric vehicles (EVs) among 1578 households living in different parts of Denmark. Typically, each household (family) would borrow the EV for a three months period. It was a requirement that the households should already own a (conventional) car in order to be eligible to participate in the demonstration project. In this way, in most cases the EV would become the household’s second car. The EVs included different models from Mitsubishi (iMiev), Peugeot (Ion), Citroën (C-Zero) and Nissan (LEAF).

TEV was framed as the greatest and most ambitious EV demonstration project in Northern Europe. From 2011 to 2014, 198 EVs were tested in 24 Danish municipalities. The demonstration project delivered a variety of “hard” data from data loggers installed in the cars and “soft” data from the test drivers’ experiences about EV driving reported in “driving books” and by weekly weblogging.

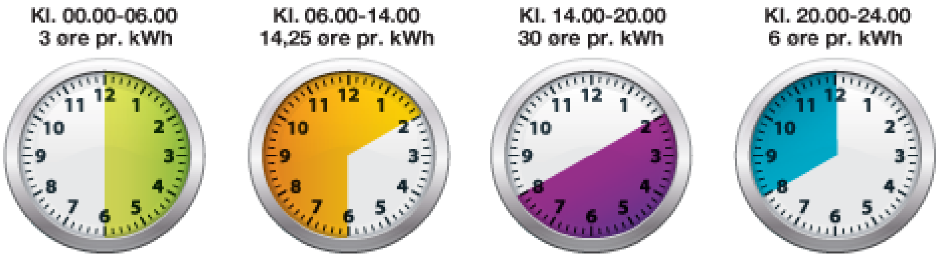
Overall, the project has provided the company Clever with knowledge about the operational reliability, charging patterns and driving needs related to use of EVs. In addition, the project provided in-depth knowledge on the energy potential of the state-of-art EVs and challenges for further operation. Part of the goal of the demonstration project was to test the difference between two ways of performing the EV battery charging; manual load management and automated load management controlled by the operator.

Besides Clever's own funding and sponsorships from private companies, the demonstration project got public funding from the Danish Transport Authority, the Danish Energy Agency and several municipalities. Owned by five Danish utility companies, Clever's overall business strategy is to install smart equipment to manage users' electricity consumption and save the grid for critical peak loads. Hence, the comprehensive data collection of the test-driving was basically used to develop the company's future business and operation strategy to improve the smart grid potential of EVs in Denmark (Clever's final report, 2014; interviews with the operator conducted in 2013). In parallel with the implementation of the demo project, Clever opened a nation-wide network of EV charging stations in 2012.

3.1.2 Dynamic Network Tariff (DNT)

A small number of the "test drivers" of the Test-an-EV demonstration additionally participated in another smart grid demonstration implemented by the electricity supplier and distribution system operator SE (South Energy) aiming to test how dynamic network tariffs influence consumers' everyday consumption patterns. This demonstration project was named Dynamic Network Tariff (DNT).

The DNT trial offered 18 test drivers variable network tariffs and static time-of-use pricing (Darby & McKenna, 2012) for the network tariff. For instance, the network tariff was ten times cheaper during the night hours 0-6 (0.4 euro cent/kWh) than in the peak hours 14-20 (4 euro cent/kWh).



Together with the market electricity price and taxes, the total electricity price for Danish household customers is about 0.3 euro/kWh. Thus, the maximum variation in the network tariff represents about 15% of the total electricity price and hence represents a relatively weak price signal. In addition to DNT, the participants also had a spot price agreement, which is a real-time pricing scheme (Darby & McKenna, 2012) following the hour-by-hour market price of electricity on the Nordic *Nord Pool* spot market. The average market price was about 4-5 euro cent/kWh. However, the interviews with the households showed that none of them adopted the real-time pricing scheme as they experienced the hour-by-hour and day-by-day changes in electricity prices too complicated to follow and integrate with their daily energy-consuming practices.

The combined TEV and DNT trial aimed to test the impact of economic incentives on households' flexibility to time shift their electricity consumption to hours with low electricity demand in order to avoid peak load. Like Clever, SE presumed that the participants' incentive to consume electricity during the most affordable hours of the day would increase by participating in two smart grid trials at the same time. In particular, the consumption patterns were expected to change in relation to dishwashing, laundry activities and EV charging.

The DNT ran from April to November 2012, while the combined DNT and TEV trial ran from May to October 2012 (thus, the 18 participants in the combined trial were offered six months participation in TEV instead of just three months like the other test drivers). None of the households participating in both DNT and TEV had electric heat pumps or PVs, which was the criteria set by the project owners to avoid confusion related to the interpretation of the consumption data.

As part of the trial, Clever wanted to test the difference between two ways of performing the EV battery charging; manual load management and automated load management controlled by the operator. The shift from manual to automated load management was implemented in September 2012.

The households participating in the combined trial lived in detached houses in suburban areas of the middle-sized cities Aabenraa and Sønderborg situated in the South of Jutland, which is characterised by being an economically declining region of Denmark.

3.2 Research design and methods

The overall objective of the WP3 study has been to expand our understanding of the complexity of factors in the everyday life influencing the success of smart grid initiatives for households. The theoretical approach has been inspired by practice theories, and as part of this, a particular focus has been on the status and role of materiality and technical designs in shaping (new) social practices of the families and the possible implications of this for the energy consumption.

The empirical study draw on a mixed-methods approach combining different methods in order to contribute with multi-faceted descriptions of the cases and the experiences of the households with the DNT and TEV demonstrations. The main empirical methods applied were semi-structured qualitative interviews and focus groups. In addition, the study also includes participant observation, analysis of the test drivers self-reporting via weblogging and field notes as well as quantitative data in form of a statistical analysis of the hourly-recorded metering data of the electricity consumption of the households participating in the combined trial. In the following, we will provide a more detailed description of each of these methods.

3.2.1 Semi-structured qualitative interviews

Eight of the 18 participants in the combined DNT and TEV trial took part in individual, semi-structured interviews (Kvale, 1996). The aim of these interviews was to provide insight into the everyday perspectives of the households. The interviews were carried out during the summer of 2012.

The underlying basis for the selection of interviewees (as well as focus group participants) was to get the highest possible variation on variables such as gender, age, income, marital status, household size, number of children living at home, description of motivation in the application (to Clever/TEV) and driving needs (km). The assumption was that diversity would contribute to a more comprehensive understanding of the complex nature of households' interaction with the EV technology and static time-of-use pricing. All households were living in detached houses with a garden and a garage.

The goal of the interviews was to achieve knowledge about the interaction between the two smart grid projects TEV and DNT and the everyday social practices of the households; to explore how the trials influenced on households' habits and routines and vice versa. The approach was aimed to be as open-minded and inductive as possible, even though the interviews will always be a co-construction between the interviewer and the interviewee. The design of the interview guide and the approach were inspired by Kvale's thoughts on the semi-structured qualitative interview (Kvale, 1996) and Spradley's descriptive questioning techniques (Spradley, 1979).

The interview guide was semi-structured and thus designed to follow different topics/themes around challenges and advantages related to the participants' temporal rescheduling of their consumption patterns and re-organizing of their driving activities. Though most of the interviewees only involved the person who had originally applied for participation in the TEV, the interviews also aimed at giving insight into the relationships within the households and to cover other household members' experiences and perceptions. The interviews were carried out at the home of the interviewees and lasted 1-2 hours. See Table 1 for more details.

Table 1: Details about the interviewed test drivers (combined trial)

Participants*	**Anne-Mette**	**Søren**	**Ebbe**	**Hans**	**Mia**	**Viola**	**Hannah**	**Nicolas**
Age and gender	61, f*	42, m*	51, m	45, m	33, f	32,f	48, f	36, m
Household size	2	4	3	2	2	4	2	4
Children	0	2h*, 1o*	1h, 2o	1h	0	2h	1h, 3o	2h
Daily transport needs(km)	40-60	20-40	60-70	60-70	20-40	20-40	0-20	40-60

* participants' names are changed to ensure anonymity; f indicates female and m indicates male; h indicates the number of children living at home; o indicates children no longer living at home.

The transcribed interviews were later coded in order to organize the material into analytical themes and observations. Due to the abductive research approach, the different analytical themes occurred during the process of coding afterwards.

In addition to the interviews, semi-structured interviews were also done with the managers from Clever and the funder from the Ministry, primarily focusing on their roles as "change agents" (Strengers, 2012). The interview guides for these interviews focused on aims, strategies, challenges, advantages and future interventions related to mobility operation. In particular, the interviews with the project leader and project coordinator from Clever, respectively, attempted to illuminate their experiences related to operationalizing the demonstration project. The interview with the funder attempted to achieve knowledge about overall assumptions of how to reach the goals for decarbonizing the transportation sector, how TEV was a strategical measure to reach that, the background for funding the demonstration project, expected outputs and what the funder so far had experienced as core challenges and advantages related to TEV.

3.2.2 Focus groups

Three focus groups with participants living in the suburbs north of Copenhagen were carried out in the winter of 2013. Focus groups are suitable of exploring how "meaning" is constructed in the social interaction between people (Halkier, 2010; Morgan, 1997). The moderator of focus groups aims to stimulate the participants' reflections in relation to a specific topic, in this case the sense making related to EV driving. As part of this, the aim of the focus groups was to discover normative negotiations and positions revealed in the discussions. The focus group discussion centred on a number of themes about meaning related to driving in general, participation in the demonstration, EV driving, adoption, charging behaviour, sharing experiences etc.

The participants in all three focus groups were very eager to discuss and reflect about the sense making of EV driving. The participants were very open about what they found bad and good about EV driving. The discussions in the focus groups underpinned the findings in the individual interviews about “the good life” as coupled with powerful comprehensions of freedom, flexibility and individuality determined by conventional driving.

Table 2 shows details about the test drivers participating in the focus groups.

Table 2: Details about the participants in the focus groups

	Focus group 1			**Focus group 2**		**Focus group 3**		
Participants*	Cevin	Bella	Max	Maya	Lily	Mark	Mia	Jacob
Age and gender	53, m*	45, f	33, m	35, f	43, f	54, m	34, f	59, m
Households size	1	4	4	4	4	3	4	2
Children	0	1h*, 1o*	2h	2h	2h	1h, 1o	2h	3o
Daily transport needs (km)	40-60	60-70	40-60	60-70	60-70	20-40	20-40	0-20

* participants’ names are changed to ensure anonymity; m indicates male and f indicates female; h indicates the number of children living at home; o indicates children no longer living at home.

3.2.3 Participant observation, blogging and field notes

In addition to qualitative interviews and focus groups, the WP3 study also builds upon qualitative data from participant observation, field notes and the TEV participants’ weblogging about their personal experiences. The participant observations were in particular made in relation to the information and mid-term meetings of the trials. The purpose was to observe the operator’s framing of the project, to observe the expectations among the participants and the operators and to discover the operator’s strategic tools of ensuring engagement among the trial participants and commit them to follow the trial scripts and concepts during the test period.

As an important part of the TEV trial, the participants were obliged to blog on a weekly basis about their experiences and feelings related to be a “test driver”. The blog entries were included as a part of the empirical material.

Finally, field notes summing up the experiences from the interviews (including observations about atmosphere, noises, the spatial and material organization of the home etc.) were written right after each qualitative interview with the trial participants. Similar notes were prepared after each focus group.

3.2.4 Quantitative analysis of metering data

In addition to the qualitative methods described above, a quantitative (statistical) analysis was also carried out of the hourly-recorded metering data (delivered by SE) from DNT. On basis of these data, load profiles were developed (both for all participants in DNT and for the sub-sample of households participating both in DNT and TEV). In order to avoid summer and autumn holidays, July, August and October were excluded. Also, May were excluded from the analysis because of start-up problems in the beginning of the TEV trial. Thus, the statistical analysis focuses only on the load profiles of June and September (comparing 2011, 2012 and 2013).

The DNT trial included 184 customers (hereof, 18 customers also participated in TEV). For the purpose of the statistical analysis, meter installations related to farms, second homes or customers within retail or education were excluded from the sample due to the assumption of these having quite different load profiles compared with family homes. This reduced the sample size to 171. Furthermore, households with a negative annual consumption in 2013, which indicates that they had installed PVs after the end of the trials, were also excluded as well as a few customers with insufficient data due to metering fails. This limited the final sample to 159 households, which was divided into three groups (Table 3).

Table 3: Three categories of households in DNT sample. Note: None of the households participating in both DNT and TEV had electric heating/heat pumps or PVs.

Type (sub-sample)	**Number**	**Share of sample (%)**
Households participating in both DNT + TEV	14	9%
Households participating in DNT (with electric heating/heat pump)	31	19%
Households participating in DNT (without electric heating/heat pump)	114	72%
Total	159	100%

First, the load profile for each meter installation (i.e. household) was normalised in relation to the average hourly electricity consumption for the period (100% = average hourly load) for this meter. Next, the average of the normalised load profiles was calculated for each of the three groups above.

4. Results and analysis

The analysis and findings of this study have been reported in a number of research papers and a thesis (see list of publications in Section 1). In this section, we will summarize the main results and analytical findings (with references to papers).

4.1 Review of smart grid development in Denmark and the role of households

Our introductory literature review and review of Danish smart grid projects involving households (Christensen et al., 2013) shows that the mainstream vision of smart grid design and technology is dominated by an “supply-driven” assumption to accomplish demand-side management through consumers “micro-operation” in relation to consuming, storing and producing electricity depending on the overall requirements of the system.

The majority of Danish smart grid projects and activities targeting households can be divided into two different approaches. The first approach (the dominating) focuses on pure technological solutions controlled by automated and/or remote management of appliances controlled by the electricity companies. This approach includes very little participation of consumers. In opposition, the other approach assumes flexibility to be provided through active participation of consumers motivated by information and electricity prices (time-of-use pricing). For both approaches, however, our analysis highlights the risk for technology-centred designs to reinforce un-intended side effects such as rebound effects. Instead of continuing the dominant techno-rational approach to consumption change, it is proposed that interventions – operators and other core actors – should recognise the configurations and complexities of collective performances of inconspicuous electricity consumption in the everyday life. Hence, the theoretical practice-based orientation was set to guide the following analysis in WP3.

4.2 Integration of smart grid technologies in households – changing everyday practices

The qualitative interviews with households participating in the combined DNT and TEV trials demonstrate how the integration of EVs and time-of-use pricing as new smart grid technologies (solutions) influences the everyday practices of the household members (Friis & Gram-Hanssen, 2013). More specifically, the study shows changes in relation to the participants’ driving practices and the timing of their everyday practices more generally.

The new *driving performances* were characterised by test drivers’ increased consciousness about the engines’ energy use and limitations of the battery capacity, which initiated more environmental-friendly driving techniques. Thus, all interviewees expressed how the EV increases their awareness of driving distances and they were in general aware about the electricity consumption while driving and attempting to drive as “economic” as possible. For instance, one interviewee (Anne-Mette) said:

> Well I'm certainly more aware of where I actually drive and it has surprised me how much you actually drive. The EVs' battery capacity makes you incredible aware of, hey, you have again travelled 100 km. (…) well the air-conditioning is only on if it is really necessary.

Also, some interviewees started to bundle their activities (travel destinations) through coordination and planning in order to reduce the number of kilometres and avoiding running "empty" on the battery. For instance, a businessman developed a new routine of coordinating his different appointments with customers and business partners (in time and space) instead of spreading them over the week. He explained:

> Earlier I just randomly threw meetings in [in the calendar] and now I think 'where do you call from? From Aabenraa! Okay what else do I have to do in that area' (…) during the test period I've become much better to cluster my appointments in specific geographical places. (Nicolas)

The above illustrates how the limitations of the battery capacity essentially helped (forced) the participants to develop more energy efficient driving patterns. However, the interviews also indicate that there might be negative unintended implications of increased use of EVs. Thus, almost all interviewees stated that they used the EV more often in comparison with their conventional car. This was due to different reasons such as the interviewees found it "funny" to test the new car, the pleasure of driving an EV or that it feels easier and cheaper to go for a quick "get-away" in the EV. For instance, one interviewee explains:

> I must say that for these short distances into town, well, then I take the electric car rather than walk as I did before. You don't think as much about saving the car engine, because you don't have the same wear on the electric car, as you have on the other. (…) in a diesel car you better drive some longer distances (…). (Hans)

Also, the notion of EV driving as being more environmentally friendly than driving in combustion engine cars made it feel less worse to take the car also for short trips instead of going by bike or foot.

In addition, the EV trial period also seemed to increase the participants' experience of a need for an extra car (i.e. having two cars). However, this is probably a particularity for the TEV trial, as it was a requirement for the households to have a (conventional) car already before the trial.

With regard to the timing of everyday practices (and their related electricity consumption), the interviews show that many of the households managed to time shift their dishwashing, laundry and EV charging to low-tariff hours in the late evening and night. These findings are elaborated in further detail in the following section (and in the papers (Christensen & Friis, 2016; Friis & Christensen, 2016. Friis & Gram-Hanssen (2013) demonstrate that the interviewed participants' engagement in relation to the static time-of-use pricing (DNT) was strengthen by the combination of the two trials (DNT and TEV) and their related technologies/solution. Thus, an interviewee said:

> If we didn't have a car (EV), the benefits of the Project Dynamic Pricing [DNT] would have been incredibly low. (Nicolas)

Thus, the results indicate that there can be strong benefits (mutual reinforcement) from combining different smart grid technologies and solutions.

By scrutinising the different elements configuring the practices, the WP3 study demonstrates how different links and interrelations between the elements of practices (see Chapter 2) developed new driving performances and new practices of postponing dishwashing, laundry and EV charging. However, rather than explaining the high flexibility as a matter of economic incentives (like the EV operators did), Friis & Gram-Hanssen (2013) emphasise the elements of “institutionalised knowledge and explicit rules” and “engagement” as fundamental for the participants’ new practices.

4.3 Time shifting energy demand practices

In Friis & Christensen (2016), the everyday temporal context and implications of the time-of-use pricing scheme *Dynamic Networking Tariffs* are analysed in detail. Following Southerton (2012), we analyse how the temporality of practices are shaped by the collective and personal temporal rhythms as well as how practices are themselves shaping the collective and personal temporality. More specifically, we study how the time shifting of dishwashing, laundry and EV charging influences the temporal rhythms of the household as well as how the efforts and experiences with time shifting these practices are shaped by the shared temporal rhythms of the households (and the institutionalized rhythms of society on a wider scale).

The analysis showed that the time shifting created new “coupling constraints” (Hägerstrand, 1985) in the everyday life of the households, e.g. loading/unloading the washing and dishwashing machine in the mornings, which challenged household members’ (feeling of) control over the temporal organisation of activities and practices in their daily life. Thus, the mornings can be experienced as more time pressured because of the extra doings to be done in the morning, which also threatens the “family togetherness” around the breakfast table (cherished by the families), as demonstrated by the following quotes from the interview with a 42-year old father (Søren):

> (…) we have … to get up a little earlier or take a shorter shower. And Signe [the daughter] has to find her clothes quicker. In the beginning we consequently finished our mornings too fast, which meant that we were actually ready to leave before time.
>
> Before, we were united here in the kitchen, now it is more like one is outside hanging laundry, while another is inside unloading the dishwasher. We have to hurry up a little extra.

Following Southerton’s concept of “hot spots” and “cold spots” (Southerton, 2012; 2003), the new practices of hanging clothes up in the tightly scheduled mornings (hot spots) challenged the cherished qualities like being together (cold spots) around the breakfast table. Thus, time shifting electricity-consuming activities like dishwashing and laundry to the night hours challenge the existing everyday time-patterns (rhythms) of the households and in this way creates experiences of stress and inconvenience.

On basis of this, we recommend future smart grid interventions to be convenient, reliable, predictable and not too time demanding. Further, the analysis indicates that synchronisation between practices (whenever possible) can be important for households’ engagement in time shifting. Thus, the interviews show that the households relatively easily developed a routine of plugging in the recharging cable before going to bed (as part of the “shutting-down-the-home” routine in late evening).

Considering practices as a “nexus of sayings and doings” (Schatzki, 1996), our research compared the interviewees’ “sayings” about (their own) time shifting with the “doings” as represented in the load profiles developed on basis of the hourly-recorded metering data. This first and foremost confirmed the “sayings” by verifying a new peak during the night hours among the households participating in both DNT and TEV (see Figure 2), which indicates that future demand-side management strategies could benefit from combining interventions.

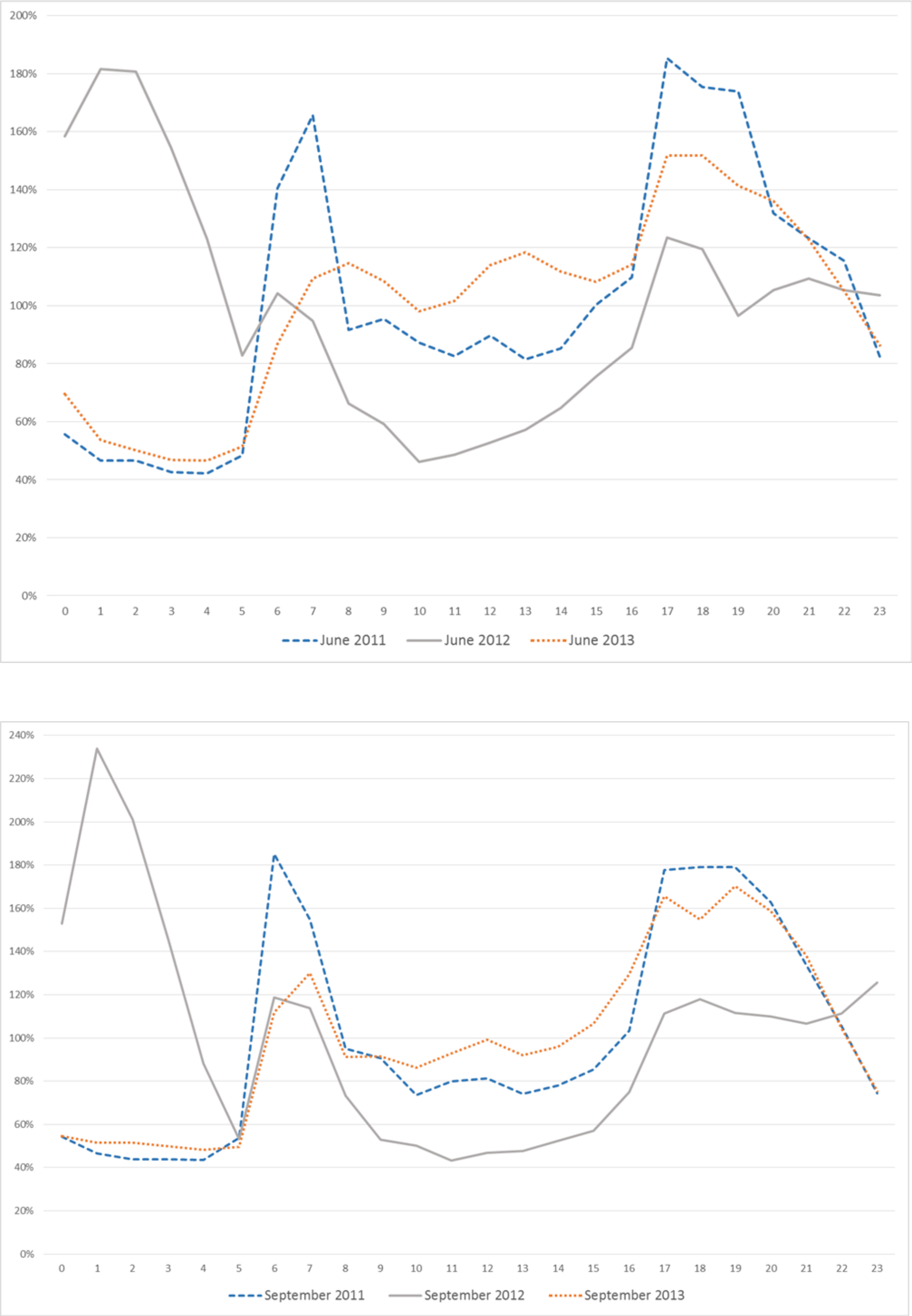


Figure 2: Load profiles of the households with an EV for 2011-2013 for weekdays in June and September. Note: Hours shown on X-axis are in Danish Summer Time. 100% represents the average hourly load of the sample.

Additionally, the study finds that the reason why in particular the practices of dishwashing, laundering and EV charging are time shifted also relates to the fact that these practices involve the use of technologies that semi-automate some of the activities. Thus, the timing of the electricity consumption and the bodily involvement in practices are partly decoupled, which makes it easier to time shift the activities (e.g. postponing dishwashing to the night hours).

Also, the results indicate that static time-of-use pricing schemes (like the Dynamic Network Tariff tested in DNT) are much easier for households to “learn” and “adapt” their everyday practices to in comparison with real-time time-of-use pricing (which the participants were also offered). To follow the real-time prices was perceived as too time demanding as this would require developing an entirely new practice of consulting day-to-day price information and continuous planning of daily practices. This indicates that there are strong benefits of static time-of-use pricing (compared with real-time pricing) because of its simplicity and because it is possible to develop new daily habits and routines, like washing the clothes during the night, which can be incorporated into the temporality of everyday life.

In addition to the above results and observations about the temporal implications of time-of-use pricing, the study also explored the spatial and material implications of time-shifting daily practices, reported in Christensen & Friis (2016). The implications of the materiality and spatial layout of the home are seldom recognised by studies of smart grid solutions, but do nevertheless play an important role. For instance, the noise from dishwashers and washing machines can keep people from postponing dishwashing and clothes washing to the night hours as this disturb their night sleep. Thus, the layout and placing of rooms in the home can have significant influence on the likeliness of getting people to time-shift their electricity consumption. Also, this indicates that the current smart grid demand-side management solutions are primarily designed for detached single-family homes with a large floor space, while it is less probable that noise-making activities can be time shifted to night hours in apartment blocks with close-living neighbours.

4.4 Interventions in mobility practices

The WP3 study also looked into the reasons for the low uptake and non-adoption of EVs. This was based on the initial observation of the missing connection between the slow uptake of EVs (and the EV test drivers’ general rejection of the idea of buying an EV after the trial) and, on the other hand, the claims of the EV operator about the EVs ability to meet car drivers’ needs.

The EV operators’ statistical analysis showed that EVs should be able to cover about 99% of the driving needs of the TEV participants. However, the qualitative study of the participants’ own perspective in WP3 shows a different picture. None of the participants wanted to acquire an EV themselves – mainly due to their experience of the tested engines being incompatible with their everyday transport practices because of limited driving range, lower comfort and security and a high purchase price.

The WP3 analysis (reported in Friis, 2016) demonstrates the need to go beyond existing assumptions about EV adoption. First, the analysis illuminates the mobility operators’ strategy to increase adoption. This analysis is inspired by Spurling and McMeekin’s (2014) conceptualisation of three cross-cutting practice dynamics for successive intervention in mobility patterns. They developed three alternative practice-aligned framings for the successive intervention in mobility patterns: 1) recrafting practices, 2) substituting practices and 3) changing how practices interlock. The WP3 study shows that the intervention by the Danish EV operator to some extend tried to “recraft” and “substitute” conventional driving practices, but failed to consider how practices interlock, which our study finds to be fundamental for sustainable transition.

The design of the TEV trial did not challenge the test drivers’ existing practices related to their daily transport and how these practices interlock. Instead, the operator sought to convince the TEV participants that the EV would meet their existing and future mobility demand. By highlighting the EV's competiveness on the market, the operator did not recognize how driving practices are usually performed in order to accomplish the performance of other practices such as work and leisure activities, grocery shopping etc. The following quote from the focus groups illustrates how car mobility involves a complexity of interlocked practices and activities and how the limited battery capacity (both with regard to driving range and amount of energy for heating of the cabin) creates experiences of inconvenience and lack of comfortability:

> All these thoughts of logistics. I can't drive as far as I need for fulfilling the things that I have planned in my everyday life (…) I have to think much more about my transportation. I have not had the spontaneity to take a detour when someone calls me on the road, and things like that. All the time I had to plan, Oh, all right, what am I going to do today? What car should I take? I am simply used to expect that the car is not something to think about, right. It's just there and simply has to run. It has been way too difficult thinking about these logistics… (Bella).

Another example, also showing how the daily auto mobility consists of sequences of trips related to different activities, is this:

> When I get home there are very few extra kilometres to run on, which means that you really have to consider what to do next (…) some days I had to drive home earlier from work to recharge the battery and make it ready for my evening activities. (Cevin).

Our study emphasises how EVs caused new configurations of systems of interconnected everyday practices (both temporally and spatially), which people were not prepared to accept. In particular, this was the case during wintertime due to increased energy consumption for heating the passenger compartment and low temperatures affecting the battery capacity.

Overall, the empirical results from the focus groups indicate that mobility interventions (like the one implemented by the EV operator) should recognise the system of practices (Watson, 2012) of the current (auto) mobility system. Thus, interventions should acknowledge the path dependency of practice intersections in order to change the level, scale and character of current demand. In correspondence with recent research by authors like Shove et al. (2015), Shove & Walker (2014) and Spurling & McMeekin (2014), this points to a need for new configurations of "normality" in relation to mobility and for bringing the "negotiability of demand" on the political agenda. Moreover, the analysis calls for further conceptualisations of whom, where, when and how to govern the current resource-intensive mobility practices.

Whereas the primary focus in relation to intervention has been on the strategic governance level of the TEV demonstration, the research related to WP3 has also inspired more theoretical discussions of how theories of learning and social interaction could inspire more workable designs for intervention and change of social practices related to energy consumption (Christensen, 2014).

6. Conclusions and recommendations

On basis of the research findings of WP3, summarized in Chapter 5, a number of conclusions and recommendations (policy implications) can be made.

The “techno-economic” or “techno-rational regime” is still dominating the implementation of smart grid technologies targeted households. Within this regime, electrification of the current transportation system is seen as crucial, which implies that EVs are assigned a central role for the future energy system. The mainstream assumption is to accommodate the challenge of increasing fluctuations in the energy system from renewable sources by economic incentives and technological innovation. Following this, designs and strategies are often developed without duly acknowledgement of the complexity of people’s everyday life and social practices.

The studied electric mobility intervention (TEV) only partly acknowledges the complexity of the everyday life of the participating households, and the EV operator to a large extent reproduced the widespread representation of EVs as a substitution for conventional combustion engine cars by underscoring the EV’s ability to cover existing transportation needs. In addition, the intervention draws on the economic rationality by stressing the lower operation costs of EVs.

By demonstrating how everyday habits and routines are interwoven in socio-material systems of consumption, the WP3 study suggests that smart grid operators, and other key actors, should recognise the collective nature of daily practices and how these are interrelated in “systems of practices”.

It is of course important to note that the results from our study of the TEV and DNT trials are influenced by the deficiencies of the involved technologies. Both the EVs and the charging-boxes (for the remotely controlled charging of the EVs) represent first generation mass-produced versions. This has most likely influenced the results. In particular, the participants in the focus groups (who were EV test drivers in the wintertime) experienced the EV as too unsafe, uncomfortable, inconvenient and too expensive.

The study explores the normalised habits and routines related to the energy consumption of people’s everyday life. Our analysis of the combined TEV and DNT trial showed, among other things, that most participants time-shifted their EV charging, laundry and dishwashing activities to low-tariff periods. The qualitative analysis shows that this was in particular due to the participating households’ commitment and engagement with regard to following the operators’ rules and the intentions of the trials. In comparison, economic incentives had a minor impact on developing the new practices. This shows that engagement, commitment and the experience of participating in collective action play a significant role in order to achieve time shifting.

Moreover, the temporality of the everyday life and practices of households are pivotal for the households’ flexibility of time shifting their electricity consumption. Time shifting routines and practices influence the synchronisations and interrelations between social practices and, by doing this, has a high impact on the flexibility.

The analysis of time shifting also demonstrates how social practices are interrelated and dependent on wider systems of practices partly shaped by collective and institutional rhythms and the temporalities of the households and their members. This also involves time constraints that make many everyday practices difficult to time shift (for instance the timing of dinner cooking and working hours). Hence, smart grid solutions and strategies should be aware of (and integrate) the temporalities of practices and households' everyday life (including differences between households).

The study revealed a number of unintended, negative consequences of the smart grid integration. Most alerting was that the test drivers participating in the focus groups (without a time-of-use pricing scheme) plugged-in their EVs when they came home from work. By doing this, the recharging of the EVs coincided with the critical evening load peak between 5 and 7 PM. This demonstrates the need to combine EVs with other measures/solutions (like time-of-use pricing) in order to avoid new or exacerbated peak loads and grid capacity problems. Moreover, several participants expressed that the EV increased the amount of driving trips during the trial and thus replaced bicycle rides and walking. These examples of unintended, negative consequences show exactly why it is so important to take the dynamics of everyday life and daily practices into account when planning and designing smart grid solutions and interventions.

The study also shows that the low uptake of EVs is not only about the lack of economic incentives (such as low taxes on EVs), but is also a result of the current infrastructure and systems of auto mobility being based on the combustion engine car. Auto mobility is a key example of a deeply complex and profoundly embedded socio-technical system, which requires fundamental transition that goes beyond mere technological changes in order to ensure a large-scale reduction in fossil fuel consumption. Employing a system of practices approach suggests interventions to intervene with (and challenge) the systems of practices in which car mobility is embedded. Instead of reproducing traditional approaches and understandings by focusing on technological "fixes" or trying to change people's individual behaviour through information campaigns, our analysis emphasises that reducing fossil fuels on the scale that appears to be necessary requires interventions to change the entire system of resource-intensive practices. "Unlocking" the current systems of practices requires interventions that take into account the path dependency of the present infrastructural systems of (mobility) practices and how they connect with other practices like working practices, grocery-shopping practices and leisure activities. Essentially, such ambitious interventions would bring the "negotiability of demand" on the agenda.

See also the IHSMAG publication "Recommendations and criteria for the design of smart grid solutions for households" (Christensen et al., 2016) for further policy and design recommendations developed on basis of WP3 (as well as the other WPs in IHSMAG).

7. Literature

Bourdieu, P. (1990). *The Logic of Practice*. Stanford University Press.

Bourdieu, P. (1998). *Practical Reason: On the Theory of Action*. Stanford, California: Stanford University Press.

Burgess, J., Bedford, T., Hobson, K., Davies, G., & Harrison, C. (2003). (Un)sustainable consumption. In F. Berkhout, M. Leach, & I. Scoones (Eds.), *Negotiating Environmental Change: New Perspectives from Social Science*. Cheltenham UK: Edward Elgar.

Butler, J. (1990). *Gender Trouble: Feminism and the subversion of identity*. New York: Routledge.

Christensen, T. H. (2014). The role of learning and social interaction for changing practices. 24-27 August 2014, Stockholm, Sweden. *Paper for the workshop "A Social Practice Perspective on the Smart Grid" at the ICT for Sustainability, ICT4S 2014 Conference*.

Christensen, T. H., & Friis, F. (2016) Materiality and automation of household practices: Experiences from a Danish time shifting trial. *Paper Prepared for DEMAND Centre Conference, Lancaster, 13-15 April 2016*.

Christensen, T. H., Friis, F., Ryghaug, M., Skjølsvold, T. M., Throndsen, W., Fernandez, S. R., & Perez, E. S. (2016). *IHSMAG WP5: Recommendations and criteria for the design of smart grid solutions for households - Lessons learned for designers and policy makers from the IHSMAG project*. Copenhagen: Danish Building Research Institute.

Christensen, T. H., Gram-Hanssen, K., & Friis, F. (Eds.). (2013). Households in the smart grid: existing knowledge and new approaches, in Hansson, L.,Holmberg, U. & Brembeck, H. (red.) *Making sense of consumption: Selections from the 2nd Nordic Conference on Consumer Research 2012*. Göteborg: Centre for Consumer Science, University Gothenburg. Kap. 20, pp. 333-348.

Christensen, T. H., & Røpke, I. (2005). Can practice theory inspire studies on ICTs in everyday life? *Paper for the 7th Conference of the European Sociological Association, Torun, Poland*.

Clever's final report. (2014). *Test-En-Elbil Afsluttende Rapport*. Clever.

Darby, S. J., & McKenna, E. (2012). Social implications of residential demand response in cool temperate climates. *Energy Policy*, *49*, 759–769. http://doi.org/10.1016/j.enpol.2012.07.026

Foucault, M. (1978). *The History of Sexuality*. New York: Pantheon Books.

Friis, F. (2016). *Integrating smart grid solutions within everyday life: A study of households practices related to electric vehicles and time-of-use pricing*. Aalborg University, Danish Building Research Institute.

Friis, F., & Christensen, T. H. (2016). The challenge of time shifting energy demand practices: Insights from Denmark. *Energy Research & Social Science*, ?(?), ?

Friis, F., & Gram-Hanssen, K. (2013). Integration of Smart Grid Technologies in Households: How Electric Vehicles and Dynamic Pricing change Social Practices in the Everyday Life? *Proceedings of ECEEE 2013 Summer Study 2013. Lindström, T. L. (Red.). European Council for an Energy Efficient Economy, ECEEE, S. 1019-1030 12 S. (ECEEE Summer Study, Vol. 2013).*

Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy*, *39*(4), 495–510. http://doi.org/10.1016/j.respol.2010.01.022

Giddens, A. (1984). *The Constitution of Society: Outline of the Theory of Structuration*. Cambridge: Polity Press.

Gram-Hanssen, K. (2011). Understanding change and continuity in residential energy consumption. *Journal of Consumer Culture*, *11*(1), 61–78. http://doi.org/10.1177/1469540510391725

Hägerstrand, T. (1985). *Time-Geography: Focus on the Corporeality of Man, Society, and Environment. The Science and Praxis of Complexity*. Tokyo: The United Nations University.

Halkier, B. (2010). Focus groups as social enactments: integrating interaction and content in the analysis of focus group data. *Qualitative Research*, *10*(1), 71–89. http://doi.org/10.1177/1468794109348683

Halkier, B., & Jensen, I. (2008). Det sociale som performativitet - et praksisteoretisk perspektiv på analyse og metode. *Dansk Sociologi*, *19*(3), 49–68.

Hargreaves, T. (2011). Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change. *Journal of Consumer Culture*, *11*(1), 79–99. http://doi.org/10.1177/1469540510390500

Hargreaves, T., Longhurst, N., & Seyfang, G. (2013). Up, down, round and round: connecting regimes and practices in innovation for sustainability. *Environment and Planning A*, *45*(2), 402–420. http://doi.org/10.1068/a45124

Kvale, S. (1996). *InterViews: An Introduction to Qualitative Research Interviewing*. Sage Publication Inc, London.

Latour, B. (1993). We Have Never Been Modern — Bruno Latour | Harvard University Press. http://www.hup.harvard.edu/catalog.php?isbn=9780674948396

McMeekin, A., & Southerton, D. (2012). Sustainability transitions and final consumption: practices and socio-technical systems. *Routledge*, *Vol. 24*(No. 4), 345–361.

Morgan, D. L. (1997). *Focus Groups as Qualitative Research*. Sage Publications.

Reckwitz, A. (2002). Toward a Theory of Social Practices: A Development in Culturalist Theorizing. *European Journal of Social Theory*, *5*(2), 243–263. http://doi.org/10.1177/13684310222225432

Schatzki, T. (1996). *Social practices: A Wittgensteinian Approach to Human Activity and the Social*. New York: Cambridge University Press.

Schatzki, T. R., Knorr-Cetina, K., & Savigny, E. von. (2001). *The practice turn in contemporary theory*. London; New York: Routledge.

Shove, E. (2003). *Comfort, Cleanliness and Convenience: The Social Organization of Normality*. Oxford: Berg Publishers.

Shove, E. (2010). Beyond the ABC: Climate Change Policy and Theories of Social Change. *Environment and Planning A*, *42*(6), 1273–1285. http://doi.org/10.1068/a42282

Shove, E., & Chappells, H. (2001). Ordinary consumption and extraordinary relationships: utilities and their users. In J. Gronow & A. Warde (Eds.), *Ordinary consumption*. London: Routledge.

Shove, E., & Pantzar, M. (2005). Consumers, Producers and Practices: Understanding the invention and reinvention of Nordic walking. *Journal of Consumer Culture*, *5*(1), 43–64.

Shove, E., Pantzar, M., & Watson, M. (2012). *The Dynamics of Social Practice: Everyday Life and How it Changes*. London: Sage.

Shove, E., & Walker, G. (2014). What Is Energy For? Social Practice and Energy Demand. *Theory, Culture & Society*, 263276414536746. http://doi.org/10.1177/0263276414536746

Shove, E., Watson, M., Hand, M., & Ingram, J. (2007). *The Design of Everyday Life*. Berg Publishers.

Shove, E., Watson, M., & Spurling, N. (2015). Conceptualizing connections: Energy demand, infrastructures and social practices. *European Journal of Social Theory* 18(3), 247-287. http://doi.org/10.1177/1368431015579964

Southerton, D. (2003). Squeezing time: Allocating practices, coordinating networks and scheduling society. *Time & Society*, *12*(1), 5–25.

Southerton, D. (2012). Habits, routines and temporalities of consumption: From individual behaviours to the reproduction of everyday practices. *Time & Society*, *22*(3), 335–355. http://doi.org/10.1177/0961463X12464228

Southerton, D., Chappells, H., & Van Vliet, B. (Eds.). (2004). *Sustainable Consumption: The Implications of Changing Infrastructures of Provision*. Cheltenham UK: Edward Elgar Publishing Limited.

Spaargaren, G., & Van Vliet, B. (2000). Lifestyles, Consumption and the Environment: The Ecological Modernisation of Domestic Consumption. *Environmental Politics*, *9*(1).

Spradley, J. P. (1979). *The Ethnographic Interview* (11th printing ed.). New York: Fort Worth: Holt, Rinehart and Winston.

Spurling, N., & McMeekin, A. (2014). Interventions in practices. In *Social Practices, Intervention and Sustainability - Beyond behaviour change*.

Strengers, Y., & Maller, C. (2014). *Social Practices, Intervention and Sustainability: Beyond behaviour change*. Routledge, London.

Warde, A. (2005). Consumption and Theories of Practice. *Journal of Consumer Culture*, *5*(2), 131–153. http://doi.org/10.1177/1469540505053090

Watson, M. (2012). How theories of practice can inform transition to a decarbonised transport system. *Journal of Transport Geography*, *24*, 488–496. http://doi.org/10.1016/j.jtrangeo.2012.04.002

TECHNOLOGICAL CHALLENGES AND SOLUTIONS AT THE HOUSEHOLD LEVEL

Practical approach: development of a user interface

Sandra Riaño Fernández
TECNALIA

Eutimio Sánchez Pérez
TECNALIA

This report presents the outcome of work package WP4 TECHNOLOGICAL CHALLENGES AND SOLUTIONS AT THE HOUSE-HOLD LEVEL of the ERA-Net SmartGrids project "Integrating households in the smart grid" (IHSMAG)

This report is published as part of the ERA-Net SmartGrids project “Integrating households in the smart grid” (IHSMAG). See www.ihsmag.eu for further information.

CONTENT

Summary

The aim of WP4 is to detect technological challenges related to the integration of households as an actor of the smart grid system, and then provide designers, planners and policy-makers with a set of criteria, which tries to overcome the barriers related to smart grid solutions at the household level. This WP also tries to identify intermediate steps that could be taken to progress in the process.

From this perspective, a practical approach has been chosen: to develop a user interface which monitors end user consumption and provides them with recommendations aimed to change their consumption patterns. This interface, which is called Home Display, has been introduced as the key tool of a test pilot involving real households.

1. Introduction

This report is an outcome of work package WP4 Technological challenges and solutions at the household level of the project *Integrating Households in the Smart Grid* (IHSMAG), which involves partners from Norway, Denmark and the Basque Country (Spain). The aim of IHSMAG is to contribute with knowledge of how to develop comprehensive designs of smart grid solutions that involve households in the smart grid.[6]

WP4 is headed by ZIV Metering Solutions with the support of Tecnalia Research & Innovation. This work package focuses on the technological challenges related to the development of smart grid solutions in households. The role that households are able to play in the future smart grids is being estimated as highly relevant by the experts, but this role would not be fulfilled without a suitable automation of the building and smart grid system adaptation.

Until very recently households have not been considered as a relevant stakeholder of the smart grid system. Therefore, this WP deals with technical barriers linked to introducing a new member that has not been taken into account in the system deployment.

The most relevant challenges at this level include problems of interoperability, development of communication standards, lack of household appliances with communication and control capabilities, lack of on-line consumption display devices and the necessity of keeping a balance between reachable information and privacy data.

WP4 is not only aimed to provide designers, planners and policy-makers with a clear picture of the technical issues and barriers related to smart grid solutions at the household level, but also identify intermediate steps that could be taken to advance the process.

A practical approach of developing an advanced monitoring tool has been chosen, so technical barriers could be in some way tested, rather than merely theorizing, making feasible the proposal of realistic intermediate steps to integrate the household in the smart grid. This tool, called Home Display, is an application, which runs on smart devices, such as smart phones and tablets. This approach is detailed in the following chapters.

---

[6] For more information about the IHSMAG project, see the website: www.ihsmag.eu

2. Approach

In order to develop a set of design criteria for introducing smart grid solutions at household level, taking into account their technical context and their everyday practices, a practical approach has been adopted.

Thus, a user interface, which is called the Home Display, has been developed. This user-friendly interface provides the users with information about their electrical consumption. Besides monitoring the electrical consumption, the developed display tool includes some active demand management capabilities, taking in some way the smart grid system and its regulatory rules into consideration.

Within the scope of Home Display development, a test pilot involving households, electrical equipment manufacturers and distribution system operators has been done in Spain. In this way, assumptions and solutions suggested in this WP have been clarified through real users and equipment.

The Home Display application faces the challenge of introducing the end user as an actor of the smart grid without expensive deployment. Following the approach of proposing realistic intermediate step, the developed Home Display uses wireless communications, communicating with existing equipment and adapting the access to the current system to the household technological requirements.

Current context of smart grid communications

It has been considered that the smart grid system integrates an Advanced Metering Infrastructure (AMI) composed by smart meters, metering data concentrators and a central dispatch at least. Although this entire infrastructure is provided by the Distribution System Operator, the commercialization companies are in charge of end user billing. So, the AMI is used to measure, price and in some cases control end user consumptions.

Data concentrators and central dispatch are accessible through internet via IP communications like TCP or GSM/GPRS/3G.

This means, on the one hand, that end users could somehow reach the data stored in these systems through internet.

On the other hand, using the existing smart grid equipment requires having advanced knowledge about the communication protocol used by the distribution system operator. And, what is more, it implies accessing to sensitive information related to customers' electrical and related economic data. So, it is mandatory to achieve secure communications which will ensure a safe exchange of confidential data.

The technology selected through the specification phase of Home Display deployment covers all the requirements mentioned above, and that is the Web Services.

Web Services technology is a method of communications between two electronic devices over the World Wide Web, with specific protocols related to how integrity and confidentiality can be enforced on messages.

Taking advance of the widespread access to internet, and fitting with existing communications standards, Web Services remains as a good choice to face Home Display communications with smart grid system.

Current context of automation at the houses

The first problem detected while designing a general interface is the unequal degree of automation at the houses. Trying to find a practical approach to this implementation, an analysis of the most commonly used technologies at this level has been done. This analysis has aimed to highlight the following facts:

- the widespread Internet access that European inhabitants enjoy
- the complementary role to the PC played by the tablets and smartphones nowadays
- the lack of automated household appliances, and the difficulties to improve this issue when the Spanish manufacturers are a sector affected negatively by the global economic crisis

The monitoring application developed has been designed taking advance of these facts. This way seemed sensible to implement a monitoring application for end users, which does not imply buying a new device, and to reject those solutions, which require proprietary protocols while still using a standard hardware.

Final approach

Built on the premise that the Home Display must be a cost effective solution, all the facts mentioned at previous subchapters have led to develop the Home Display as an app under open operating systems, which will run in the smart devices owned by the households (tablets or smart phones).

The visual interface has been implemented as a separated module, which allows being encapsulated for different operative system, such Android or iOS. Moreover, the visual interface is independent of the communication module fulfilling data from smart grid system. These points ensure long-term flexibility for the Home Display application.

Furthermore, a test pilot with real households interacting with the smart grid system through the developed Home Display has also been deemed necessary. This test pilot complete a compelling practical approach to the challenge of gathering a set of criteria related to technological barriers and solutions of integrating households in the smart grid.

3. Method

This chapter describes the method applied to obtain the recommendations and conclusions related to technical challenges and solutions at the household level.

System architecture

Home Display has been designed to fit within the current smart grid system, and also it is flexible enough to allow future developments. In this spirit, the architecture appearing at next figure has been selected.

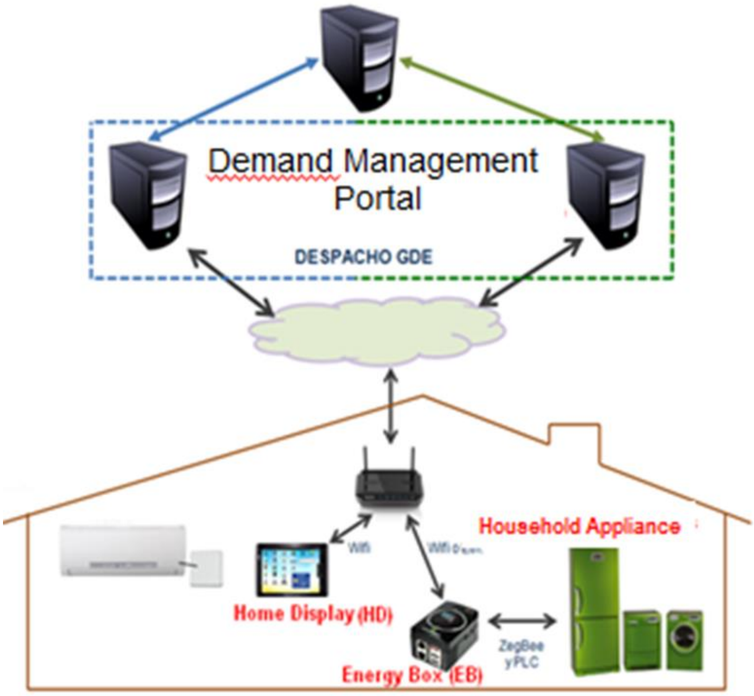


Figure 2: Architecture for Home Display integration

The elements are described in the following subchapters.

Demand Management Portal

This element is a dedicated server to exchange data with the other two elements at household level (Energy Box and Home Display).

The current smart metering system is focused on billing consumption of end user and this fact has performance implications:

- Existing data concentrator devices gather consumption of meters once per day
- Communications are slow, because speed for retrieving consumption data is not critical, so they are used for billing purposes

In this context, a dedicated server to interchange data with end users is necessary, in order to separate smart grid performance for pricing and performance for integrating households.

Home Display

This is the application that works as end user interface. In order to offer useful information, it communicates with the Demand Management Portal and with the Energy Box appliance. Home Display characteristics, performance and other issues are detailed through the document.

Energy box and household appliances

The Demand Management Portal allows end users to access their total consumption through the Home Display application. However, this aggregated consumption seems to be insufficient if the objective is to increase household awareness about their consumption.

For this reason, the Energy box concept has been introduced at the architecture. Energy Box is a dedicated device, which interacts with some kind of smart household appliance, providing disaggregated consumption data. Furthermore, Energy Box is able to shift certain cycles of appliance performance to more appropriated consumption periods from the smart grid system point of view.

Platform requirements

The technical requirements related to the platform in which Home Display has been developed are listed below.

Programming language

HTML5 has been chosen as programming language, since it is the last revision of core technology markup language used for structuring and presenting content for the World Wide Web. It is the best option to develop a flexible application to run in Smartphones or Tablet, because it is portable to multiple operative systems, such as Windows, Android or iOS.

Hardware requirements

Due to the wide range of devices, and in spite of the theoretical portability of HTML5, it has been mandatory to optimize the developments by choosing a specific device with a specific screen resolution. In this case, the device is a Nexus 7”, with 1280x800 pixels screen.

Moreover, as it has been developed using HTML5, the application is portable to PC, as long as Google Chrome is used as navigator. Obviously, all touch-sensitive features are not available for PC.

Software requirements

Despite the theoretical portability to the vast majority of operating system, and focusing on the correct performance of the Home Display application, it has been developed to run on Android 2.3 or higher.

Moreover, the design has been done taking into account the portability to iOS operating system.

Functional requirements

The Home Display application must performance as a user interface, providing the suitable information, which may cause changes at electrical consumption patterns.

Following this approach, functional requirements have been defined as data received by application, and data sent by application

Data received by application

The application must monitor data, which contribute to modify the consumption pattern of households, and also keeping in mind that the main aim is to integrate them into smart grid system.

The conducted analyses have gathered the following set of data as relevant to fulfil those objectives:

- Hourly total consumption of electricity
- Daily total consumption of electricity
- Hourly disaggregated consumption of smart appliances
- Daily disaggregated consumption of smart appliances
- Daily average consumption
- Daily desired consumption curve (by the utility)
- Hourly qualitative recommendation with the aim of modifying consumption pattern
- Information about environmental impact of individual consumption.

Data sent by application

The main objective is to integrate the end user in the smart grid system, so not only obtain or provide data about their consumption is needed, but also it is sensible to somehow take their opinion into account.

Accordingly, the following data have been identified as interesting for the utility:

- Navigation data: most popular screens and this kind of information.
- End user feedback: opinion, comments
- Timeline about accepted and rejected recommendations
- Application start-up and closure time
- Errors

Not considered data

Other data have been examined, but they have not been included within the scope of the Home Display, such as:

- Energy cost, due to the reluctance of utilities involved at Spanish IHSMAG Advisory board to include this data at the interface and because this is based on DSO (Distribution System Operator) data, not on contractual or commercialization data.
- Quantitative recommendation of consumption (hourly target numeric values of power (kW) for one week), due to the inefficiency of this kind of signal. This is because the disaggregated consumption is not available at the vast majority of homes, and due to the little scope for action at household level. Quantitative recommendations are more targeted to industrial consumers.

Visualization features

This subchapter details the visualization requirements fulfilled by the Home Display application. This interface has the following screens:

- Login
- Daily consumption (per hour)
- Monthly consumption (per day)
- Notifications
- User area
- Help

Moreover, a toolbar has been added to the top of the screen.

Toolbar

There is a toolbar located at the top of screen, aimed to make navigation easier. The following figure shows the toolbar, and the features are listed below.

Figure 3: Home Display toolbar

- Consumption semaphore: It indicates if there are recommendations for the current hour or not, through its colour:
    - Grey: there is not any recommendation
    - Green: it is a period suitable for consuming electricity
    - Red: it is recommendable to shift consumption to a later period (postpone consumption)
- Notification icon: Indicates that new recommendations for the following days have been received, changing its colour from grey to orange. It is also a direct access to Notifications screen.
- Menu: Provides a shortcut to all the screens of the application

Login screen

This screen only appears where the login and password are not at application internal database. It is necessary to ensure confidentiality of consumption data.

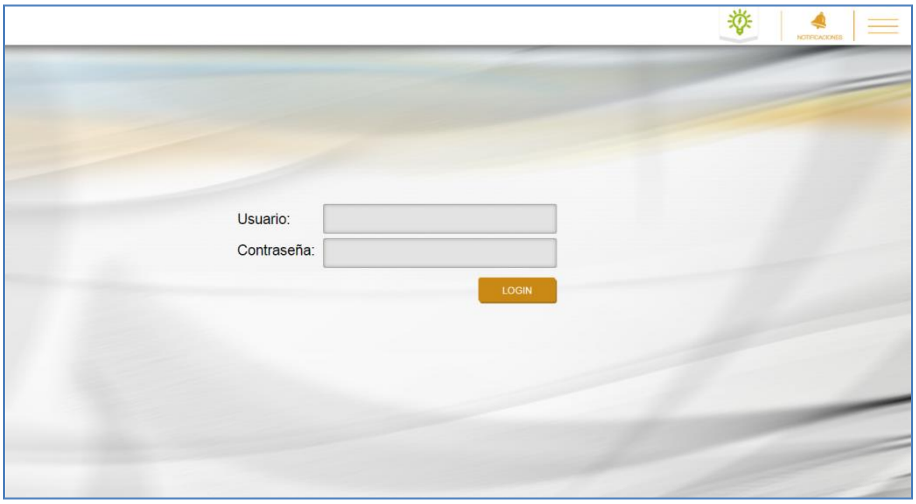


Figure 4: Login screen

Daily consumption screen

This screen shows the daily consumption, providing data for each hour. The following data are shown:

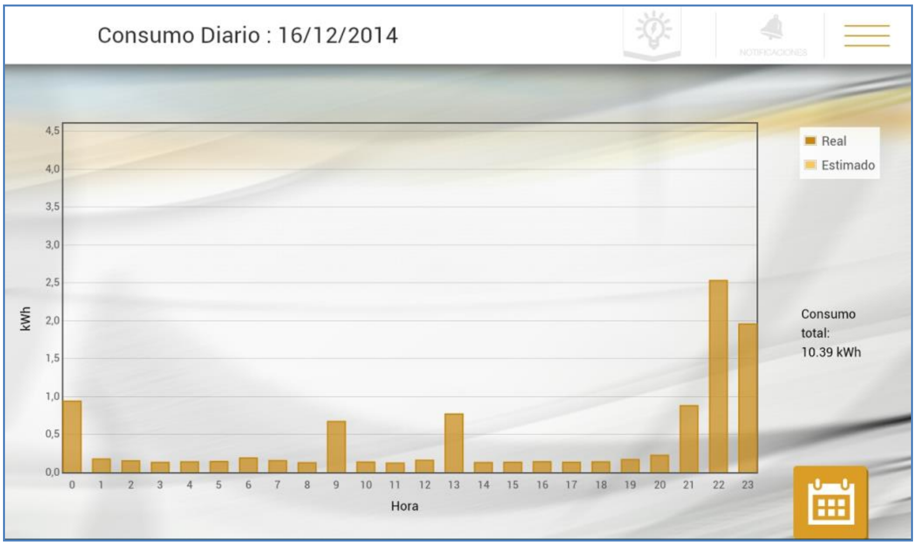
- Date
- Total energy consumed at home during the whole day
- Aggregated energy consumed at each hour of the day
- House appliance consumption during the whole day (if Energy Box and smart appliance are available at home)
- Household appliance hourly consumption (if Energy Box and smart appliance are available at home)

There are some constraints related to this set of data:

1. Only data among test pilot valid dates are displayed
2. If there is not an Energy Box or Smart household appliance, only the aggregated consumption is displayed.
3. Full scale of consumption graph is calculated per each end user on the basis on the contracted power
4. Hourly consumption data are shown with different colour if they are real data obtained from the meters, or if they have been estimated by the DSO (Distribution System Operator)

Furthermore, the following user actions are available:

- Drag to right: It shows the previous day screen.
- Drag to left: It shows the following day screen
- Calendar: It shows a pop-up calendar to select the date. Clicking a specific day, it navigates to that day consumption screen.


Consumo Diario : 16/12/2014

Consumo total: 10.39 kWh

Figure 5: Daily consumption screen without Energy Box

Monthly consumption (per day) screen

This screen shows the monthly consumption, with data per day. The following data are provided:

- Month
- Total energy consumed at home during the whole month
- Aggregated energy consumed at each day of the month
- House appliance consumption during the whole month (if Energy Box and smart appliance are available at home)
- Household appliance daily consumption (if Energy Box and smart appliance are available at home)

There are some constraints related to this set of data:

1. Only data among test pilot valid dates are displayed
2. If there is not an Energy Box or Smart household appliance, only the aggregated consumption is displayed.
3. Full scale of consumption graph is calculated per each end user on the basis on the contracted power
4. Daily consumption data are shown with different colour if they are real data obtained from the meters, or if they have been estimated by the DSO

Furthermore, the following user actions are available:

- Drag to right: It shows the previous month screen.
- Drag to left: It shows the following month screen (if available)
- Calendar: It shows a pop-up calendar to select the date. Clicking a specific date, it navigates to that month consumption screen.

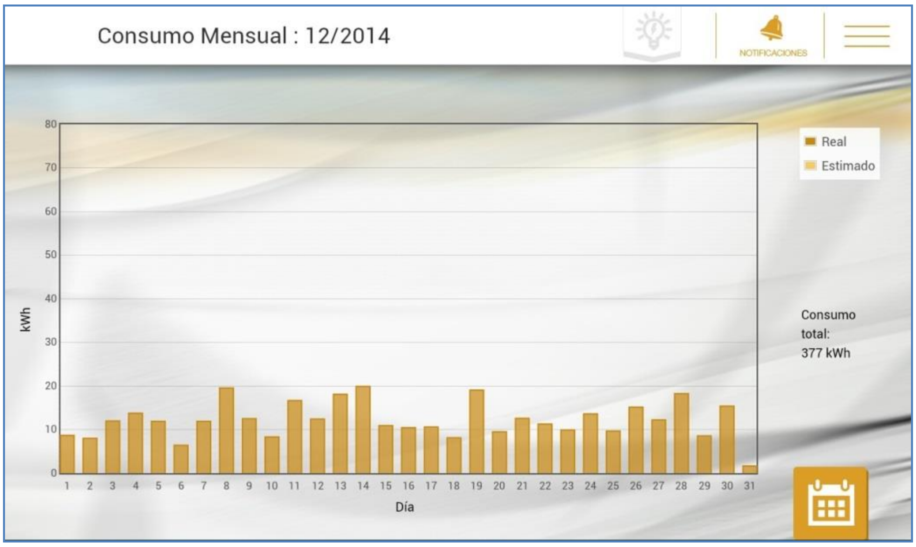


Figure 6: Monthly consumption screen without Energy Box

Notifications screen

Once the shortcut icon at the toolbar changes its colour to orange, users are suggested to navigate to Notification screen, where new qualitative recommendations for the following days are listed.

These recommendations are qualitative, indicating if a period is suitable for energy consumption or if it would desirable to shift some consumption to another period. If there is not any recommendation for one period, it is not listed, because the main objective is to focus user attention to the existing suggestions.

These qualitative recommendations are shown for each current hour at the tools bar semaphore, so this screen, together with the User Area screen, allows the users to plan their future consumption.

Fecha	Hora	Suceso
Wednesday, December 17, 2014	06:00:00	Momento apropiado para un mayor consumo
Wednesday, December 17, 2014	07:00:00	Momento apropiado para un mayor consumo
Wednesday, December 17, 2014	16:00:00	Modere su consumo, por favor
Thursday, December 18, 2014	07:00:00	Momento apropiado para un mayor consumo
Thursday, December 18, 2014	08:00:00	Momento apropiado para un mayor consumo
Thursday, December 18, 2014	20:00:00	Modere su consumo, por favor
Saturday, December 20, 2014	06:00:00	Momento apropiado para un mayor consumo
Saturday, December 20, 2014	07:00:00	Momento apropiado para un mayor consumo

Figure 7: Notifications screen

User Area screen

This screen is focused on increasing the users' awareness about their consumption impact. For this reason, the environmental impact of their previous day consumption is shown when they access this screen, accompanied with an image, which reflects whether the consumption has been environmental friendly or not.

Moreover, all the recommendation for the current day and the following ones are shown in a graphical way:

- Red mark at clocks means that in this period consumption is not recommended.
- Green mark at clocks means that this period is suitable for consume electricity.

Calendar shortcut allows selecting the following days with recommendations in order to show them at screen clocks. As said before, this screen works together with Notifications one, where recommendations are available in text format.

Additionally, there is the possibility for users to send comments to the utility, through the text box that is below the image working as environmental semaphore.

Área de Usuario : 16/12/2014

Analizando el impacto ambiental de su consumo eléctrico del 15/12/2014, su comportamiento ha sido bueno

Indique las medidas que ha llevado a cabo

Figure 8: User Area screen (16/12/2014)

Área de Usuario : 17/12/2014

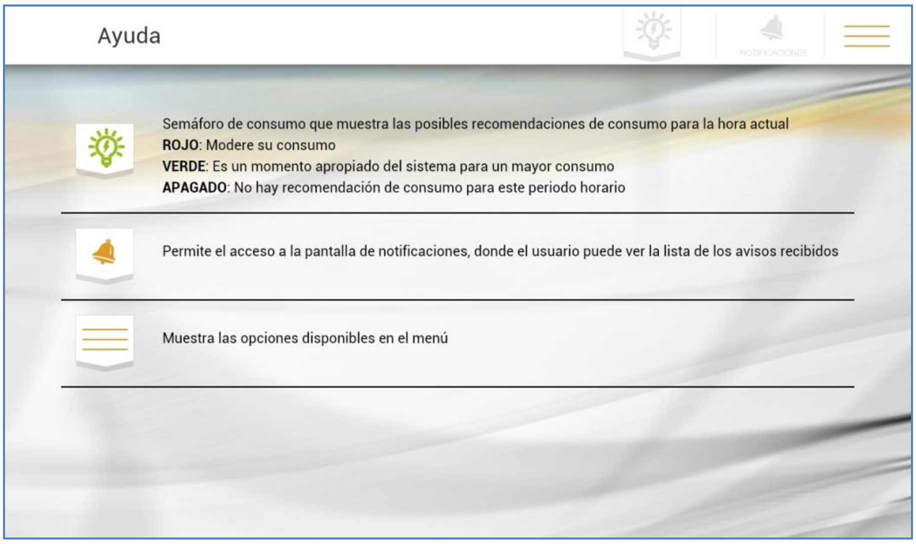
Analizando el impacto ambiental de su consumo eléctrico del 15/12/2014, su comportamiento ha sido bueno

Indique las medidas que ha llevado a cabo

Figure 8: User Area screen (17/12/2014)

Help screen

This screen lists the features of the toolbar, previously detailed.



Ayuda

Semáforo de consumo que muestra las posibles recomendaciones de consumo para la hora actual
ROJO: Modere su consumo
VERDE: Es un momento apropiado del sistema para un mayor consumo
APAGADO: No hay recomendación de consumo para este periodo horario

Permite el acceso a la pantalla de notificaciones, donde el usuario puede ver la lista de los avisos recibidos

Muestra las opciones disponibles en el menú

Figure 9: Help screen

Communication requirements

As written earlier in the “Approach” chapter, the Home Display application must communicate with the smart grid system, and web services technology has been selected as the best approach.

This technology follows a standard, and it allows enough flexibility to consider Home Display as a generic solution. This application works as Web Service client, while the Demand Management Portal (at DSO) is the Web Service server.

Taking the nature of the application into account, as well as its context, two issues have been considered:

- Cyber security
- CORS (Cross Origin Resource Sharing) protocol

They are explained in the following subchapters.

Cyber security

All communications through Web Services between Home Display and the Demand Management Portal must be cyber secure. The server holds confidential data about consumption of end user, and access to data of other users must be impossible.

In this case, two solutions have been offered to ensure cybersecurity:
- The access to server is done via login and password
- The Demand Management Portal has encrypted its communications using a trusted certificate from a Certification Authority (CA).

This way the clients connecting to this server (tablets or smartphone where Home Display runs) are assured to be involved in safe communications, where access to confidential data is password-protected.

CORS (Cross Origin Resource Sharing) protocol

The nature of the application, which has been developed in HTML5, adds a problem to the Web Services communications. This is that, due to security matters, a web navigator only is able to serve information to pages belonging to the same domain that request the info, in order to avoid undesired access to the information.

The Home Display application belongs to the domain of the local system where the device runs. In addition, it is needed that it can retrieve information from the domain of the web server, which is obviously different from the local system.

In order to overcome this technical constraint, there are two possible solutions:

1. Using CORS protocol: On the one hand, CORS protocol has been defined by the World Wide Web Consortium (W3C) to regulate the access of web navigators to the servers from other domains. Both sides of communication (client and server) must implement the protocol to avoid the problem.
2. Restrict the performance of the Home Display to smart devices (tablets and smart-phone). On the other hand, the development environment of smart devices applications encapsulates them overcoming the technical constraint of cross domain access. If the server does not implement the CORS protocol, Home Display runs properly on tablets and smartphone. Unfortunately, the portability of HTML5 to PC platforms would be wasted, since the visual interface would work in this platform, but communications to server would not.

Taking the opinion of Spanish Advisory Board into account, and focusing in the main objective of the Home Display development, which is designed to run on smart devices, the second solution was selected.

3. Analysis and results

This chapter combines the analysis carried out and the obtained results.

Design changes during implementation phase

During the Home Display implementation phase there has been some modifications to the application design. Some of them have been caused through the normal process of redefinition, but others have been caused for external facts beyond the implementation control. All of them are described below.

Due to causes beyond the implementation control

During the implementation phase, one of the members of the Spanish Advisory Board went bankrupt. This member was the one providing smart household appliance for the test pilot. With this withdrawal, all the features related with Energy Box and its related smart household appliances were not included in the test pilot with real users. Therefore, only tests in laboratory environment could be done.

On the one hand, some technical features such as communications have been tested. But on the other, the results are not linked to real end user experiences, so no conclusions to its convenience could have been taken.

The figures below show how the screens were designed to display smart appliance daily consumption, as well as the monthly one.

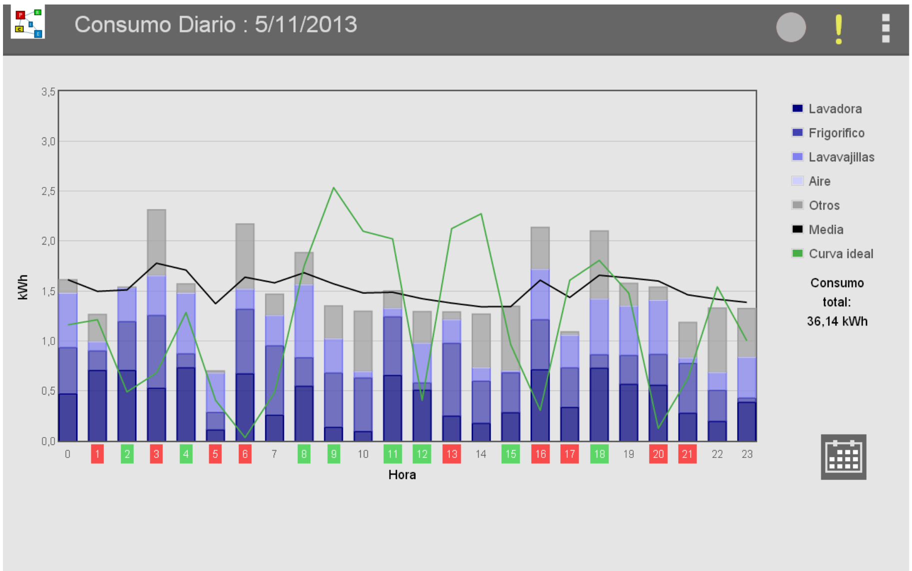


Figure 10: Designed screen for daily consumption including appliances

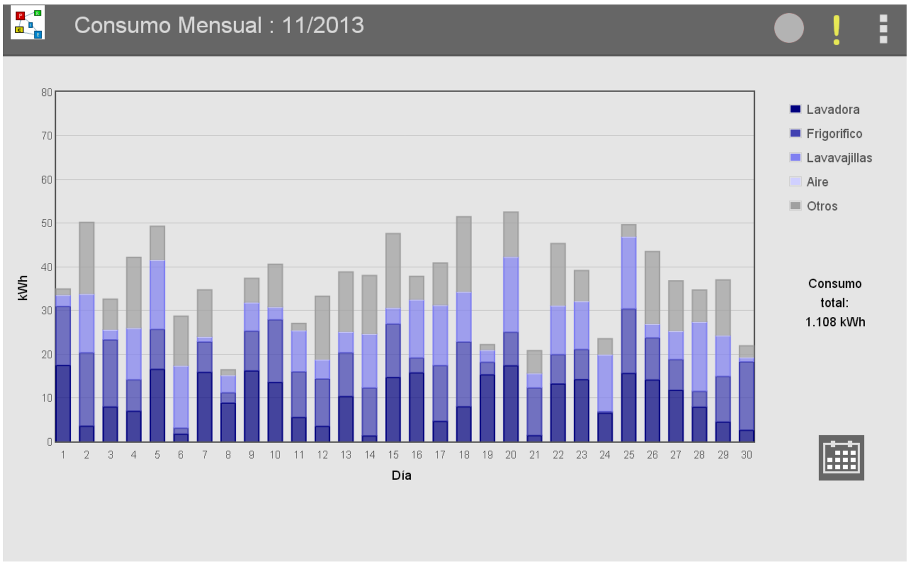


Figure 11: Designed screen for monthly consumption including appliances

These two figures also apply to some of the changes between the designed Home Display and the final test pilot implementation. All these changes are mentioned in the following subchapter.

Due to design improvement

During the implementation phase, the Spanish Advisory board suggested some changes at the design of Home Display, trying to improve the features of the Home Display. Some of them were also motivated by the withdrawal of the manufacturer of household appliance.

All the changes related to design improvement are listed below.

1. Besides functional changes, the Home Display application has undergone a radical aesthetical change. This change aims to increase the user's overall trust, offering a more professional image of the application, despite of being part of a test pilot. And, of course, it also aims to engage more users through an attractive design.

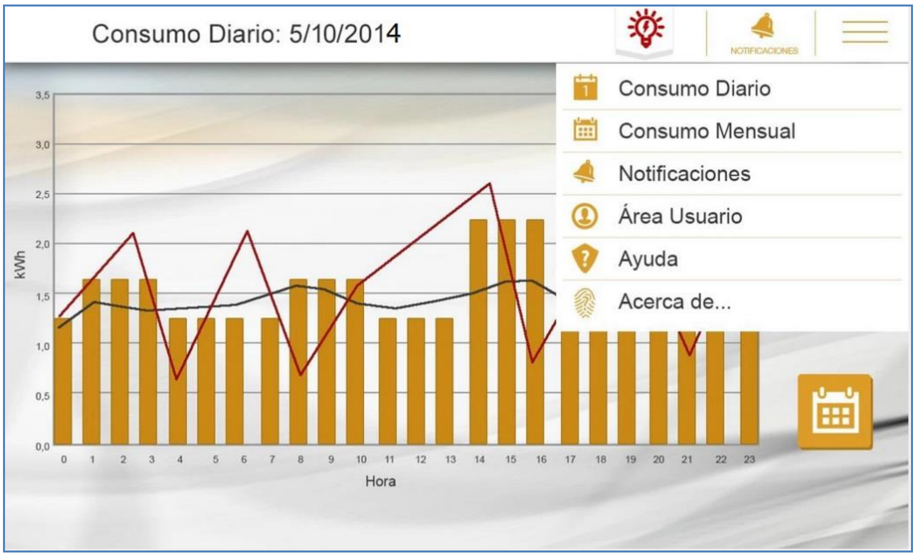


Figure 12: Aesthetical changes of Home Display

2. Elimination of average aggregated consumption: It was considered that the average of the aggregated consumption did not offer relevant information, and maybe the user would prefer a simpler screen.
3. Curve of utility hourly desired consumption: This data was offered afterwards, when the consumption of previous days was checked. It was considered that the real time semaphore indicating whether the period is suitable for consumption or not was more efficient to succeed in achieving changes in consumption pattern. Following the approach of displaying only the more relevant information in Home Display, this curve was deleted from the final version.
4. Full scale of consumption graph has been adjusted on basis on the contracted power of each user of Home Display, trying to optimize the visualization of data.
5. Display of estimated values, changing the colour at graphs. Something not taken into account during the design was communication problem between meters and the Demand Management Portal. In other words, if one meter is not able to transmit all the required data in the time that the portal considers appropriate, some data will be missed at the Home Display. As no data means zero value, it would be the same display as no consumption. In order to avoid misleading information, the Demand Management Portal fills the missing data from meters with estimated values based on historical consumption for the user. As these values may differ from real ones, estimated data are displayed with a different colour, and it is indicated at chart legend.
6. The inclusion of estimated values has increased the number of colours at consumption screen, so the Spanish Advisory Board decided to eliminate the colour marks at abscissa axis, those which indicates whether a recommendation had been sent in this hour or not. Again, this decision was motivated in favour of clarity and simplicity.
7. Feedback about the usability of the Home Display has been marked as relevant by the Advisory Board. Therefore, some statistics about screen usages are sent to the Demand Management Portal.
8. Another minor change has been adding a message to inform to the user if the server is out of order when trying to retrieve data. From the same perspective, adding an email to contact in case of any problem has been decided.
9. Besides the existence of the help screen, a more detailed user manual of the application has been considered as useful, and it is available at the test pilot web.

Test pilot

The analysis of the results has been contrasted through a test pilot with real end users.

Test pilot description

This test pilot took place from September 2014 to January 2015 at the Henares Corridor area, a residential and industrial area around Henares River, which flows between the cities of Madrid and Guadalajara. It has more than 500,000 inhabitants.

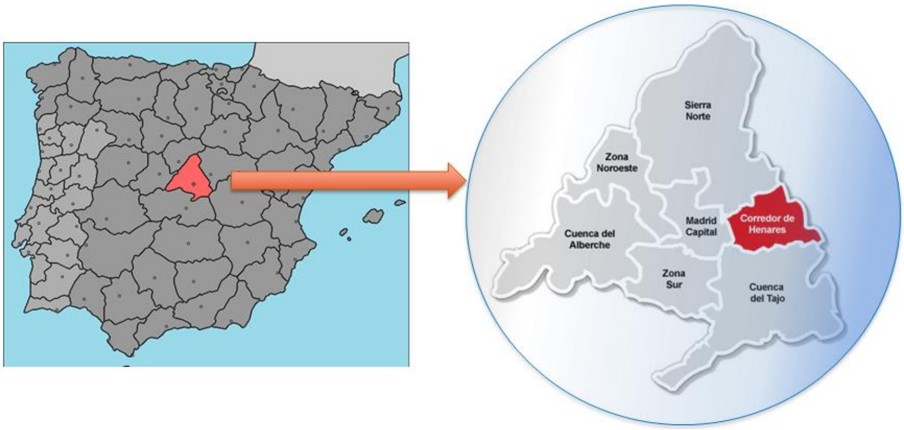


Figure 13: Henares Corridor area

The test pilot offered the opportunity of monitoring their consumption to the Henares inhabitants, with the objective of knowing whether the displayed information was useful or not, and whether it helps to optimize the electrical consumption or not.

Massive mailing aimed to recruit volunteers for the test pilot was launched in August 2014, because there was an ambition of enrolling around one thousands of household. 8,000 letters have been sent to Spanish utilities customers. In addition to the mailing, information campaigns took place at local entities, such as Universities and among Advisory board members. The challenge for this recruitment was to involve at least 1,000 volunteers, following this process:

1. If no letter had been received, a simplified Web application form could be filled to validate whether the house was within the pilot scope or not.
2. Once the end-users had received the letter or validated their home location, they could fulfil the adhesion form in the pilot Web. At this step, legal implications of their involvement and restricted use of information were communicated to the households. It is important to stress that users were given adequate notice of the constraint of the application, since it was part of a research development test pilot.
3. Predefining e-mails were automatically sent to confirm the adherence to the test pilot.
4. Once the end-users were registered at the Demand Management Portal, a new confirmation e-mail containing the android application access, the user login and password was sent. At this point, approved users were able to visualize their electrical consumption on their tablets.

The test pilot was aimed to increase user awareness about their electrical consumption, providing daily and monthly consumption. Moreover, the users were given some recommendation to shift consumption towards suitable periods and they are even enabled to send comments about their consumption changes. Besides, an e-mail contact was given in order to address eventualities. All these features have been covered by the advanced user interface described at previous chapters: the Home Display application.

The Home Display was also published at Google Play in order to be downloaded by the users, as a decision of the Spanish Advisory Board

Test pilot results

The test pilot results have been analyzed with regard to the following issues:

- Recruitment process
- Occurrences during the test pilot
- Home Display application use
- Follow-up of Home Display recommendations

The success rate of selected recruitment process has been around 4%, taking the following data into account:

- 8,000 letters were sent to end-users living at Henares Corridor
- The Tablet market penetration rate in Madrid in 2013 were 26.9%, (source Spanish Statistical Office).
- 125 households fulfilled the adhesion form, but only 54% of them owned an Android Tablet (67 end-users).
- Finally, only 88% of them have ever used the Home Display application.

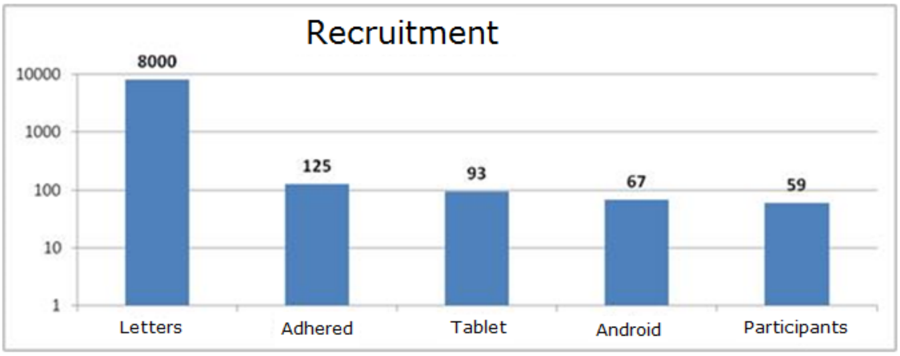


Figure 14: Recruitment process

The vast majority of negative occurrences during the test pilot are related to the lack of suitable smart device to run Home Display (Technical error and Fails to meet requirement categories). The other main cause of incidences was related to errors at registration process, or users not registered at test pilot who had downloaded the application from Google play and intended to connect to the test pilot server (User Error category). Next figures detail the cumulative occurrences evolution along the time and the total occurrences percentage by type.

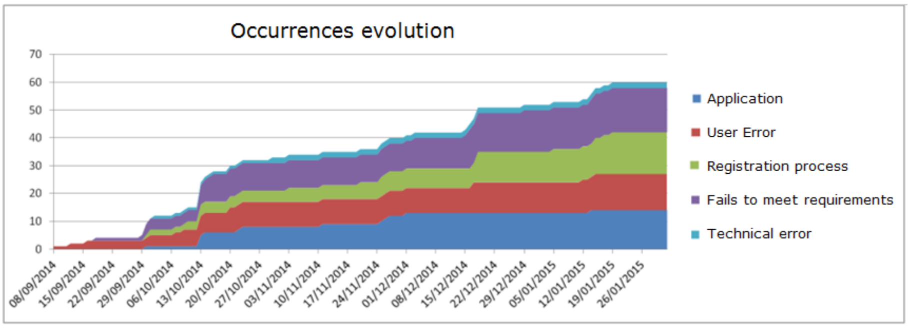


Figure 15: Occurrences evolution by type

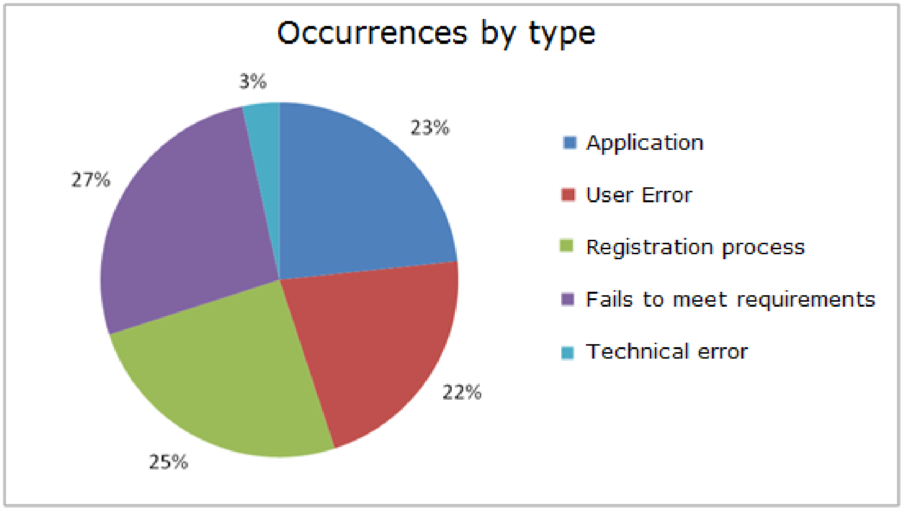


Figure 16: Occurrences by type (%)

Analysis of the Home Display application use can be seen in Figure 17, which shows the use of application by the most involved participants (15) and the total number of users accessing the application per day. Figure 18 also offers the interesting data of number of days that households used Home Display.

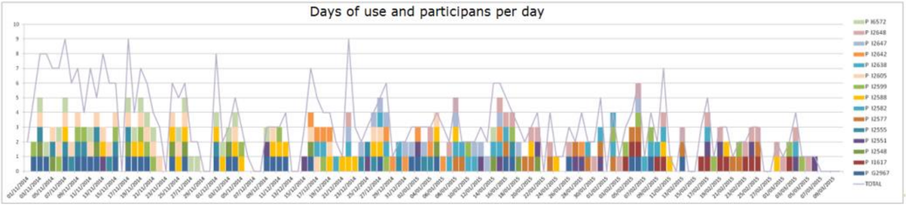


Figure 17: Home Display usage

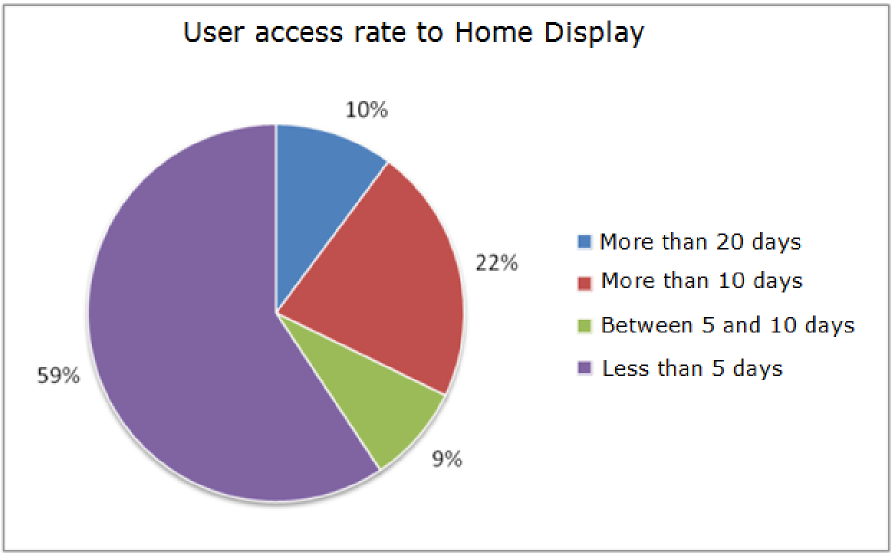


Figure 18: Home Display user access rate

In view of the previous graphs, the following facts can be highlighted:

- The maximum number of end-users with concurrent access per day to Home Display application is 9 out of 59 total participants.
- Most of participants (59%) have entered to the application less than five days during the test pilot
- The interest of household in the application decreases significantly with time. They are more engaged the days right after application download. So, the evolution of household awareness about their electrical consumption seems unachievable.

The last evaluation done is focused on the follow-up of utility recommendations. Due to the lack of commitment of household involved at test pilot, and their intermittent use of the Home Display application, the analysis of the recommendations follow-up has been done comparing the aggregated consumptions. On the one hand, the consumption of a control group of the area, and on the other hand, the aggregated consumption of household involved at test pilot. This procedure has the disadvantage that whether the test pilot consumers have seen the recommendation or not remains unknown. Nevertheless, some impact of recommendations on the consumption can be noticed, as shown in Figure 19 and Figure 20.

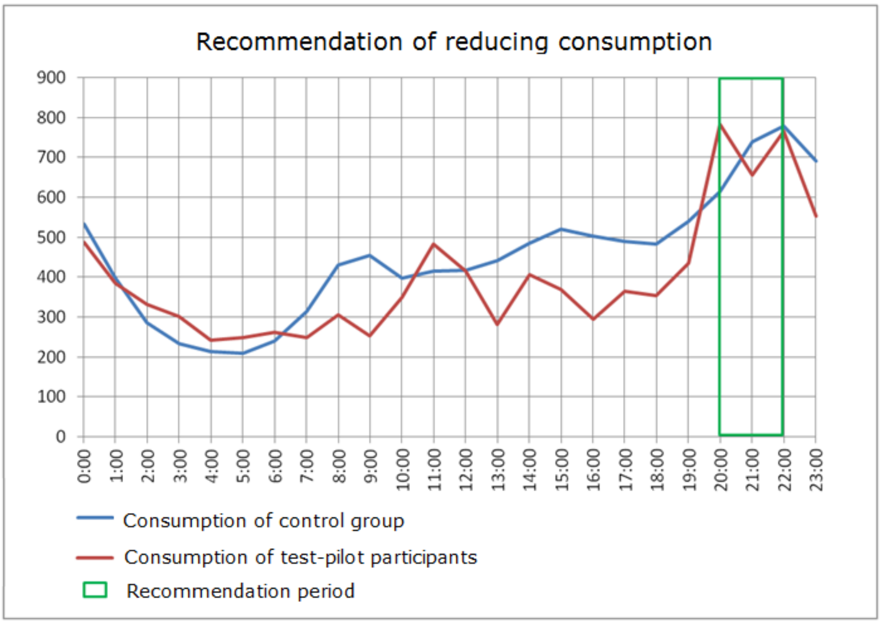


Figure 19: Follow-up of reducing consumption recommendations at specific day

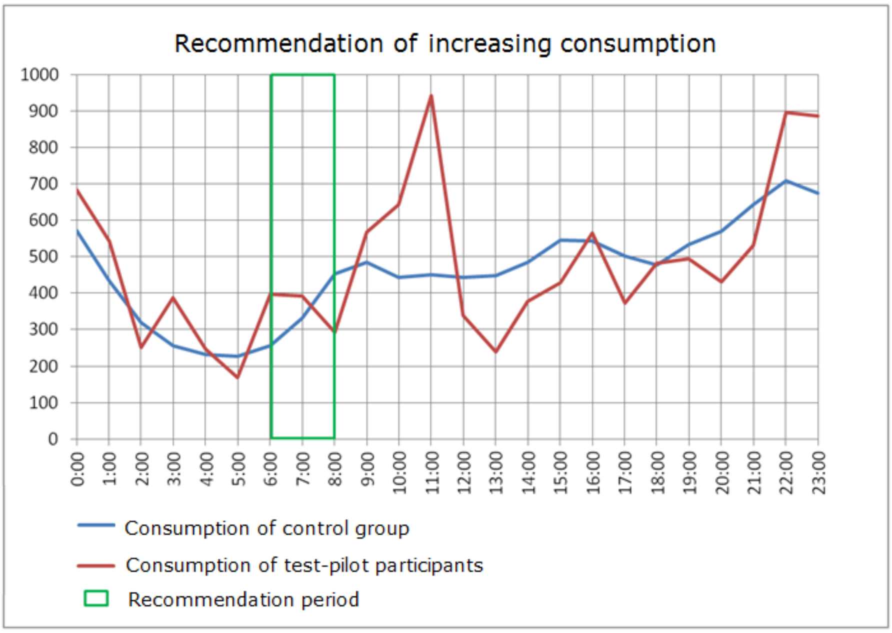


Figure 20: Follow-up of reducing consumption recommendations at specific day

However, some undesired side effects have been observed when comparing the total follow-up of recommendations: Almost 70% of the increasing consumption recommendations were followed by test pilot consumers, while only the 33% of the reducing consumption suggestions were followed. This is shown in the next figure.

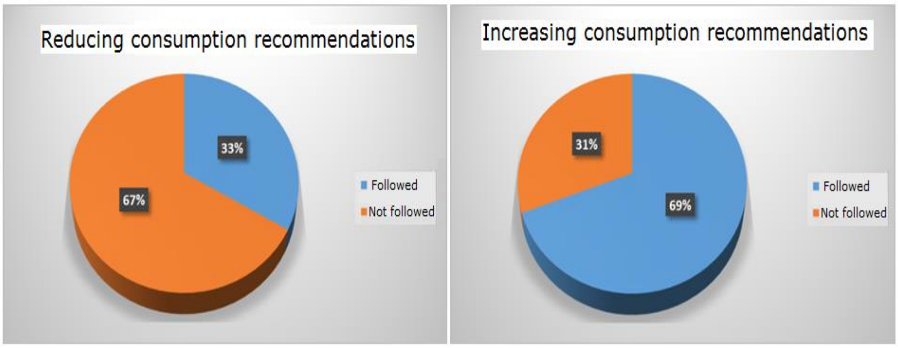


Figure 21: Comparison of total follow-up of recommendations by type

In conclusion, the scarce number of participants in the test pilot and their low involvement has hampered the analysis of results. It has been difficult to extract general conclusions when the sample size was relatively small.

It has also implied that classification of test pilot users in target groups by sociological factors was unfeasible. Moreover, the overwhelming majority of users have not sent their impressions or acceptance of recommendations. Without this feedback, recommendation effects remain unknown, due to the impossibility of discriminating if changes at consumption were coincidental or they have been encouraged to do it.

Despite of the poor involvement of households, some technological challenges was specified through the Home Display application design, implementation and use. The conclusions and recommendations are detailed in the following chapter.

10. Conclusions and recommendations

In order to realise the objectives, the barriers identified to allow end users to participate in active demand management have been gathered. Similarly, technological challenges through analysis about the Information and communication technology requirements have been summarised.

The conclusions reached are based on the analysis done and also they have been contrasted within the test pilot frame.

Detected technological barriers

Analysing the challenges of incorporating households in the smart grid system, several technological barriers have been detected. These barriers are related to the participation of the end-user in active demand, but some of them also relate to the interaction with other stakeholders at smart grid system.

The barriers are of technical and non-technical nature, and they can be collected in the following groups:

- Barriers related to the availability of Smart Equipment
- Barriers related to general interoperability
- Barriers related to security, robustness and scalability
- Barriers related to privacy issues

They are described in the following subchapters.

Availability of Smart Equipment Barriers

This group of barriers is related to the equipment, which should give sense to the “smart” word applied to electrical grids.

The main barriers detected are a consequence of the overall lack of smart appliances, especially when the European economic situation does not help to face the cost of replacing current appliances by new ones.

Although the Energy Box is an alternative to smart appliances, its introduction in homes is difficult because of the lack of maturity and the needed electrical modification for its installation.

On the one hand, the roll out of smart meters is still insufficient, despite the efforts to regulate this issue. Moreover, it is true that installing advanced meters improves the quality of electrical distribution, but it should be acknowledge that this is the beginning of the smart grid, and not the end. More work on regulation and interoperability should be done once the roll out of smart meter ends. Besides, it is essential not to relegate this equipment to pricing purposes determined by utilities, so an agreement on a minimum functionality that smart meters support is needed.

On the other hand, the unequal degree of automation of houses does not allow taking full advance of smart meters from the end users point of view. It is valuable to obtain data about aggregated consumption, but it would be more useful for end users accessing disaggregated consumption, giving clues about where consumption comes from. The lack of Building Management Systems (BMS) at home level and their standardization is a challenge to face if real integration of end users in the smart grid is desired.

General interoperability barriers

End users have been taken as a simple consumer, in order words, as a passive subject. Involving them as an active actor of the smart grid implies changes at Distribution System Operator, in the sense that it is the intermediary entity between the smart grid and the end-users.

Therefore, communications must be redefined to allow accessing this new actor, who has different necessities that the existing ones in the current smart grid. Interoperability issues between devices include:

- Communication level
- Syntactic level
- Semantic level
- Services interface level

Security, robustness and scalability barriers

The barriers related with security of the information exchange are subdivided into:

- Integrity of the information to guarantee that the information exchanged is not modified in any way by any party. Integrating end users in the smart grid involves increasing security to avoid fraud.
- Confidentiality of the information, because not only the information must not be modified, but also it must not be accessed by other parties.

Privacy barriers

Privacy may be a significant barrier for the introduction of households in demand response, especially if data protection measures are not included early in the system design. The public image of active demand is crucial, and it may become problematic, because there is a lot of information about the users. Legal regulations concerning data protection should take care about:

- The data would be sufficiently protected
- Participation in active demand programs would not be mandatory
- Affirm a strong commitment not to misuse the data from the households by users.

Identified solutions

Once the barriers have been detected, some solutions have been proposed. Some of them are general guidelines aimed to overcome barriers, but other ones have been concluded through the Home Display implementation and testing.

General solutions

Some general solutions to the described barriers are

- The roll out of smart meters, which is being supported by European regulations.
- The development of Building Energy Management systems for homes, including smart household appliances and/or Energy Boxes eligible for demand response actions.
- The European commission has issued the mandate M/490 for eliminating the interoperability barriers in Smart grids.
- There are several solutions to security, such as using dedicated lines, using tunnels, using the available Internet protocol, IP filtering or message encryption by Certification Authority certificates.
- Transparency statement and a fluid communication with the public is a good starting point to avoid privacy barriers, but regulations about privacy policies goes further than intentions, and they seems to be essential for building households trust.

Applied solutions in the Home Display implementation

Trying to proceed with intermediate steps rather than the overall solutions, some specific solutions have been detected during the practical approach.

Designing a user interface to start introducing end users at smart grid system seems to be a good approach. Some guidelines followed during this process have been:

- Balance between a rather formal and a playful interface, including data in graphs as well as an attractive appearance,
- Different methods are applied to motivate the end user: personal score relating consumption and environmental impact, short term and real time consumption recommendations
- User friendly. Simplicity has been a main guideline, and in addition to the help screen a more detailed user manual has been distributed among households involved in test pilot. All the included data are easily understood by users.
- Multimodal. Home Display may not be limited to one specific display device, as it is HTML5 based, and its communications are deployed as a web service. Some little additional developments would allow use on personal computers and also tablets with other operative system, such as iOS. In theory, it can interoperate via all kind of internet connected devices. Nevertheless, and as it has been mentioned before, the current Demand Management Portal does not support communications if Home Display is running on a personal computer.

Unfortunately, some features of the Home Display could not be tested with users, due to the withdrawal of the smart household appliance manufacturer. This fact has exclude comparisons between users provided with aggregated and disaggregated consumptions.

Using current smart meters, but developing a dedicated Demand Management Portal to communicate with users, is a cost-effective solution, because it minimizes the impact of introducing new actors in data exchange. Moreover, the communication speed is considerably improved using a dedicated server for users, comparing to accessing the smart meter data concentrator.

Confidentiality and security of data has been granted: households are provided with a user login and password, and communications are encrypted through a certificate issued by a Certification Authority. This is another reason to choose a dedicated server, because meter data concentrators are embedded devices, where implementing security issues are almost impossible.

Placing the verification of the application within a test pilot framework may be a double-edged sword, because on the one hand, participating is voluntary, avoiding the feeling of vested interest from utilities. But on the other hand, this fact caused less households to be involved in the test pilot.

Transparency has been managed through a sign-up form. All the test pilot participants had to accept the legal implication of being involved in the test pilot, which inform them about the statistic record of Home Display usage.

Set of criteria for smart grid developers and planners

1. Real time economical information about electrical consumption is not always provided by the Distribution System Operator or Commercialization Companies to households. This parameter seems to be a powerful incentive to modify their consumptions.

2. Specific and proprietary web services must be developed for every utility company and for every system (data concentrator or dispatch). One of the problems for smart grids deployment is facing the enormously competitive electricity market. Thus, forcing utilities to adopt the same tool in order to allow end users to communicate with their servers may be doomed to failure. But proposing a general solution, based on standards such as web services technology, where each utility develops its proprietary tool might sound realistic

3. Dedicated servers, as the Demand Management Portal, should be implemented. In this approach data are provided by current smart meter infrastructure, but communications with users works in parallel. Thus, communication speed when users retrieve data is improved, as well as dealing with cyber security issues.

4. To avoid lost data due to communications issues, it is a good idea that the dedicated server would be able to estimate missing data, as long as estimations would be accurate. This avoids repeating requests to meters when they are congested. However, if estimated data are displayed to the user, they must be marked as not real with the aim of avoiding misleading data and to follow the transparency statement.

5. Feedback data should be available on a non-aggregated level in order to promote energy savings. In this context, real efforts must be made in the automation of household appliances in order to provide online data of their consumption. Otherwise, the end users will be only informed about their aggregated consumption, which gives no clear idea of when and where electricity has been consumed. Automated household appliances are prepared for not only monitoring the electricity consumption of the household appliance, but also to control them even remotely. There are more possibilities for users to shift their consumption patterns if they are helped by intelligent appliances. The same is applicable for Smart Energy Boxes to avoid the replacement of home appliances.

6. Allowing the access of end users to consumption and tariff data stored at smart grid system implies the development of safe and reliable protocol to minimize data leaks or misuse.

7. Due to privacy matters, each end user may be limited to know their own data, but providing comparisons between the own consumption and the average consumption of households belonging to a certain group area may be really interesting. These groups may be done on basis of some certain common characteristics, such as geographical area (neighbourhood, city, country…), social characteristics (age, gender, marital status, number of residents, etc.) or even electricity contract type.

8. Real time notifications if a user-defined threshold (daily or monthly) is reached would imply a modification on the consumption profile, but it requires development in the electric utility side.

9. End users have unequal levels of knowledge about electrical parameters. So, the provided data should be easily understandable. Graphs and images are the best option.

10. There should be available some information related to environmental impact of energy consumption. Besides this, this information must be based on homogeneous, realistic and standard criteria, such as CO_2 emissions.

11. The unpredictability of end users requires collecting historical data of electrical consumption in order to elaborate patterns of behaviour. These data should be stored and accessible to end users.

12. Recommendations given to households should be planned on the basis of the house automation level. If only total aggregated consumption is provided, qualitative recommendations, such as indicating suitable or restricted periods to consume, are the most suitable ones. Quantitative recommendations make no sense since the users does not know how much electricity is consumed by individual devices. These ones would work if disaggregated consumption of certain devices is somehow displayed.

13. In order to achieve changes in consumption pattern, households should receive recommendations in advance, therefore easing the consumption scheduling. In the same way, updates within the current day should be limited with the intention of not disturbing user schedules based on previous recommendations.

14. To maximize the recommendations acceptance, these should be suggested only in really critical moments. For instance, only two recommendation periods along the day.

15. Involving households in the smart grid system requires offering them some incentives beyond information about their consumption. Otherwise, their interest decreases after a short time period.

16. Literature

Christensen et al, 2013. "Country-specific factors for the development of household smart grid solutions - comparison of the electricity systems, energy policies and smart grid R&D and demonstration projects in Spain, Norway and Denmark." Danish Building Research Institute (Aalborg University), Tecnalia (Spain), Norwegian University of Science and Technology. (WP1 Report)

Darby, 2010. “Smart metering: what potential for householder engagement?” Building Research and Information 38(5), 442–457

Fischer, 2007. “Feedback on Household electricity, consumption”, Energy Efficiency (2008) 1:79–104

Hargreaves et al, 2010. “Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors”. Energy Policy 38, 6111–6119.

https://www.android.com/

http://www.apple.com/es/ios/?cid=wwa-es-kwg-features-com

http://en.wikipedia.org/wiki/HTML5

http://en.wikipedia.org/wiki/Cross-origin_resource_sharing

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

European Comission, 2011, “Standardization Mandate to European Standardisation Organisations (ESOs) to support European Smart Grid deployment”. Smart Grid mandate

Recommendations and criteria for the design of smart grid solutions for households

Lessons learned for designers and policy makers from the IHSMAG project

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

Marianne Ryghaug, Tomas Moe Skjølsvold & William Throndsen
Norwegian University of Science and Technology

Sandra Riaño Fernandez & Eutimio Sanchez Perez
Tecnalia, Spain

June 2016

Report from the ERA-Net SmartGrids project “Integrating households in the smart grid” (IHSMAG) – www.ihsmag.eu

This report is published as part of the ERA-Net SmartGrids project “Integrating households in the smart grid” (IHSMAG). See www.ihsmag.eu for further information.

CONTENT

1. **Introduction**

Since the 2000s, we have witnessed a growing interest in developing the “smart grid”. No consensus about the exact definition of the smart grid exists, but it is often associated with an increasingly dynamic electricity system that involves a growing number of actors and with existing actors taking on new or multiple roles (e.g. consumers becoming “prosumers”, i.e. both electricity producers and consumers). A key role is often assigned to the integration of new information and communication technologies (ICT) as the basis for a two-way flow of information between electricity consumers, electricity producers and network/system operators in order to enable new smart grid services, e.g. continuous feedback to consumers about their electricity consumption. (Brown & Zhou, 2013; Coll-Mayor et al., 2007; Wissner, 2011)

A number of current issues and developments are often identified as important “drivers” behind the smart grid. The most prevalent are: The need to integrate increasing amounts of renewable electricity generation (as part of climate change mitigation and increased energy sovereignty); ensure the further liberalisation of the electricity market; avoid grid capacity challenges from future increases in electricity consumption (e.g. due to more electric vehicles or increasing micro generation from local PVs and wind turbines) and handle already existing peak-hour capacity problems; make the network management and payment (invoicing) more cost-effective; and, in some countries, reduce problems with electricity theft. (Brown & Zhou, 2013; Geelen et al., 2013)

In the project *Integrating Households in the Smart Grid* (IHSMAG), we have not decided on one specific definition of the smart grid. Rather, our approach has been relatively open as we understand the smart grid as basically characterised by:

- An increased integration of new ICTs (including an Advanced Metering Infrastructure, AMI) that enables new ways of communicating between different actors.
- 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).

Obviously, it is necessary to distinguish between the visions about the future smart grid (i.e. *how we talk about the smart grid?*) and the actual changes taking place (i.e. *how the grid is actually changing?*). As seen before in the history of technology, we will most likely witness substantial differences between the original visions and the actual realization of the smart grid over the coming years. For instance, just a few years ago, much attention was on electric vehicles as a way of storing surplus electricity generation for later redelivery to the grid (*vehicle-to-grid*), but the interest has faded somewhat within recent years (probably reflecting the slow uptake of electric vehicles in most countries). Similarly, visions amongst policy makers in the early 2000s tended to highlight that providing electricity consumers with feedback on their current consumption would be the cornerstone of the smart grid, and the means to reach most goals. As technologies have developed, experience has been gained and the visions of implicated actors have changed (Skjølsvold 2014; Ballo 2015). Thus, the focus and interests of the smart grid debate is shifting gradually over time.

While there has been much discussion about the smart grid and its role for households for about ten years, the actual achievements still seem limited. Advanced Metering Infrastructures (AMI), often just termed *smart meters*, are widely diffused in many countries (partly due to regulation and mandatory roll-out), but most of the other elements of the smart grid *vision* are still in the development stage. Many resources are invested by the public and commercial sector in R&D and demonstration projects all over Europe (and in other parts of the world). However, it seems to be a challenge to agree on a common understanding of what "smart" grids means, to get the solutions implemented and working in "real life", and on market conditions.

There might be several reasons why it is so challenging to transform the original visions of smart grids into workable solutions. Likely, one of the reasons is that the smart grid debate and development in the early years was surrounded by some degree of "hype" that resulted in rather ambitious, and sometimes over-optimistic, visions of the future smart grid, perhaps especially regarding the role of active end users (Throndsen 2016. Also, the field is permeated by a wide range of actors with often differing understandings of what the smart grid should be and with different vested interests. In line with this, Hargreaves et al. (2015) has pointed out that the smart grid – in idea and materiality – is a nuanced fabric formed by interests from a range of different stakeholders. Thus, attempts to "steer the future smart grid are not centralized but formed by multiple distributed practices and actions across public, private, research and civil society sectors" (ibid: 104). This finding has been substantiated by the studies conducted in the IHSMAG project (see, e.g. Skjølsvold & Ryghaug, 2015).

We might now be entering a new phase in the smart grid development, where we will witness a re-evaluation and re-adjustment of the original visions based on experiences from the early years' smart grid pilots and demonstrations. This report, based on the experiences from a number of demonstration projects in Norway, Spain and Denmark, will be a contribution to this.

In relation to private consumers' and households' use of smart grid solutions, which is the focus of the IHSMAG project, another reason for the slow progress is probably related to the fact that much smart grid research, design, development and policy making has been based on a rather narrow understanding of the users of smart grid technologies as consumers. The focus has primarily been on technical and financial considerations and less on broadening our understanding of users and their contextually bound practises (Geelen et al., 2013; Hargreaves et al., 2015; Skjølsvold & Lindkvist 2015). Research and development has typically been based on an understanding of users as consumers, as "rational" individuals that primarily react to economic incentives and concerns about self-interest and utility (Verbong et al., 2013; Strengers, 2013; Hargreaves et al., 2010). In this way, the smart grid field does not differ much from the general approach within consumer-oriented, environmental policies and campaigns (Shove 2010; Shove & Walker 2014) that has tended to view users essentially as a "homo economicus"; as consumers that restlessly seek out new opportunities for maximising personal economic gain. This conceptualisation has also been coined "Resource Man" by Strengers (2013), who has pointed out that this "efficient and well-informed micro-resource manager who exercises control and choice over his consumption and energy options" is a quite misleading understanding (ibid.: 34-35). Solutions based on this understanding tend to over-emphasise the role of information and economic incentives as main vehicles to get people involved and change behaviour. While this may be quite relevant for a minority of users, their lion's share will not easily be incentivised with such an approach.

In line with this, a review of smart grid projects in Europe (Gangale et al., 2013) shows that smart grid projects typically use information as the primary means to change consumers interest, values and knowledge in order to involve them, while only a few employ more comprehensive approaches such as social marketing or emphasis how to best engage users. Also, the review found that the two most widespread “motivational factors” employed to engage consumers was the reduction of, or control over, the electricity bill (a financial incentive) and environmental concerns (a “green values” incentive). The former refers directly to the Resource Man understanding of the consumer, whereas the second relates to the prevalent understanding of smart grids as part of the decarbonisation strategy of the energy system and, thus, addresses a more general concern for the environment. Verbong et al. (2013: 124) conclude:

> “Although users have become more central in smart grids projects, the focus in the smart grids community is, maybe not surprising, still mainly on technological issues and economic incentives. From this perspective users are often regarded as a potential barrier to smart grids deployment and financial incentives the best instrument to persuade or seduce the users.”

In spite of this, there seems to be a growing recognition of the limitations of such approaches, as well as the need to develop new conceptualisations of users and how to involve them in the future smart grid (Gangale et al., 2013; Hargreaves et al., 2015; Skjølsvold et al. 2015). In other words, an approach that is based on a comprehensive understanding of consumers as users engaged in electricity-consuming everyday practices instead of users being reduced to (self-interest driven) “barriers” in smart grid development. The findings from the IHSMAG project, presented in this report, is a contribution to this crucial change of perspectives.

Another critique of the smart grid development is that the focus is often on *specific* (technical) solutions “rather than the system as a whole” (Geelen et al., 2013: 158). Thus, “product and service development, and as a consequence the related research, has typically focused on empowering end-users with technical solutions and financial incentives.” (Ibid.) According to this critique, there is a need to widen the scope and seek out design solutions that integrate all levels and aspects of the smart grid; i.e. technological solutions that work together with everyday practices of single households and at the same time are aligned with the development of the electricity system, policies and regulations.

The aim of the IHSMAG project has been to contribute with knowledge on how to develop comprehensive designs of smart grid solutions for households. On the basis of experiences and results from a number of demonstration projects in Norway, Denmark and the Basque Country (Spain), IHSMAG has explored how the success of household smart grid solutions depends on household technologies, everyday practices of the household members as well as the overall electricity system and regulatory environment. In this way, our aim has been to provide knowledge and recommendations on how to develop integrative smart grid solutions that take the technical, system-related and social context of households into account.

The IHSMAG project includes three main work packages, each of them focusing on one specific aspect of household smart grid technologies:

The everyday life of households (this work package was conducted by Danish Building Research Institute, Aalborg University)
The regulatory and system context of the electricity system (conducted by Norwegian University of Science and Technology)
The development of new technical solutions in households (conducted by ZIV Metering Solutions / Tecnalia, Spain).

Each of these work packages has resulted in a number of empirical studies with findings and practical lessons about how to improve the design of smart grid solutions for households (reported in separate papers and work package reports; see list of project publications in Chapter 5).

In this report, the outcome of the three main work packages is synthesised in order to develop a number of key lessons from the IHSMAG project regarding *design criteria and policy recommendations* on how to develop *comprehensive and integrative smart grid solutions* that take the technical, system-related and social and everyday life context of households into account. Or, in other words: How to create smart grid solutions for households that work in practice?

The report is organised into two main sections. The first main section (Chapter 2) focuses on design criteria and recommendations for *smart grid designers* (i.e. persons involved in the specific designing of technical solutions related to households). The second main section (Chapter 3) focuses on recommendations for *policy makers, planners and others* involved in defining the conditions for the smart grid development or actually organising the design and development processes, like national energy agencies, politicians, planners within TSOs, DSOs etc. It is obvious that it is in many cases difficult to make a clear distinction between these two groups. However, we find it useful to make this distinction as a way of organising the outcomes of our project.

The IHSMAG project

The "Integrating Households in the Smart Grid" (IHSMAG) project contributed with knowledge on how to develop comprehensive designs of smart grid solutions that involve households in the smart grid. On the basis of experiences and results from a number of demonstration projects in Norway, Denmark and the Basque Country (Spain), the
project explored how household smart grid solutions depend on household technologies, everyday practices and the overall electricity system and regulatory rules.

The project began in January 2012 and finished in May 2016 and was supported by the Second ERA-Net Smart Grid Joint Call.

Find more information about the project and its results at:
www.ihsmag.eu

2. Recommendations for designers

This section focuses on recommendations and design criteria for the specific design of smart grids solutions for households. These criteria are therefore particularly relevant for people directly involved in development of technical solutions and the set-up of new demonstration projects, etc.

The guiding questions for identifying and developing the following recommendations have been:

What kind of (technical) solutions work in practice? How do they work?
What kind of (technical) solutions does not seem to work in practice?
How can integrated and comprehensive design processes be supported?
  For instance: What kind of actors and expertise should be involved in the design process? How to involve the users in the design process?
What kind of organizational processes work best for the development of the smart grid solution?
What type of regulation may assist the development of the smart grid?

Below, we will present the main recommendations for what should be considered important design criteria based on the results from the IHSMAG project. We begin with the more general observations about what is important to keep in mind when designing smart grid solutions for households and end with a number of specific recommendations. In the following presentation, we will also refer to key findings from other studies, when relevant.

2.1 Do not focus on economic incentives only

The IHSMAG project finds some evidence of economic incentives playing a role in motivating people to take part in smart grid trials and demonstration projects. For instance, the Spanish feedback test pilot (see Riaño Fernandez & Sanchez Perez, 2015) confirms in some way this line of thought, since the fact of not offering economic incentives to the participants is assumed to be an important cause of the failure to meet the participant recruitment objective. Another example is the interviewed participants in the Danish demonstration project *Dynamic Network Tariffs* (a static time-of-use pricing scheme), who emphasise that the possibility of saving money was one of the reasons (among others) why they postponed their consumption to the low-tariff night hours (Friis & Christensen, In press). However, the interviews also indicate that during the demonstration period, the economic incentive to some degree faded into the background, and other reasons became more important, such as more general environmental concerns or the possibility of contributing to an overall (sustainable) transition of the energy system. This was also demonstrated in interviews with smart meter users in the Norwegian Demo Steinkjer (Throndsen & Ryghaug, 2015; Jørgensen 2015). This indicates that it is important for people to find the participation meaningful for them in a broader sense, and not only related to potential economic gains, in order for them to engage actively with smart grid solutions.

Thus, while economic incentives can work as an “eye catcher” in relation to attracting and recruiting consumers for smart grid solutions, it is important to see this as just one among many other possible incentives that may be perceived as meaningful reasons to participate. This is especially important when achievable financial savings are relatively small, as often seems to be the case of time-of-use pricing solutions, and if not, there is a risk of a “backlash” when the participants realize that they save very little money. This was observed in interviews with household participants in the Norwegian demonstration projects *Smart Energi Hvaler* and *Demo Steinkjer*, where disappointment by marginal savings led to disengagement of some consumers and made them less enthusiastic about the smart grid (Jørgensen 2015; Throndsen and Ryghaug 2015). This is in line with other studies concluding that users who do not achieve the expected savings, notwithstanding their behavioural change, might consider the whole experience disappointing and frustrating (Gangale et al. 2013; Hargreaves et al. 2010). Emphasising too strongly possible economic gains can therefore be a double-edged sword, and it is important to strike the right balance.

A similar conclusion is reached in an Australian study of the flexibility of routines in households with children (Nicholls & Strenger, 2015), which recommends that:

> “In particular, understandings of householders’ community responsibility towards energy and electricity assets, the important role of gender in family households, and the dynamics of family routines, are needed to inform energy reforms with this and other household groups.” (p. vii)

We have found related dynamics amongst interviewed users in Norwegian demonstration projects. Often, one person – typically the father/husband/man living in the household – was the one who was originally motivated to participate, partly because of potential economic gains. This, however, often did not translate into significant practice changes, because other household members such as women or children had other and often conflicting motivations, interests and routines. Thus, even in households where a character with similar traits to the Resource Man or Homo Economicus was identified, there were difficulties in implementing the technology in practise as the acts and visions of the resource man was challenged and obstructed by other members of the household pursuing conflicting interests and practices in the context of their everyday life. It was typically the male householders that engaged with the technologies and these processes often alienated significant others in the household. Finally, on the basis of these findings, the paper calls for new design practices in the field of smart energy technology. (Jørgensen, 2015; Jørgensen et al., forthcomming)

That the dominant understanding of simple cause-effect relationship between provision of feedback and rational decision-making does not grasp the dynamics in households’ interaction with smart technologies, is also stressed in a UK field study of households’ feedback on smart energy monitors (Hargreaves et al., 2010), whereby the authors suggest that domestic energy consumption is a social and collective rather than individualised process. The study of Norwegian households come to the same conclusion, stressing the importance of future research focussing more on households and less on the individual energy consumer as the key unit of analysis (Jørgensen et al. forthcoming). This might point to a strategy, which focuses on fostering co-operative and energy-saving household dynamic, and not on educating individuals about their energy consumption.

Other reasons for households’ participation in smart grid solutions could include elements such as the feeling of contributing to a sustainable transition of the energy system; avoiding risks of blackout; saving investments; contribute to energy security in times of crisis; avoiding environmental damage; avoiding expanding the grid capacity and, as a result of this, avoiding new power grid lines (as seen in the debate about the future electricity grid, see Throndsen 2016 for a thorough discussion of the Norwegian case). A higher degree of involvement in these kinds of issues was in fact requested by some of the respondents in the Norwegian study, who also expressed regrets that they were only being allowed to give input to the smart grid development and use as “pure customers”. Put differently, they felt somewhat left out of important democratic decision-making processes regarding the development of the grid, and would like to be involved more fundamentally in the development of the Norwegian energy system (Throndsen and Ryghaug 2015).

Along these lines, a typical motivation revealed by our study was the feeling of being “part of a community” or a “collective movement”. This was illustrated in the interviews with the participants in the Danish demo projects *Dynamic Network Tariff* and *Test-an-EV* (EV: Electric Vehicle). Here, the interviewed participants often talked about themselves as taking part (along with the other participants) in shaping a new energy system. More specifically, the set-up of especially the *Test-an-EV* project with several information meetings and continuous feedback from the project to the participants seemed to promote a more active involvement of the participants than what one would otherwise expect – and also a high degree of loyalty to the project among many of the interviewees (Friis & Gram-Hanssen, 2013). This indicates that frequent and extensive involvement of participants in smart grid demos can promote a higher level of empowerment, commitment and activity regarding energy issues.

These general observations are very much in line with the previous points made in Chapter 1 about the need to replace today’s common understanding of consumers as informed, rational individuals primarily motivated by economic incentives with a broader and multi-facetted understanding of a user: A user, who by no means thinks of her-/himself as only a consumer, as a “barrier”, but who rather calls for a greater extent of engagement with the technology and the community as a whole.

2.2 Ensure active (and wholehearted) involvement of users

There are consistent links between gaining results with smart grid technologies in households and involving users actively. This could be done in multiple ways, none of them, of course, exclusive to each other. Users could be invited to participate in the design process, and in shaping the smart grid set-up. Further, once included in projects, for as long as they are ongoing there is a need for a continuous activity aimed at supporting the users’ continued engagement. This could include informational activities that provide information about the smart grid technologies and give realistic expectations about their potential. In addition, supporting interaction between users (e.g. sharing experiences with the smart grid solutions) through e.g. physical meetings or via social media could support continued engagement. In this way, the smart grid projects could also support processes of collective learning among the users in relation to new technologies and new practices (see also Christensen, 2014).

These activities should, if possible, be organised at neighbourhood levels, i.e. at the grassroots level, involving the relevance of smart grid technologies in the local context. Keywords would be community, neighbourhood, collaboration, etc. For instance, the study of Norwegian initiatives like the *Demo Steinkjer* and *Smart Energi Hvaler* projects indicates that local “enthusiasts” can play a key role in pushing projects forward, manage the projects, secure that they meet their goals and in making sure that all involved actors are able to formulate their interests, and to work towards the same goal (e.g. health system, building sector etc.). This can for example be entrepreneurially oriented local “champions”, well known in the local community. An example of this was the mayor of Hvaler, who took on a role as a spokesperson for the *Smart Energi Hvaler* project. This project also worked towards engaging users through introducing new concepts and add-ons to the community as time passed. Thus, once the involved users had learned and become familiar with the basics of smart grid and smart home technology, the project introduced new concepts such as the possibility of becoming prosumers through micro-generation of renewable energy or become providers of flexibility through mobilizing the many second homes in the area to balance the grid (see, Skjølsvold and Ryghaug, 2015).

It appears important to facilitate the potential of learning over time, and to make sure that the system continues to provide new and relevant information. This also prevents users from “cooling down”, something that seems to be an active stance the user may adopt, rather than a condition occurring in a passive fashion. This can happen, for instance, in cases where the provision of information from the demo project goes silent for periods or does not take into account and accommodate to the feedback from the users.

Another example of user involvement can be found in the Norwegian *Demo Lyse* project. Here, health care organizations, nurses and the elderly took part in the shaping of the project in order to avoid this user group becoming alienated from what could otherwise be perceived as a too complicated technology. This kind of “local anchoring” of projects can also help ensure that smart grid initiatives for households and at the community level align with specific local challenges and opportunities (see, Skjølsvold and Ryghaug, 2015).

These observations are in line with the findings of other studies. As noted by Verbong et al. (2013: 122): “Approaching users from a centralized top-down perspective increases the likelihood that they will act as barriers.” Typically, top-down approaches experience problems with recruiting consumers and keeping them engaged over longer time, whereas projects with a bottom-up approach seem to experience this as a smaller problem (see also Geelen et al., 2013 on the potential role of community-based energy cooperatives). Thus, while top-down approaches often understand user involvement in terms of a challenges or barriers, the users to a higher degree become important resources to play along with when approached from a bottom-up perspective.

This also challenges the classical “design-and-adopt” approach (often associated with top-down approaches), where the design of technical solutions primarily belongs to the domain of engineers. Rather, the design of smart grid solutions should involve the users already from the beginning of the design process. An early involvement increases the users’ feeling of ownership to the development. Furthermore, as Gangale et al. (2013: 626) point out, a successful engaging of consumers “involves iterative rather than consecutive phases, where continuous observation of consumer response allows adjusting the engagement strategy to the feedback obtained.” These are particularly important principles for user engagement in many smart grid projects where the user has a key role if the project is to meet its goals.

Previous research has shown that smart grid designers tend to believe that the smart grid and its many components are too complex and complicated for ordinary household users to understand (e.g. Schick and Winthereik, 2013; Skjølsvold and Lindkvist, 2015), and that they therefore cannot actively participate in the design and innovation processes. This was also one of the lessons learned from the Spanish feedback pilot in the IHSMAG project. Focused on overcoming technological barriers, the development of the feedback solution to households and the test pilot neglected the real audience.

Much of what we have done in IHSMAG, and what other similar studies suggest, is that it might actually be the other way around. The everyday practices of households are too complex to incorporate in smart grid designs without actually engaging them at an early stage.

A similar experience was found in the Spanish feedback test pilot, where the recruitment of household participants happened primarily by letter. Focusing on specific target groups was not considered pertinent, because the target audience of the test pilot was *any household* living in the Henares Corridor who owned an Android tablet and was interested in taking part. This general and relatively impersonal recruitment method proved to be ineffective. It is likely that concretizing the target audience and creating opportunities to interact with households would have resulted in stronger participation.

An approach, NTNU has been experimenting with as a spin-off from the IHSMAG project, is to conduct smart grid design workshops, where social science students take part in designing solutions that they believe would work in student housing facilities. Our observation from these exercises is that they intuitively identify many problems known in the research literature, while they – at the same time – are able to come up with original ideas and solutions based on knowledge about their own everyday lives and practices.

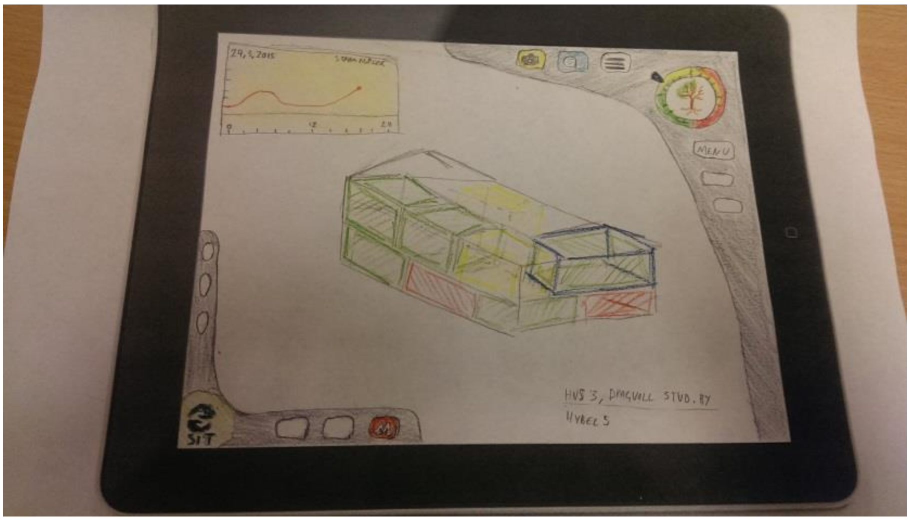


Figure 22. From design workshop for student houses

Another important observation from the IHSMAG project is that users easily detect half-hearted user enrolment efforts (as also indicated earlier). Uncertainty typically characterise early stages of developing and implementing new technologies, and users therefore need few reasons to consolidate scepticism towards utilities or policy makers if not taken seriously. This may ultimately lead to reluctance or scepticism towards smart grid technologies. Scepticism will often be abundant, as also the Spanish test pilot proved, and should be met with realistic expectation building in a transparent setting. Wholehearted involvement of users must be done through non-paternalistic dialogue.

Despite all these pitfalls and the general critique of the traditional approach to designing smart grid solutions for households, the demonstration projects followed in IHSMAG also demonstrate that it is possible to design solutions and approaches, which engage consumers. One example is the Danish *Test-an-EV* and *Dynamic Network Tariff* projects, which experienced a (surprisingly) high level of active involvement on part of the participants. As mentioned earlier, one of the reasons for this seems to be the set-up of the demonstration projects, including several information meetings, frequent feedback to participants about the project, the feeling of being part of an important pilot project and obligations such as daily blogging, continuous documentation of driving patterns, etc.

2.3 Remember the potentially unexpected actors

Since successful design, and ultimately successful use of smart grid solutions, seems to be aided by embedding such solutions in local communities and regions, it is important to keep in mind that the involved group of users or households will not always be the same. In IHSMAG our main focus has been on households. Households, however, might be many things, and they are part of diverse networks with diverse interests. Thus, it is important to look beyond the obvious participants (electricity producers, grid companies and “users”) when establishing smart grid solutions.

In Norway, for example, *Demo Lyse* has managed to build a quite successful demonstration project around the notion of welfare technology. The idea here was that smart meters combined with various smart in-home technologies could be useful not only for shifting or reducing electricity consumption, but for making it easier for the elderly and disabled to live in their homes. Through welfare technologies, the aim was to reduce the need for institutionalization or hospitalization, and a new opportunity for commerce emerged at the same time. From the beginning, however, it might not be self-evident that health care organizations had a role to play in smart grid technology development.

Another example with some of the same dynamics could be observed in the Norwegian *Skarpnes Neighbourhood* project. Here, the smart grid demonstration scheme was initiated as a by-product of another “green” technology development, namely the establishment of a new near-zero emission buildings neighbourhood. This was an effort to establish new types of households, which would reduce the overall electricity consumption. This approach did not originally grow out of a smart grid-related idea. However, it soon became clear that all the new, automated technologies that were to be included in this neighbourhood project eventually could pose a challenge for the electricity grid of the area. Thus, it was actually the building contractor who was the catalyst behind the effort from the start (see, Skjølsvold and Ryghaug, 2015).

Electricity grids constitute a vital societal infrastructure, in principle used by all. Thus, it is important to look at the potential users in an area where a pilot is planned and take into account their individual needs. In *Demo Lyse*, an innovation workshop with nurses and other representatives in the healthcare sector led to a new approach towards designing technology also for households. It is impossible to predict similar synergetic relationships in other settings, but we want to emphasize the generative potential in searching for them and exploring them.

In sum, the IHSMAG project shows the need to make the smart grid distributed and multiple by opening up for a democratic approach including a wide range of different stakeholders, interests and aims in policy and decision-making as well as in specific design and innovation projects.

2.4 Look for positive synergies between smart grid solutions

Trial and demonstration projects often aim to involve households in relation to one specific type of solution (e.g. energy feedback to consumers, energy efficiency or time shifting of electricity consumption). However, experience from the study of Danish households participating in both the trials *Dynamic Network Tariff* and *Test-an-EV* indicates that the combination of solutions (in this case time-of-use pricing and electric vehicles) might imply potential synergies that can strengthen the effectiveness of otherwise separate solutions. In the Danish case, the initial focus was primarily on encouraging demo participants to charge their EV in hours with low electricity price (non-peak hours). Interestingly, our study showed a spill-over effect in relation to time shifting within other areas of consumption (in particular laundering and dish-washing). (Friis and Christensen, In press)

The design of smart grid solutions should take into account and encourage these kinds of synergies and positive spill over effects.

2.5 Be aware of possible negative, unintended effects

It is well known within the literature on energy saving that higher energy efficiency is often followed by increases in consumption, which partly offsets the achieved (technical) savings. This kind of unintended effect is known as the rebound effect and has been demonstrated in relation to many consumption areas, such as driving and home-efficiency improvements (see e.g. Greening et al., 2000 and Sorrell, 2009)

Similar examples of unintended, negative effects (rebound effects) might be expected in relation to the implementation of smart grid solutions. One example from the Danish IHSMAG study is how the “branding” of electric vehicles (EVs) as an energy efficient and environmentally friendly alternative to combustion engine cars made some participants feel more relaxed of using the car more often as it would not “make harm to the environment” and because of the cheaper price of electricity compared to petrol. In particular, some started to use the car more often for shorter trips instead of cycling and walking (even though some of the increase in the driving frequency presumably also relates to the participants’ eagerness to test the new EV technology).

Additionally, and even more crucial, some of the participants experienced that having two cars in the household (their ordinary car and the EV) was convenient in relation to their efforts to juggle the obligations and duties of their everyday life. They found the idea of acquiring an extra car (after the end of the test pilot) attractive. Future designs and promotions of EVs should take this kind of potential rebound effects into account.

In the Norwegian study, we have identified two main unintended consequences of participating in smart grid demonstration projects. The first has been noted already, and was found amongst users who thought the promotion of the smart grid solutions oversold the rhetoric of “savings” and monetary rewards. When such rewards were not realized, users reported that what they had learned from e.g. in-home display information was that it was incredibly cheap to consume electricity, and consequently they did no longer see any reasons for changing to less energy intensive routines.

A related example could be observed amongst some users in *Demo Steinkjer*. This group had installed a smart meter, but in order to access the feedback data from this meter they had to log in to a new online portal. Thus, they explained that the main difference between their old and “new electricity consumption behaviour” was that they no longer had to read the electricity meters themselves and that they no longer received the electricity bill in the mail. The bills were now automatically sent to their bank, the payment automatically drawn from their account, thus the smart grid had forged them from minimal confrontation with their electricity consumption every quarter of the year in the past to no engagement at all. This actually made them less preoccupied with their energy use.

An example of a potential “systemic” rebound effects relates to peak shaving: The electricity sector shows increasing interest in time shifting the electricity consumption of households – often by use of time-of-use pricing and economic incentives. As a result (and if the initiatives are successful), this will increase households’ electricity consumption in some periods (particularly in the night) and reducing it at other times (peak hours). However, emphasising the possibility for saving money when consuming electricity at times when electricity is “cheap” might indirectly motivate households to increase their overall electricity consumption, as they would regard new (increased) electricity consumption as inexpensive as long as this happens at low-peak hours.

Something similar to this was observed in the Spanish feedback test pilot in relation to the participants’ response to qualitative consumption recommendations. More than 67% of the recommendations encouraging increase in consumption (in hours with high level of electricity production and low level of consumption) were followed, while only 31% of the recommendations on reducing consumption were followed.

2.6 Data needs to be collected and made accessible to end-users without compromising data privacy

The roll-out of Advanced Metering Infrastructures (smart meters) opens up for new opportunities of utilising the detailed data about households’ electricity consumption patterns for different purposes, including detailed feedback. In principle, data could also be shared with third parties (based on the customers informed consent), who could offer various kinds of services such as tailored energy saving advice based on the historical metering data. Also, the energy supplier could offer similar services to customers.

However, important questions regarding privacy and data security follow with the new opportunities for detailed monitoring and storing of households’ consumption data. Thus, the question of data protection, privacy and data ownership has been identified as one of the main issues and challenges related to the smart grid development (see e.g. Gupta, 2012; Heffner, 2011). Therefore, allowing users (or third parties) to access consumption data stored by the smart grid system implies the development of a safe and reliable protocol to minimize data leaks or misuse.

First of all, secure authentication must be implemented. Before accessing the smart grid system, the users must identify themselves. The most common methods to implement authentication are: 1) Entering an assigned username and password or 2) Providing IP address or MAC filtering (in this case, only the defined IP addresses or MACs can access the Smart Grid System). An additional cybersecurity solution is to encrypt the data.

In the Spanish feedback test pilot, not only username and password login was implemented, but also the server containing all participant consumption had encrypted communication, using a trusted certificate from a Certification Authority (CA). In this way, privacy was guaranteed for all involved parties (utilities, households and distributors).

Another noteworthy issue related to data collection observed in the Spanish feedback test pilot in the Henares Corridor was the consequences of making the Home Display App available through the Google app store. Here, people that did not adhere to the test pilot were able to download the application, and, consequently, to send a request to the dedicated server. They were not allowed to access any information as long as they did not have a registered username or password, but their requests of trying to access the system caused traffic data, which reduced the communication efficiency.

At the same time, specific and proprietary web services must be developed for every utility company and for every system (data concentrator or dispatch) based on a shared set of web standards. One of the problems for smart grid deployment is facing the enormously competitive electricity market. Thus, forcing utilities to adopt the same tool in order to allow end-users to communicate with their servers may be doomed to fail. But proposing a general solution, based on standards such as web service technologies, where each utility develops its proprietary tool, might be realistic.
The Spanish test pilot followed this approach, and it proved to be effective in overcoming most of technological barriers related to communication.

2.7 Make smart grid solutions easy to understand and use

A general recommendation is that smart grid solutions should be made easy to understand and use by the households.

Users have varying levels of competences and knowledge about electricity-related parameters. Therefore, the provided data should be easily understandable. For example, information should be presented in graphs, which are easier to understand than numbers. In order to follow a standard on how to show consumption data, kWh seems to be central. However, it is advisable to add examples in order to clarify “what a kWh is”. For example, besides the consumption charts with kWh, tips such as "A dishwasher of class performance A consumes about 1 Kwh per wash cycle" or "A fridge of class performance A consumes daily about 1 Kwh" could be included in the user interface. In other words, it is recommended to visualise data and make comparisons to things people can relate to or that they have daily experiences with.

An example from the IHSMAG project, which shows the importance of simple solutions, was the Norwegian *Demo Lyse* project. Here, the participating households had a number of available technologies. They could use tablets or displays, both to receive information and to control aspects of their consumption. They could also log in to web portals and they could use their smart phones. However, in addition to these “smart” solutions, many users had installed hard-wired scenario switches, pre-programmed with settings for the home such as “day”, “night”, “vacation”, “movie” etc. In terms of popularity and frequency of use, these simple, analogous looking type of switches were by far the most popular amongst users.

Figure 23. Smart grid solutions can be very simple, but still popular (the labels state: Home/Away, Normal/Reduced, TV set on/TV set off).

In relation to load shifting by use of time-of-use pricing, the findings from the Danish demo project *Dynamic Network Tariffs* show that schemes based on fixed price intervals (also called *static time-of-use pricing*) are easier to understand by 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 depending on the fact that static time-of-use pricing conveyed a general and comprehensible information about at which hours it would be most suitable for the system and for the participants' personal economy to consume electricity. Similar results have been found in other trials with static time-of-use pricing. For instance, Darby & McKenna (2012) conclude, on the basis of the experiences from an Irish trial, that "the main factor affecting customer response was the existence of time-varying prices, rather than the actual figures involved" (ibid.: 766). Thus, a general recommendation is that fixed price intervals should be preferred over real-time pricing for households – at least for solutions that aim at the active involvement of households in shifting their daily practices (like dishwashing and washing clothes). However, this may not apply to situations with automated or remotely controlled systems.

This has also implications for what kind of system challenges that time shifting of household consumption might contribute to: It is more likely that households can contribute to general shifts in electricity consumption (e.g. peak-shaving) rather than the day-to-day and even hour-to-hour challenge of balancing power consumption with intermittent renewable electricity generation. Thus, electricity systems based on a high share of "uncontrollable" power production (like wind power) might find solutions targeting an active involvement of households less feasible compared to electricity systems primarily based on more controllable sources (like hydropower).

Simplicity can sometimes (but not always) relate to automation of specific actions or processes through, e.g., centralized, remote control. An example of this is from the Danish *Dynamic Network Tariff* trial, were the interviewed participants expressed a high willingness to let the mobility operator control the charging of their EVs during the night, which would guarantee them the cheapest electricity price. The households' acceptance of central load management was not only about money saving, but also a question about convenience and comfort. The assumption among the participants was that with central load management, they would avoid the trouble with remembering to plug-in the cable and start recharging before going to sleep – although most participants did succeed in doing this on a regular basis, even without the central control.

2.8 Time shifting energy consumption – take into account the temporal rhythms and the spatial qualities of the home

Within the smart grid development, there is much focus on demand-side management and time shifting. The Danish study shows that households are able to time shift some of their everyday consumption, but this most likely happens in relation to practices that involves *semi-automation* of daily practices. More specifically, the *Dynamic Network Tariff* trial in particular showed time shifting of dishwashing and laundering (in addition to charging EVs). Our findings suggest that this was mainly due to the fact that these practices involve semi-automation, i.e. some of the activities related to, e.g., dishwashing are delegated to the dishwasher, which can run its cycle independently of the household members' direct intervention. This makes it possible to time shift these cycles to night time, for instance.

However, the study also shows that time shifting has implications for the daily rhythms and temporality of the household members and can be a source of inconvenience. This was in particular the case in relation to time shifting laundering to the night hours, which resulted in a new activity (habit) of hanging clothes to dry in the morning hours. As this activity coincides with the often rather busy morning hours in families, this is experienced by many as stressful and inconvenient. Also because handling the laundry in the morning implies that one parent needs to be away from the common areas of the home, and in this way cannot take part in what for many was considered meaningful and much appreciated family time around breakfast.

No matter how trivial or "mundane" this example might seem, it points to the important observation that solutions aimed at influencing household members to shift the timing of their daily practices need to recognise the temporal complexity of the household members' everyday life and the meaningful social interaction within the home. Thus, to ensure designs that work in practice, it is crucial to develop time shifting solutions and designs with a keen eye to this complexity and through active involvement of the prospect users through the entire design.

Our study also shows that not only the temporality of practices and the everyday life of households play an important role, but also the materiality of the home and its spatial layout. Thus, noise from machines running during the night (e.g. dishwashers and washing machines) can interfere with other activities of the household members (like sleeping if the machines are placed close to bedrooms). In this way, noise can effectively hinder the time shifting of activities such as dishwashing and laundering. This can be a problem within the household, but also between households in apartment buildings where neighbours live close to each other. These aspects need to be taken into consideration when designing solutions for time shifting. Thus, when designing “smart grid ready” appliances, so called trivial aspects such as creating low noise and vibration technologies can essentially be equally important design criteria for the smart grid ready appliances than built-in features for remote control etc.

Finally, in relation to time shifting, it has been pointed out at several occasions that insurance policies covering fire and household contents do not cover fires caused by white goods like dishwashers, washing machines and tumble dryers running while people are not at home. In addition, experts and consumers’ organisations recommend people not to run their white goods while they are not at home or at sleep due to risks of water damage or fires (see, e.g., Forbrugerrådet Tænk, 2016). This indicates that there might be important challenges related to insurance policies and potential health risks related to time shifting. It seems as these aspects deserve further exploration.

2.9 Promote energy saving through comparisons with others

Providing households with (visual) comparisons of the size of their own electricity consumption with the size of the consumption of their neighbours or households similar to themselves might be a way of increasing general awareness about own electricity consumption and motivate to save electricity. Obviously, data security and privacy issues have to be considered when taking such measures. However, grouping users on basis of certain common characteristics and providing the average data of the group (who shares these characteristics) could be a way of avoiding privacy matters. In this way, each household could compare their own consumption with others’ consumption without disclosing individual consumption data. Possible common characteristics include geographical area (neighbourhood, city and country), socio-demographic characteristics (age, gender, marital status and number of residents) and type of electricity contract. However, this has to be done in a thoughtful way. The *Demo Steinkjer* respondents were moderately sceptical about this type of comparison, as they feared that they would be compared with not really comparable household neighbours (for instance differing a lot regarding number of household members, size of floor space etc.). The parameters making the basis of such comparisons should therefore be transparent to the users or they may be dismissed by end users, in turn rendering these kinds of initiatives ineffective.

Previous demonstration projects have shown that comparison with others do have a relative high influence on customers’ interest in saving energy. An often-mentioned example is the American OPOWER project in which electricity customers were mailed a “Home Energy Report” that included neighbour comparisons as well as energy conservation tips. The study indicated an average reduction in electricity consumption of 2% (compared to a control group) and showed highest reduction rates for customers in the highest consumption decile (Allcott, 2011). More generally, studies indicate that normative social influence (like comparing one’s own performance with others) and social norms (“what other people do” – or are believed to do) are having a greater impact on people’s energy conservation activities compared to other kinds of initiatives such as general information about environmental negative effects of electricity consumption (Nolan et al., 2008). However, the real (long-term) savings and effects from these kinds of studies are often difficult to detect.

2.10 Feedback data should be real-time

Feedback information to households should ideally be real-time. One example could be real time notifications if a threshold consumption level defined by a user (daily or monthly) is exceeded. This could be an incentive for households to save energy. The threshold could be based on the household's historical electricity consumption (i.e. their “normal consumption”), a self-defined maximum level of consumption or the average consumption of similar households (cf. Section 2.8). This kind of solutions requires technical development on the electricity utility side in order to be able to provide this kind of service to the customers.

Another example could be real-time information about the environmental impact of energy consumption (based on data about the actual mix of electricity generation in the system). The information should be based on homogeneous, realistic and standard criteria.

For feedback solutions more generally, other studies also indicate the importance of real-time feedback. For example, Hargreaves et al. (2013) found that real-time feedback is important for householders as this makes it possible for them to monitor and follow what impact their changes of daily habits have on the energy consumption. In our project we found that real-time feedback data supports active “experimentation” and learning processes in relation to energy saving (Christensen, 2014: Jørgensen 2015).

2.11 Feedback data available on a non-aggregated level

Efforts should be made in developing solutions that make it possible to provide households with consumption data on a non-aggregated level (i.e. an appliance-specific breakdown of the households' electricity consumption). Otherwise, the users will only be informed about their aggregated consumption, which gives no clear idea of when and where electricity has been consumed. Like real-time feedback, this would support active experimentation and learning processes regarding the household's use of electricity and possible ways of saving electricity. Previous studies have reached similar conclusions, e.g. Fischer (2008) and Hargreaves (2013).

2.12 Smart home appliances

Related to the previous section, the technology in homes seems to be crucial in relation to providing non-aggregated consumption data. The development of mini-meters or smart plugs, which provides data on the electricity consumption of specific devices, is a key to increase awareness of users about their electrical consumption.

In relation to this, smart home appliances would be the second step. Once the non-aggregated consumption of certain devices is available, the possibility of choosing other performance cycles to change consumption pattern is a powerful tool. Selecting eco programmes on washing machines or dishwashers, being offered to reduce the brightness of television or computer, or even being able to pre-program a reduction of the set-point temperature of the fridge when it is not being used are more specific examples of potential uses of smart appliance.

In the long term, automated household appliances should be prepared not only for monitoring the electricity consumption of the appliances or control them manually, but also for controlling them remotely. In this way, the home appliances would be prepared for demand-side management (like time shifting of electricity consumption) on a short-term basis. This could be a supplement to other solutions that more directly and actively involve consumers in time shifting their electricity consumption.

3. Recommendations for policy makers

This section focuses on recommendations and key lessons for policy makers and people involved in the overall designing of smart grid development processes (e.g. planners and system designers).

The guiding questions for identifying and developing the following recommendations have been:

What kinds of actors play key roles? And how?
How to support a comprehensive and integrated approach through policy-making?
What are the more general policy-making implications of the results of the IHSMAG project?
What kind of existing approaches should be promoted? What kind of approaches should be avoided?
What are the key obstacles (technical, political, organizational)?

3.1 Flexibility and openness in policy important

How can we ensure a transition towards a “smarter” energy system? One option is of course to have faith in technology development and future markets, and to allow the technological development to unfold without political interference. The drawbacks of this approach are that it might take a very long time, and that much opportunity for controlling the development (or lack thereof) is lost. On the other hand, there might of course be much creative potential in a pure market driven approach with entrepreneurs pursuing the options they find viable. In IHSMAG, we have studied smart grid policy processes in Norway (see Skjølsvold, 2014). Here, the government has decided on a mandatory implementation of smart meters through regulation. In one sense, this has proven to be an effective strategy, because mandatory rules enforce some sort of transition. Additionally, our study of the Norwegian regulatory practise related to the roll-out of smart meters has led to two concrete recommendations, which we believe can facilitate learning on behalf of involved actors in smart grid roll-out processes.

Our first recommendation is that there should be *ample time* between the regulation is announced and its enforcement. In the Norwegian case, the authorities’ intention to implement the technology through grid management regulations became known to the industry actors already in 2008 after some years of debating the issue already. Thus, political imaginaries of “what” the smart grid could become in the future was in the making, and network operators were forced to involve themselves in this process by the roll-out being made mandatory by regulation. As the final wording of the regulation was not ready before 2013, this has given Norwegian stakeholders more than ten years to prepare for this massive infrastructure upgrade.

Initially, this time was spent by grid operators to collaborate on establishing a shared interpretation of the regulation, which was important for the regulator as well, because the goal of the smart grid is to create solutions that harmonise across regions and borders, as well as with potential market solutions in the future. Network owners on their end were driven by the need to make technology choices which would “fit” into the smart grid in the future, something which caused involvement in smart meter development to be a virtue of necessity for many of them (Throndsen, 2016). The study of the Norwegian demonstration projects shows that this basis, once established, enabled different actors to “use” the mandatory smart meter roll-out to achieve quite different goals, more specific to local needs and circumstances, and to experiment with quite different set-ups, both in terms of organization, choice of technology, user focus, and collaboration with other relevant actors (Skjølsvold and Ryghaug, 2015). Such goals and ideas were not necessarily explicitly formulated before the authorities announced that they would make the roll-out mandatory. This suggests that an artefact such as a smart meter holds great potential as an entity with generative capacity in terms of paving the way for collaborative efforts, as was seen in the case of Norwegian network owners organising themselves in a middle-out fashion in order to meet the regulatory demands and establish a shared understanding, again constituting a common risk mitigation exercise. Given less time to establish this common basis and understanding, it is uncertain whether the local-specific heterogeneity observed among different demo projects would have been achieved.

Further, the monopolized Norwegian electricity grid sector was highly ambiguous towards the roll-out at an early stage. Providing time for trial and error might also be a way to engage and establish enthusiasm amongst core actors in the electricity sector.

Embedding a broad technological scheme such as the smart grid in a local setting takes time. It requires that new business models are designed, that new inter-sectorial networks are established and maintained over time, that new social relations thrive, and that there are trust among the relevant stakeholders. This is also a challenge that involves bridging some crucial gaps between scholarly approaches such as power engineering, ICT engineering and business/economics and various social sciences. Thus, we advise that mandatory roll-outs should be designed with ample time for learning in order to coming to terms with all these issues *before* the full scale roll-out is conducted.

In addition, it is important to make regulation that allows for, and perhaps stimulates, *flexible solutions*. As we have already suggested, different localities, regions and countries consist of very different actor constellations and interest structures. This means that there are many different potential ways of mobilizing and designing smart meters and related technology, by which implementers can create value for themselves, beyond the obvious possibilities of in-home displays and automated control.

Our second recommendation is that it could strengthen the potential for innovation if the regulation of technology is relatively *open-ended*, with quite open standards so that it can be used for multiple purposes and be exploited by third parties. This would allow different actors to build new solutions “on top of” the technology. Examples of this were identified in both the *Demo Hvaler* and the *Demo Lyse* case studies in Norway. In Demo Lyse, for example, radically different solutions and set-ups were established for student housing facilities and for the elderly.

Building on Elinor Ostroms work on systems of common pool resource management, Maarten Wolsink (2012) suggests that smart grids and distributed energy systems share many of the traits of these systems. Decades of research on polycentric commons (such as grazing lands, fisheries, water sources etc.) – where the outcomes are shaped by the collective action of many stakeholders – suggests that top-down regulation without an eye towards local institutions, customs and practices usually fails. Instead, systems that are allowed to operate based on some sort of localized logic have a better chance. Wolsink (2012) compares the current smart grid regulation development to the early development of renewable energy, one or two decades ago. Then, social issues were largely neglected, and thus the development of renewables was hampered. In Wolsink's eyes, we do the same mistake today if local social issues are not brought to the forefront of policy development.

Other researchers also bring the latter recommendation forward. For instance, Friedrichsen et al. (2014) advocate for more flexibility in the future regulation of smart grids and notes that "the increasing number of and heterogeneity of stakeholders make 'one-size-fits-all' regulation simply less suitable, whilst regulation needs to take account of various interests" (ibid.: 261). The authors also conclude that due to the decentralisation of the electricity system, the entering of new actors and existing actors getting new roles, more individualised approaches and more coordination of the stakeholders across the system are needed.

3.2 Use intermediaries to engage the public

Both in a physical and metaphorical sense, there is often a long distance between authorities and households in which the technologies are brought to use. The same can be said about the distance between the authorities and electricity sector companies. Thus, regulators should strive to enrol intermediary organizations or actors who can engage in active dialogue with implicated actors at different scales. In Norway, for instance, the non-profit industry organization *Energy Norway*, who represents about 270 companies involved in the production, distribution and trading of electricity, has been crucial for establishing arenas where actors from different industries and the policy and regulation sphere can exchange experiences and opinions about common problems and solutions. It has also served as an arena for negotiating the outcome of the smart grid efforts, made robust by broad support by the actors. This was necessary because of the infrastructural characteristic of the smart meter, and the need for it to be more or less uniform across the country, and indeed, across borders.

The next step in developing the smart grid is creating viable and marketable solutions for end users. In Norway, this has been left entirely up to the market as the smart meter is installed by grid companies. Thus, the market has been given the task of further exploiting the potential made possible by the capabilities of the smart meter. In comparing the situation of the mandatory roll-out with the burgeoning market place of smart grid solutions, it is plausible that some sort of venue, similar to the one set up by *Energy Norway*, could prove conducive. If so, the need for uniform solutions by the network is replaced by the need for *relevant* solutions by the users; meetings between actual users and designers can occur and may cater for solutions, which resonate better with the needs of households, neighbourhoods and communities.

Some examples of the use of intermediaries can be seen through the four Norwegian smart grid demonstration projects studied in IHSMAG. In one sense, these projects are clear examples of direct efforts of public engagement. For most participants in such projects, they represent the first encounter with smart grid technology. As with all first encounters, this is not trivial. If this encounter creates aversion or negativity due to perceived lacks or neglects in the ambitions of designers and technology, the route towards achieving user relevant outcomes might become much longer. Furthermore, when participating in demonstration projects, households and citizens are turned into opinion leaders who might also serve as intermediaries, distributing knowledge, attitudes etc. to their respective social networks.

The Norwegian study illustrates how important demonstration projects are as both active intermediaries and incubators for public engagement, and regardless of whether they manage this task successfully as well as unsuccessfully. Several of the respondents in *Demo Steinkjer*, for example, stressed that the sudden lack of engagement and dialogue in the later phase of the project constituted a vacuum, which created frustration with and speculation around both the technology and the project in general. At first they were introduced as a “very important” part of the smart grid, but a year later they felt they were largely forgotten, constituted by a lack in follow-up on part of the demo. On the other hand, *Demo Hvaler* illustrates that it is possible to use demonstration projects to mobilize a very positive political dialogue between local authorities, industry and market actors, and citizens regarding issues such as sustainability, renewable energy and the smart, relevant uses of smart grid technologies.

With these dynamics in mind, regulators should consider stimulating, funding and promoting such demonstration projects, not only as sites of technology verification, but also as sites of public engagement and genuine dialogue. This, we believe, would also create very stimulating feedback loops, which would be of great value also for those designing specific smart grid solutions.

4. Literature

Allcott, Hunt (2011): Social norms and energy conservation. *Journal of Public Economics* 95(9-10): 1082-1095.

Brown, Marilyn A. and Zhou, Shan (2013): Smart grid policies: An international review. *Wiley Interdisciplinary Reviews: Energy and Environment* 2(2): 121-139.

Coll-Mayor, Debora; Paget, Mia; and Eric Lightner (2007): Future intelligent power grids: Analysis of the vision in the European Union and the United States, *Energy Policy* 35(4): 2453-2465.

Darby, Sarah J. and McKenna, Eoghan (2012): Social implications of residential demand response in cool temperate climates. *Energy Policy* 49: 759-769.

Friedrichsen, Nele; Brandstätt, Christine; and Brunekreeft, Gert (2014): The need for more flexibility in the regulation of smart grids – stakeholder involvement. *International Economics and Economic Policy* 11(1-2): 261-275.

Fischer, Corinna (2008): Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency* 1(1): 79-104.

Forbrugerrådet Tænk (2016): Blog: Tør du vaske om natten? Weblog entry on the website of Forbrugerrådet Tænk. URL: http://taenk.dk/blogs/mit-hjem/toer-du-vaske-om-natten (accessed 2016-05-02)

Gangale, Flavia; Mengolini, Anna; and Onyeji, Ijeoma (2013): Consumer engagement: An insight from smart grid projects in Europe. *Energy Policy* 60: 621-628.

Geelen, Daphne, Reinders, Angèle and Keyson, David (2013): Empowering the end-user in smart grids: Recommendations for the design of products and services. *Energy Policy* 61: 151-161.

Greening, L.A.; Greene, D.L.; Difglio, C. (2009): Energy efficiency and consumption: The rebound effect – a survey. *Energy Policy* 28(6-7): 389-401.

Gupta, Anu (2012): Consumer adoption challenges to the smart grid. *Journal of Service Science* 5(2): 79-86.

Hargreaves, N; Chilvers, J; Hargreaves, T (2015): *What's the meaning of "smart"? A study of smart grids*. Norwich, Norfolk, UK: 3S Research Group, University of East Anglia.

Hargreaves, T; Nye, M; Burgess, J. (2010): Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy* 38: 6111-6119.

Hargreaves, T.; Nye, M.; Burgess, J. (2013): Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. *Energy Policy* 52: 126-134.

Heffner, Grayson (2011): *Smart Grid – Smart Customer Policy Needs*. (An IEA paper submitted to the Energy Efficiency Working Party). Paris: International Energy Agency.

Nicholls, Larissa and Strengers, Yolande: *Changing Demand: Flexibility of energy practices in households with children. Final report*. Melbourne, Australia: Centre for Urban Research, RMIT University.

Nolan, J. M.; Schultz, P. W.; Cialdini, R. B.; Goldstein, N. J.; Griskevicius, V. (2008): Normative social influence is underdetected. *Personality and Social Psychology Bulletin* 34(7): 913–923.

Schick, Lea and Winthereik, Brit Ross (2013): Innovating Relations – or why smart grid is not too complex for the public. *Science & Technology Studies* 26(3): 82-102.

Shove, Elizabeth (2010): Beyond the ABC: Climate change policy and theories of social change. *Environment and Planning A* 42(6): 1273-1285.

Shove, Elizabeth and Walker, Gordon (2014): What Is Energy For? Social Practice and Energy Demand. *Theory Culture & Society* 31(5): 41-58.

Sorrell, S.; Dimitropoulos, J.; Sommerville, M. (2009): Empirical estimates of the direct rebound effect: A review. *Energy Policy* 37 (4): 1356-1371.

Strengers, Yolande (2013): *Smart Energy Technologies in Everyday Life*. Basingstoke, UK: Palgrave Macmillan.

Verbong, Geert P. J.; Beemsterboer, Sjouke; and Sengers, Frans (2013): Smart grids or smart users? Involving users in developing a low carbon electricity economy. *Energy Policy* 52: 117-125.

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.

Wissner, Matthias (2011): The Smart Grid – A saucerful of secrets? *Applied Energy* 88(7): 2509-2518.

4.1 Project publications

Christensen, Toke Haunstrup (2014): The role of learning and social interaction for changing practices? Paper for the workshop "A Social Practice Perspective on the Smart Grid" at the *ICT for Sustainability ICT4S 2014 Conference*, 24-27 August 2014, Stockholm, Sweden.

Christensen, Toke Haunstrup; Ascarza, Ainhoa; Throndsen, William (2013): *Country-specific factors for the development of household smart grid solutions - comparison of the electricity systems, energy policies and smart grid R&D and demonstration projects in Spain, Norway and Denmark.* Danish Building Research Institute (Aalborg University), Tecnalia (Spain), Norwegian University of Science and Technology.

Christensen, Toke Haunstrup; Ascarza, Ainhoa; Throndsen, William; Gram-Hanssen, Kirsten; Friis, Freja (2013): The role of households in the smart grid: A comparative study. Paper for the *ECEEE 2013 Summer Study*, 3–8 June 2013, Belambra Presqu'île de Giens, France.

Christensen, Toke Haunstrup; Friis, Freja (2016): Materiality and automation of household practices: Experiences from a Danish time shifting trial. Paper for the *DEMAND Centre Conference*, 13-15 April 2016, Lancaster, UK.

Christensen, Toke Haunstrup: Gram-Hanssen, Kirsten; Friis, Freja (2012): Households in the smart grid – existing knowledge and new approaches. Paper for the *2nd Nordic Conference on Consumer Research*, 30 May – 1 June 2012, Gothenburg, Sweden.

Christensen, Toke Haunstrup; Gram-Hanssen, Kirsten; Friis, Freja (2013): Households in the smart grid – existing knowledge and new approaches. In: Hansson, L., Holmberg, U., Brembeck, H. (Eds.) *Making Sense of Consumption. Selections from the 2nd Nordic Conference on Consumer Research 2012*, p. 333-348. Göteborg: University of Gothenburg.

Riaño Fernandez, Sandra and Sanchez Perez, Eutimio (2015): *Technological challenges and solutions at the household level: Practical approach – development of a user interface*. Derio, Bizkaia (Spain): Tecnalia.

Friis, Freja; Christensen, Toke Haunstrup; Gram-Hanssen, Kirsten (2016): *Smart grid solutions in the everyday life of households. Electric vehicles and time-of-use pricing*. Copenhagen: Danish Building Research Institute (Aalborg University).

Friis, Freja; Gram-Hanssen, Kirsten (2013): Integration of smart grid technologies in households - how electric vehicles and dynamic pricing change social practices in everyday life. Paper for the *ECEEE 2013 Summer Study*, 3–8 June 2013, Belambra Presqu'île de Giens, France.

Friis, Freja and Christensen, Toke Haunstrup (2016): The challenge of time shifting energy demand practices: Insights from Denmark. *Energy Research and Social Science* 19: 124-133.

Frøysnes, Ane (2014): "Bare en jævla boks? En analyse av visjonsarbeidet knyttet til Avanserte måle- og styringssystemer (AMS)" ["Just a damn box? An analysis of visions work related to advanced metering"]. MA-thesis. Trondheim: Dept. of interdisciplinary studies of culture, NTNU.

Jørgensen, Susanne (2015) Smart strøm – smart kunder? ["Smart electricity – smart customers?"]. MA-thesis, dept. of interdisciplinary studies of culture. Trondheim: Norwegian University of Science and Technolgy (NTNU).

Jørgensen, Susanne, Skjølsvold, Tomas Moe and Marianne Ryghaug (Forthcoming). Between empowerment and alienation. How feedback technologies can harm the prospects of successful energy transitions. *Energy Research & Social Science*.

Skjølsvold, Tomas Moe; Lindkvist, Carmel (2015) Ambivalence, designing users, and user imaginaries in the European smart grid: Insights from an interdisciplinary demonstration project. *Energy Research and Social Science.* Online first: http://dx.doi.org/10.1016/j.erss.2015.08.026

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

Skjølsvold, Tomas Moe; Ryghaug, Marianne (2015): Embedding "smart" energy technology in built environments. A comparative study of four smart grid demonstration projects. *Indoor & built environment*. Online first: http://dx.doi.org/10.1177/1420326X15596210

Skjølsvold, Tomas Moe; Ryghaug, Marianne; Berker, Thomas (2015) A traveller's guide to smart grids and the social sciences. *Energy research & Social Science.* Online first: http://dx.doi.org/10.1016/j.erss.2015.08.017

Throndsen, William (2016). *Response and Responsibility. Smart meters, end use, and the possibility of a green material public.* Doctoral thesis at Norwegian University of Science and Technology, 2016:17

Throndsen, William (2016). What do experts talk about when they talk about users? Expectations and imagined users in the smart grid. *Energy Efficiency*. Online first: http://dx.doi.org/10.1007/s12053-016-9456-5

Throndsen, William (2013): Constructing the Norwegian smart grids: To fix what is not broken? Paper for the *ECEEE 2013 Summer Study*, 3–8 June 2013, Belambra Presqu'île de Giens, France.

Throndsen, William; Ryghaug, Marianne Ryghaug (2015): Material participation and the smart grid: Exploring different modes of articulation. *Energy research & Social Science*. Online first: http://dx.doi.org/10.1016/j.erss.2015.08.012