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Abstract
The electricity system is currently facing great changes due to a number of challenges, including the need to mitigate climate change and replace fossil fuels with renewable energy sources. This calls for new solutions at all levels of the electricity system. Households are assigned a key role in these changes by system developers, researchers and policy makers, e.g. by realising electricity savings or providing a more "flexible" electricity consumption (also called "load management") in order to optimise the electricity system and balance consumption with fluctuating electricity generation from e.g. wind power. Thus, development of the so-called "smart grid" is an example of how the changes of a large technological system are affecting all elements of the system.

On the basis of a comparative study of Norway, Spain and Denmark, this paper analyses differences and similarities between these countries in relation to the current electricity system, energy policy plans, smart grid research and demonstration activities. The aim of this is to explore how country-specific factors influence the conceptualisation of households' role in the future smart grid. The analysis focuses on how, for example, differences in national plans for future changes on the electricity production side (like integrating more wind power, hydropower etc.) influence smart grid strategies and understandings of the households' role in the future electricity system. Furthermore, the paper discusses the main challenges and limitations of the present approach to the integration of households in a future smart grid; particularly the importance of understanding the interaction between smart grid technologies and everyday practices. This part draws on practice theory.

Introduction
The development of a future smart grid has become high on the political agenda within the recent years. The reasons for this are many, and include (among others): The climate change agenda and the need for developing new models for energy provision and consumption based on energy resources other than fossil fuels; the peak-oil debate and the aim of many governments to ensure national energy sovereignty; the smart grid represents a new area for business expansion for the IT sector (Nyborg & Røpke 2011). Thus, besides being an often-cited catchphrase, the smart grid vision and the development of smart grid solutions are influenced by many different interests, ideas and actors, which contribute to a high degree of complexity within the field.

In recent years, there have been a large number of smart grid research & development (R&D) and demonstration projects. Many of these have been supported by national governments as well as by EU funding. Also, the energy sector and other industries invest considerable money in the development of smart grid solutions. However, despite the plethora of R&D and demonstration projects across Europe and in other parts of the world, so far only little has been achieved in terms of actually realising the smart grid visions fully. Thus, the smart grid system is still much in the making, and there is still a gap between the many visionary ideas of the future system and the practical realisation of these ideas.

The residential sector (households) is often referred to as an important part of the future smart grid. This is partly because the residential sector represents a significant share of the electricity consumption in most countries (for Spain, Norway and Denmark, the countries included in this study, the share was between 27 % in Spain and 35 % in Norway in 2009; see Table 1). As shown by the review of R&D projects in Denmark, Spain and Norway (presented later in this paper), households are often expected to play a role in relation to load management solutions (also called demand-side management solutions), electricity savings or as an important actor in adopting new technologies that are envisaged to become integral for the smart grid. Examples of new technologies are: electric vehicles (EVs), heat pumps and micro-generation like solar power and small wind turbines. However, the conceptualisation of households in the smart grid discussion often seems vague or based on simple assumptions of users as informed and rational individuals. Thus, smart grid solutions for electricity saving or load management in households are often based on a strategy that intends to motivate users/consumers to change behaviour through e.g. detailed feedback information about their daily electricity consumption patterns. Studies show that this kind of approach can have some positive effect, but that in most cases the potential for electricity savings is limited and that the electricity savings tend to lapse again after some time (e.g., Darby 2010; Klopfert & Wallenborn 2011).

We would argue that there is a need for more focus on the daily practices of the household members, and how these practices are constructed, maintained and changed over time as a result of the interaction between different social and material elements. This would give a more detailed insight into the potential and limits of changing daily practices. This approach is based on the practice theory approach, which rejects the understanding of people's behaviour as a result of rational choices. The practice theory approach will be briefly introduced in the next section.

This paper is based on the preliminary results from a survey of country-specific factors in relation to the development of smart grid solutions in Spain, Norway and Denmark. The survey was carried out as part of the international project "Integrating households in the smart grid" (IHSMAG) with participation of partners from these three countries. The aim of the project, which runs from 2012–2014 and is supported by the ERA-Net 2nd Smart Grid Call, is to contribute with knowledge on how to develop comprehensive designs of smart grid solutions that involve households.[1]

The main aim of this paper is to compare similarities and differences between Norway, Spain and Denmark with regard to the electricity system, national energy policies (including policies for smart grid development) and previous R&D and demonstration projects of smart grid solutions related to households. The comparative study is based on literature research and the collection of data about smart grid projects from the Internet and other sources. A more detailed report with the results of the study will be published on the project website later in 2013.

The comparative study forms the basis for a discussion of how country-specific factors influence the conceptualisation of households' role in the future smart grid. This is discussed and elaborated further within the theoretical framework of practice theory in order to identify possible strengths, weaknesses and "blind spots" in the current approach to develop household smart grid solutions. It is hoped that this can contribute to the further development of smart grid solutions and discussion of the involvement of households in practical solutions.

The following section introduces a framework for understanding the household as an intersection of technology, everyday practices and the electricity system. The section also includes an introduction to practice theory. Then follows a review of the energy system, energy policies and R&D and demonstration projects in each of the three countries. On the basis of this review of the country-specific factors, the following section discusses how the role of households are conceptualised. The paper ends with a conclusion that summarises the main results of the paper.

Smart grid and everyday practices

The smart grid concept is characterised by a high level of interpretative flexibility (a term from the social construction of technology research that describes how technological artefacts can have different meanings and interpretations for various social groups and actors). Thus, the smart grid field is associated with a variety of different and sometimes conflicting interpretations of how technological solutions should be designed. One example relates to the idea of load management and, as noted by Nyborg & Røpke (2011), the question of who should manage consumption in order to provide flexibility; the consumers themselves or external actors like the electricity company? In some projects, focus is on automated remote management of household appliances (e.g. heat pumps and washing machines). In these projects, the "non-involvement" of the household members is regarded as an ideal and the aim is to "hide behind the panels" the management of the household's electricity consumption. This approach is sometimes termed "direct control" by technology designers. Other projects aim at active involvement of the consumers through motivating consumers to change their daily practices and thereby the pattern of their electricity consumption (e.g. postpone laundering or dish-washing) in response to information about real-time electricity prices.

A similar difference with regard to the conceptualisation of the role of households can also be found for smart grid solutions aimed at reducing electricity consumption in households. While some solutions favour home automation, others aim at making people change their electricity consuming behaviour by raising the consumers' awareness through (near to) real-time feedback about their daily consumption.

Up till now, the majority of the initiatives within smart grid solutions seem to have a technology-centred design approach. Thus, technical solutions are designed with a primary focus on the technical needs of the future electricity system, and only secondary focus on the interests and characteristics of the end-users. This develop-and-test approach implies the risk of a weak integration of the end-user context in the technological designs.

This paper, and the IHSMAG project, is based on the idea that in order to develop comprehensive smart grid solutions that work in practice, the design of them should be based on an

1. See the website www.ihsmag.eu for more information about the project.

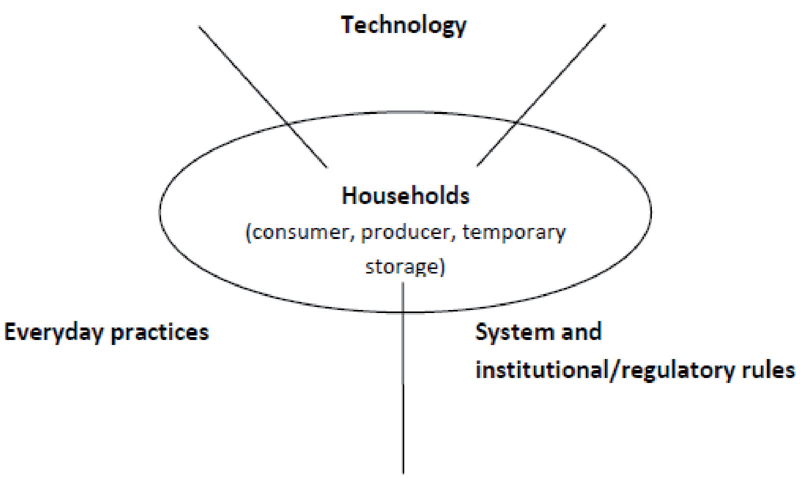

Figure 1. The household as an intersection point between technology, everyday practices and system/regulation.

integrative perspective, which includes the different social and material elements that play together in the construction of daily practices and thereby the electricity consumption patterns of the household. Focusing on one dimension of this complex system alone (e.g. the technical part or the daily behaviour of households) implies a risk of developing designs with unexpected and unintended consequences at both the household and system level.

Figure 1 illustrates a way of representing the complex interplay of social, technical, system and regulatory aspects that are mutually related the daily electricity consuming practices of the households. Ideally, a comprehensive study of smart grids should include all these elements in the analysis. The country comparison in this paper focuses particularly on the elements at the technological, system and regulatory level – and how these elements influence the conceptualisation of the households' role in the future smart grid.

The discussion of the link between everyday practices in households, on one side, and the technology, system and regulation (policies), on the other, is supported by the framework of practice theory. In recent years, the *practice theory approach* has gained ground in e.g. consumer studies (Warde 2005; Shove and Pantzar 2005). At the centre of this approach is the study of people's "doings and sayings", i.e. of their practices (Schatzki et al. 2001). The emphasis on bringing practice theory into consumer and environment studies mainly draws on practice theory as formulated by Schatzki (1996) and further elaborated by Reckwitz (2002). The practice theory approach emphasises how practices, rather than e.g. symbols or abstract structures, are the basis for both the constitution and understanding of the social sphere. In this way, the practice theory approach also stands in opposition to understandings of human action as a consequence of rational and informed choices. This approach can be found in for instance traditional public campaigns on energy saving, which in most cases are based on an understanding of causal relations between beliefs, attitudes and behaviour. An approach that has been termed the "A-Bc model" (Attitude-Behaviour connection) by Hargreaves et al. (2008) or the "ABC paradigm" (Attitude, Behaviour, and Choice) by Shove (2010).

Furthermore, practice theory accentuates the collective aspect of practices. Thus, Reckwitz (2002) states that the individual acts as a carrier of practices. Practices are coordinated entities, i.e. temporally unfolded and spatially dispersed nexus of doings and sayings (Schatzki 1996), which are held together by different elements. Different theorists identify different types or categories of elements, which hold practices together and thereby play an important role in the construction of practices. Shove and Pantzar identify three different forms of elements: Competences (the practical understandings and rules governing the performance of practices), meanings (the understandings and ideas related to practices, e.g. motivations) and material items (e.g. technologies or infrastructures). Other researchers operate with other categories of elements. For instance, Gram-Hanssen identifies the following four elements in an empirical study of practices related to indoor climate and comfort (Gram-Hanssen 2010a) and standby consumption practices (Gram-Hanssen 2010b): 1) Know-how and embodied habits; 2) institutionalised knowledge and explicit rules; 3) engagements; and 4) technologies. It is the first element (know-how and embodied habits) that, together with technologies, forms the direct link between practices and energy consumption; it is through our bodily habits ("the way we do things") and our interaction with technology that we activate flows of materials and energy. Thus, differences in practices, such as comfort practices, have important consequences for the level of energy consumption for e.g. heating.

An immediate implication of the practice theoretical understanding of the link between daily practices and energy consumption is that it might be expected that some electricity-consuming practices are more flexible for time shifting than others. Some electricity consumption related for instance to lighting or the use of information and communication technologies (ICT) is closely linked to the successful performance of specific everyday practices such as communication with friends and relatives (through digital media), entertainment like playing pc games or watching television or – as in the case of lighting – the performance of activities after sunset. In these examples, the use of electricity-consuming technologies is an essential requirement for the performance of these practices, and efforts to change the temporal pattern of the related electricity consumption would imply a time shifting of these activities (with direct implications for the daily life of the family). In comparison, other uses of electricity are more loosely associated with the performance of everyday practices. Examples of this are heating and cooling (refrigerators and freezers), which are of course a general requirement for a multitude of practices like comfort practices or cooking, but which have a greater flexibility in relation to load management due to the thermal capacity of the house or the refrigerator/freezer. For example, heating can be postponed without an immediate and dramatic decrease in the indoor temperature (and thus without direct impact on the everyday practices).

Thus, some types of electricity consumption are more likely to be subject to load management (automated or not) than others. This also depends on the meanings of the related practices, and to what degree they are embedded in the emotional and symbolic "landscape" and temporality of family life and family relations. As pointed out by Southerton (2003), the temporality of the everyday life of families are characterised by hurried periods as well as periods of relaxation and symbolic-laden interaction between family members (e.g. watching television together or being gathered at the evening meal). As some practices hold an important symbolic and emotional position in the everyday life of families, it is less likely that the electricity consumption related to these practices can be moved in time through load management than is the case of other less symbolic significant activities, e.g. doing the laundry.

Country-specific factors

This section presents the preliminary findings from the study of country-specific factors in Norway, Spain and Denmark. The presentation is divided into three subsections focusing on the electricity system, national energy policies and national smart grid research and demonstration projects.

ELECTRICITY SYSTEM

Table 1 presents some of the key figures for the development between 1990 and 2009 in population size, gross domestic product (GDP) and electricity generation and consumption in Norway, Spain and Denmark.

The total final consumption of electricity has been increasing in all three countries; most markedly in Spain (103 %), while the increase in Norway and Denmark has been much lower (9 % and 11 %, respectively). For Spain, the increase in final consumption of electricity has stopped and started to decrease since it peaked with approximately 260 TWh in 2007 and 2008. With regard to the total final consumption of electricity in the residential sector, the increases have been even higher for Spain and Norway (130 % and 20 %, respectively), while the increase is lower for Denmark (4 %).

The large increase in the Spanish electricity consumption might to a large extent have been related to high growth rates in the GDP: Thus, Spain (and Norway, too) had remarkably high growth rates (62 % and 68 %, respectively) compared with Denmark (35 %). But while Norway already had a high income level and living standard at the beginning of this period (1990), this was not the case for Spain, and thus the relative impact of the economic growth on the level of electricity consumption seems to have been much stronger in Spain compared with Norway. In addition to this, Spain has also experienced a dramatic increase in the penetration of air conditioning during this period: Today, Spain is the biggest EU air-conditioning market and represents 37 % of the EU market (followed by Italy with 20 %). The fast penetration of small residential air conditioners and their extensive use during the summer months are among the main drivers of increasing electricity consumption and have led to problems with power peaks during periods with warm weather (Bertoldi & Atanasiu 2009).

For the residential sector, the electricity share of the total final consumption (includes also fuel consumption for heating, but not for transport) is significantly higher in Norway (78 % in 2009) compared with Spain (40 %) and Denmark (20 %). This reflects the high availability of hydropower in Norway and the widespread use of electric heating in Norwegian homes. In comparison, district heating and oil- or gas-fired central heating are the dominant heating forms in Denmark (also a country with a high demand for heating due to climatic conditions). The historical emphasis on electricity – and particularly electricity for space and water heating – is also the main reason why the total final consumption of electricity per capita in the residential sector is 4–5 times higher in Norway than in Denmark and Spain.

As shown in Figure 2, the countries differ greatly with regard to the sources of energy used for electricity generation. Thus,

Table 1. Key figures on population, energy supply and consumption for 1990 and 2009. Based on data from IEA 2011a: p. IV.250–IV.251 (Denmark), p. IV.538–539 (Norway) and p. IV.628–629 (Spain).

	Spain		Norway		Denmark	
	1990	2009	1990	2009	1990	2009
Population (millions)	39.0	45.9	4.2	4.8	5.1	5.5
GDP (billion 2000 USD)	441	713	117	196	124	168
TFC of electricity (TWh)	125.8	255.4	96.8	105.3	28.4	31.6
TFC of electricity – Residential sector (TWh)	30.2	69.5	30.3	36.4	9.7	10.1
Residential electricity consumption – share of TFC of electricity (%)	24	27	31	35	34	32
Electricity share of total final energy consumption – Residential sector (%)	28	40	72	78	21	20
TFC electricity/population – Residential sector (kWh/capita)	774	1514	7214	7583	1784	1836

Note: Total final consumption (TFC) of electricity is the sum of electricity consumption by the different end-use sectors. TWh is Tera-Watt hours (equals 10^9 kWh or one billion kWh).

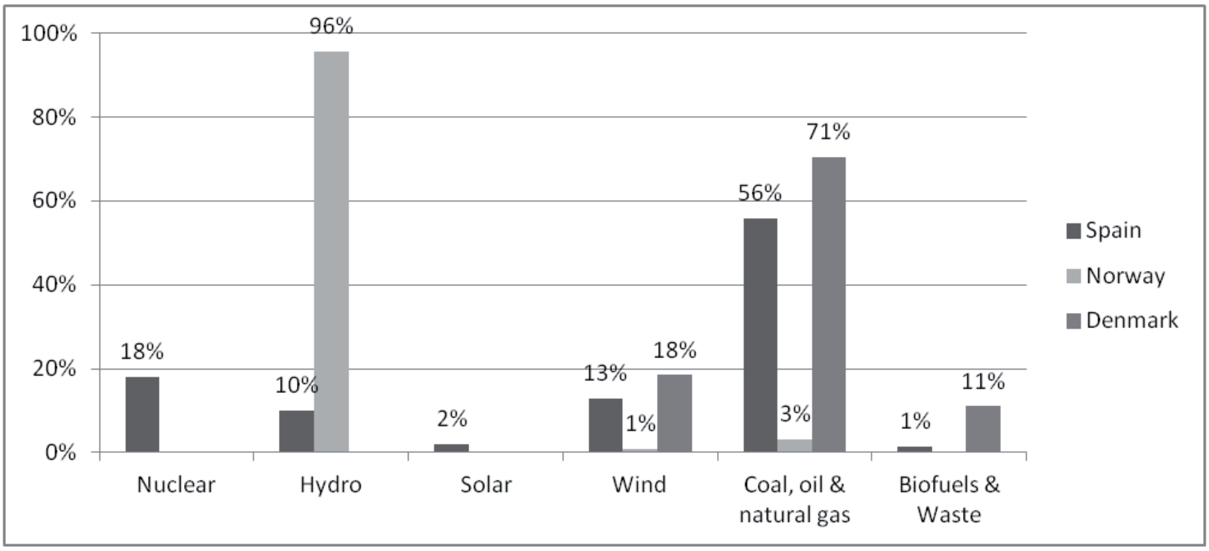

Figure 2. Distribution of 2009 electricity production (in per cent) by source of energy. Based on data from Electricity Information 2011: p. IV.251 (Denmark), p. IV.539 (Norway) and p. IV.629 (Spain).

Norwegian electricity production is almost entirely based on hydropower, while the electricity production is far more diversified in Denmark and Spain; 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). In Denmark and Spain, a considerable part of the electricity production is based on either condensing power/combined heat and power 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 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. In 2010, power production from combined-cycle gas turbines represented 26 % of the installed power capacity compared with 18 % installed hydropower capacity (REE 2010).

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 load management in the Danish smart grid discussion and R&D projects (as showed later).

As shown in Table 2, 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 one and five times higher than the Spanish one (Table 1). 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. As described in the section "Smart grid and everyday practices", some practices (and their related electricity consumption) are more difficult to time shift than other practices. This leads to the following categories of final uses that can be identified as the most likely to be subject to load management strategies: heating, cooling (fridge/freezer), laundering, air conditioning and dishwashing.

By adding up the percentages for these categories in Table 2, the share of residential electricity consumption that could (ideally) be subject to load management for the three countries are found: 51 % for Denmark, 84 % for Norway and 49 % for Spain. Thus, Norway has a very high load management potential compared with Spain and Denmark. This also partly explains why, in Denmark, the smart grid debate with regard to the question of load management focuses particularly on promoting the electrification of heating and transport through households' increased use of heat pumps and EVs. The aim of this is to increase the potential for load management.

Table 2. The distribution of the final residential electricity consumption by final use for Denmark, Norway and Spain. Note (Danish figures): "Laundry" includes dishwashers, washing machines and tumble dryers. Sources: Røpke et al. 2010 (Denmark), 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.

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

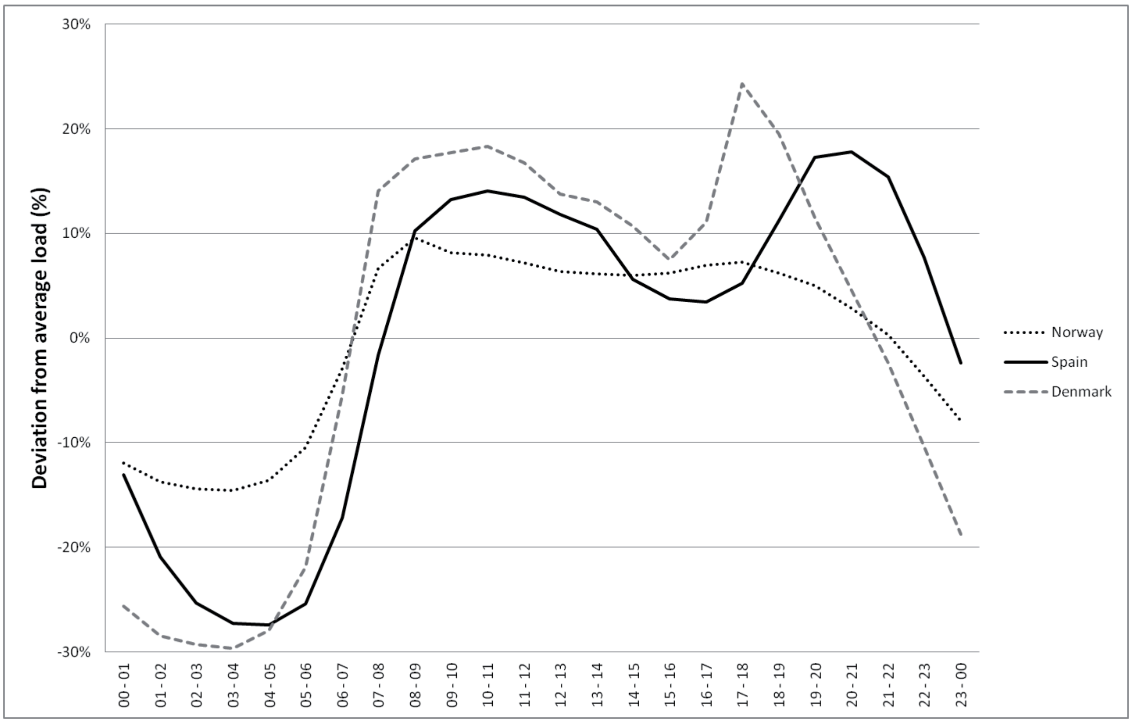

Figure 3. Comparison of load profiles for Norway, Spain and Denmark for week days in January 2012. The figure shows the hourly deviation for each country (in per cent) of the electricity consumption (all sectors) from the average consumption per hour during five week days in January (Monday 23 January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

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).

The curves in Figure 3 show 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 peaks during daytime and the dip during the night is substantial. Thus, the maximum/minimum ratio of the energy consumption in Figure 3 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, and the difference between peak 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.

On a more general level, Figure 3 shows 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 closely 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 is more 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 with larger potential for load management due to the thermal capacity of buildings. For the same reason, the Norwegian smart grid debate of the potential for 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.

None of the countries have a general scheme for dynamic pricing (spot prices) for households or small customers. In Norway, customers can in principle demand to be charged spot prices, but not according to variations in consumption or load shifting, as billed consumption is based on average weekly consumption.

NATIONAL ENERGY POLICIES

In recent years, Spain has seen a considerable increase in installed power and electricity production from wind power as well as combined-cycle gas turbines. According to government projections, both gas-fired generation and wind power are expected to increase further in the coming years. The CO_2 reduction target for Spain is 10 % by 2020 (compared with 2005). Policies in relation to supporting renewable energy are partly motivated by concerns related to security of supply (IEA 2009). The challenges of balancing demand and supply in the electricity system will increase as the share of wind power increases. The national plans for how to handle this involves improving cross-border connections, pumped storage of water (in relation to hydropower) for surplus of wind power and charging EV batteries. A specific problem in relation to balancing the supply and demand in the Spanish system is the coincidences of high power demand and low wind power production on both very hot and very cold days. Power demand typically peaks in situations with high use of electric heating (cold days) or air conditioning (hot days), and these temperature extremes typically occur at high pressure with relatively little wind (and therefore little wind-power production). (Ibid.)

In Norway, the overall energy and climate policy target is to reduce greenhouse gas emissions by 30 % (compared with 1990) by 2020 and to be carbon-neutral by 2050 (taking into account the country's contribution to emission reductions abroad). As the electricity supply and energy use in buildings are already more or less carbon-neutral due to a high share of hydropower, the reductions in greenhouse gas emissions have largely to take place within other sectors like the transport sector, industry in general and the petroleum industry in particular. Thus, measures proposed in relation to meeting the greenhouse gas reduction targets include, for the transport sector, transition from fossil fuels to more electricity or bio and hydrogen fuel as well as increased use of public transport and rail freight. Today, EVs are exempted from toll road charges and other taxes, allowed free public parking and there is also funding for infrastructure development. Other measures include a strategy for development of offshore wind power and plans for expanding hydropower production further. E.g., 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 2013a).

Even though Norway is not a member of EU, the country participates in the EU Emission Trading System (EU ETS). It is believed that Norway will play an important role in reducing emissions abroad by exporting renewable energy, but also by offering reductions due to carbon capture solutions as they mature sufficiently (NOU 2012). The Norwegian electricity system is an integrated part of the Nordic wholesale market (Nord Pool) and there is a high degree of exchange of electricity with Sweden, Denmark and Finland, and further connections to the continent are scheduled. The country 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 (IEA 2011b). A large reservoir capacity represents a very flexible energy source, but it is still vulnerable to dry years, and especially so in combination with cold weather.

As regards grid development, the focus in Norway is on solving future capacity challenges of the electricity grid (partly through load management) related to the plans of connecting offshore oil and gas production facilities with the mainland electricity grid in order to substitute oil-based thermal energy in the offshore oil sector with electricity (NOU 2012). However, this creates a need for extension of the grid, which has caused local criticism and political debate. Also, there is focus on efficiency improvements and load management solutions to preserve the flexibility of the system and avoid too high costs of upgrading the capacity of the grid. 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.

For Denmark, the overall aim is to reduce CO_2 emissions by 34 % by 2020 (compared with 1990) and to develop an energy system based on 100 % renewable energy by 2050 (Energy Plan 2012). To expand wind power production in order to mitigate climate change and improve energy sovereignty has been a main target of Danish energy plans since the 1990s. The 2012 Energy Plan stipulates that wind power should cover 50 % of electricity generation by 2020.

With 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 does 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 and initiatives 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 dynamic taxes (Energy Plan 2012).

The growing challenges of balancing input and output and the visions of a dramatic increase in wind power production has 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. Until now, focus has particularly been on load management combined with EVs and electric heating of buildings.

Roll-out of smart meters

Smart meters, which enable two-way communication between the meter (the customer) and the supplier, are seen as an infrastructural 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 manual reading of traditional meters. In fact, this might have been a main driver for the investments in smart meters in Europe. Another important driver at the EU level is the legal framework of the EU; particularly the Directive on Internal Markets from 2009, which is part of the Third Energy Package. The focus of the EU regulation is to promote market liberalisation as well as energy optimisation through the roll-out of smart meters (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.

At present, Denmark has the highest share of smart meters with (at least) hourly-based metering of the electricity consumption. By 2011, about 50 % of all customers had smart meters with remote reading installed. In comparison, only about 8 % of the Spanish electricity customers and about 4 % of the Norwegian customers had a smart meter with hourly reading (Renner et al. 2011).

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

In 2011, the Norwegian Water Resources and Energy Directorate decreed that all meters (approx. 2.7 million) are to be replaced with smart meters by 2017. In conjunction with this, a regulatory guideline was issued that was elaborated in collaboration with the directorate and all interested parties (mostly Norwegian DSOs). With respect to functionality, an extended debate ensued, resulting in Norwegian meter specifications looking like other state-of-the art smart meters developed elsewhere and in the EU. The smart meters must 1) measure in intervals of max–min 60–15 minutes, 2) use standardised user interfaces 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 a kill-switch for remote curtailment included, 6) have the 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 2013b).

There are not yet any national policies for the roll-out of smart meters in Denmark (even though about 50 % of the customers already have smart meters with hourly recording). As mentioned before, the 2012 Energy Plan focuses on developing agreement with the Danish electricity distribution companies about a voluntary roll-out of smart meters. Thus, a more specific regulation of the technical characteristics of smart meters for the Danish roll-out has not been adopted yet.

SMART GRID R&D AND DEMONSTRATION ACTIVITIES

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 smart grid, but also in Norway there are a number of smart grid projects. The following brief review of existing smart grid projects involving households shows the similarities and differences between Norway, Denmark and Spain.

Denmark

The Danish survey (reported in Christensen et al. in press), which included 18 projects, showed 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 (in the Danish case expectations of especially oil-fired boilers being replaced by heat pumps and combustion-engine cars by EVs).

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.

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 is usually assumed to be the primary driver for changing practices.

Spain

The Spanish survey included five recently finished or ongoing smart grid projects in relation to households. The projects were: 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 hard- 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) is 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.

Norway

The Norwegian survey included 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.

The role of households in the smart grid

This section summarises and discusses the main findings from the review of country-specific factors. Focus is on how the role of the households is conceptualised in relation to the smart grid; i.e. the implications of the characteristics of the energy systems, national policies and smart grid R&D and demonstration projects for the (expected) future role of households in the smart grid.

The comparison of the energy systems of the three countries shows differences with regard to the relevance of different smart grid solutions. Paradoxically, Norway appears to have the greatest potential for load management in households (due to widespread use of electric heating), but have the smallest challenge from intermittent renewable energy sources. This probably explains why there seems to be a more limited focus on load management in Norway than in Denmark and Spain.

In Denmark and Spain, high shares of intermittent renewable electricity production and ambitious goals, particularly in Denmark, for increasing renewable electricity generation call for new solutions in order to balance the production and consumption side of the electricity system. However, because of limited use of electricity for heating, the load management potential in these countries is limited, and implies a much more active involvement of households through changing their patterns of everyday practices. Seen from a practice theory perspective, changing the timing of practices like cooking, watching television or lighting seems difficult due to the embeddedness of these practices in the temporal and spatial structures of everyday life, such as the rhythms of work life, school and education, spare time activities, lunch and dinner practices and family life at home. Thus, developing large-scale load management of households' electricity consumption would in Denmark and Spain require a particular focus on the user-context in order to avoid solutions with limited effect regardless of whether these solutions are mostly automated or based on active involvement of the consumers.

The main focus regarding the implementation of smart meters is on the potential of using smart meters for load management in order to avoid imbalances on the grid. Also, the need for peak-shaving in order to avoid blackouts due to grid capacity problems in a future situation with higher electricity consumption (e.g. because of increased use of heat pumps or EVs) also play an important role. The emphasis on the load management potential of the smart grid seems to take place partly at the expense of the focus on increasing energy efficiency. Thus, the attention on employing smart meters for achieving energy savings in households (e.g. through frequent and detailed feedback to customers about their electricity consumption) seems limited in all three countries.

In this way, the smart grid debate in Norway, Denmark and Spain seems to be in line with a general shift of the focus of the energy (system) debate from energy saving to load management in relation to the implementation of renewable energy (Vidalenc & Meunier 2011). In relation to households, this might be problematic, as the potential for load management in households might be limited in countries where the major part of the electricity consumption in households is related to practices that are inflexible for time shifting (e.g. cooking and entertainment; see also discussion in the section "Smart grid and everyday practices"). The visions by policy- makers and technology designers about the potential for load management in households sometimes seem to be based on rather optimistic estimations of the potential for making (assumed rational) household members change their daily practices through price-incentives and dynamic pricing.

In addition, policy visions of the integration of households in the smart grid often build on the assumption that new areas of electricity consumption will emerge in order to create a larger potential for load management; typically replacement of combustion engine cars with EVs and fossil-fuel-based heating with heat pumps. In combination with the fact that load management generally overshadows electricity-saving options in the smart grid debate, this involves a risk of increasing the overall challenge of reducing greenhouse gas emissions from the energy system. This could happen if the smart grid policies result in higher electricity consumption through poorly designed smart grid solutions that do not take into account the user context; e.g. whether the potential for managing the charging of EVs is not feasible due to car users' intervention in the automated charging system. Thus, smart grid strategies face the risk of developing new and energy-intensive structures, which can have unintended consequences and become new challenges for energy planners and the transition of the energy system. As pointed out by Vidalenc & Meunier (2011), it is important to encourage *both* load management solutions and energy efficiency policies.

This brief survey of R&D and demonstration projects shows that load management is a central theme for projects in all countries (but particularly in Denmark and Spain), with relatively few projects focusing on energy saving. The load management 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 (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 the smart grid solution, 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 for 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 embedded in social-material structures and as collective practices formed by many different elements.

The conceptualisation of consumers as (economic) rational agents and the tendency to target consumers as individual agents have a long tradition in modern energy policy (see e.g. Godbolt et al. 2009 on the historical construction of consumers in Norwegian energy policy-making) and belong to what Shove (2010) terms the ABC paradigm ("Attitude, Behaviour and Choice"; see previous description). Furthermore, the approach within the smart grid field has until now primarily been based on the idea that change in the electricity system is primarily to come from the system side; i.e. that changes in consumer practices are seen as a response to (new) needs on the system side. The most obvious example of this is the interest in load management, which is essentially a result of new challenges on the production and distribution side of the energy system due to increased intermittent power generation (and not a need of the households *per se*).

This approach to the role of households can be queried in two ways. First of all, as also noted by Shove and others in relation to the critique of the ABC paradigm, this approach does not take into account the complexity of the social practices related to electricity consumption in households. As described earlier, everyday practices are held together by complexes of elements, which include material elements, competences and understandings (e.g. of the good family and everyday life). This means that changing practices involve changing the complex of elements and their relations. Something that goes beyond most smart grid R&D projects, which mainly focus on introducing new technical devices in the household – in some cases in combination with economic incentive schemes like dynamic pricing in order to motivate the households' use of the devices. Also, from a practice theory perspective, it is important to understand the interdependence *between* practices; particularly in relation to the temporal patterns and rhythms of the everyday life of families, which make the goal of implementing load management of practices particularly challenging.

Secondly, the individualistic approach tends to ignore the importance of the social context of everyday practices and the potential role of local communities as drivers for changes in everyday practices and at the system level. For instance, results from a large-scale testing of smart metering and feedback in the UK indicated that the highest energy savings were achieved in trials with a community approach and which involved social learning and community leadership as part of the trial (Darby et al. 2011). This is similar to the observations made by Hargreaves et al. (2011) on the potential role of civil society in relation to sustainable transitions. They emphasise the importance of understanding civil society as an important part of transitions; not only in relation to changes in everyday practices, but also on the level of socio-technical system transition, as social practices are an integrated part of these. Without neglecting the importance of state and market actors, they note that "there is growing recognition that community-level action for sustainability is a necessary and potentially powerful aspect of change, in part due to the local knowledge it captures, the social contexts for change it generates, the immediacy of its impacts, and in helping to democratise decision-making processes" (ibid., p. 4).

Unfortunately, smart grid policies and R&D projects tend to build on individualistic approaches that conceptualise household members as (economic) rational agents. For instance, only few of the R&D projects reviewed in this paper include a broader understanding of the social context of the households' everyday practices. This points at the need for developing more integrated approaches to the design of smart grid solutions; approaches that include an understanding of the complexity of everyday practices and possibly also aim at integrating the potential contribution from local community interaction in smart grid development.

Conclusion

The comparative study of the country-specific factors in Norway, Denmark and Spain shows similarities and differences in the conceptualisation of household members' future role(s) in relation to smart grid development. Regarding smart grid solutions, there seems to be a general tendency to focus more on load management than on electricity savings, particularly in Spain and Denmark. The latter countries are facing increasing challenges in relation to balancing electricity production and consumption due to increasing introduction of intermittent, renewable electricity generation.

Across the three countries, the conceptualisation of consumers as individual and (economic) rational agents appears to be dominant in the national policies and R&D projects. From a practice theory perspective, this is problematic as it implies the risk of ignoring the complexity of everyday practices and the importance of the households' social context in the development of smart grid policies and solutions. The consequence of this can be twofold: First, there is a risk of developing policies and technical solutions that will not be successful in practice or might even have unintended negative consequences. For instance, much focus is on promoting EVs in order to increase the potential of load management. However, this could be a risky route if the envisaged potential is not realised in practice and the EVs only add more load to the electricity system. Second, 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 local communities in relation to the development of comprehensible solutions that *work in practice*.

This calls for an integrative approach to the development of household smart grid solutions. An approach that integrates detailed understandings of the processes and dynamics on the socio-technical system level as well as within the everyday life of households and their surroundings.

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