*Smart system of renewable energy storage based on **IN**tegrated E**V**s and b**A**tteries to empower mobile, **D**istributed and centralised **E**nergy storage in the distribution grid*

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Contents

Abbreviations and Acronyms

Acronym	Description
DR	Demand-Response
DSM	Demand-Side Management
EV	Electric Vehicle
ILP	Imagined Lay Persons
NOBEL	Neighbourhood Oriented Brokerage Electricity and Monitoring System
PV	Photovoltaic
SESP	Smart Energy Service Provider
ToU	Time of Use
V2G	Vehicle to Grid
VPP	Virtual Power Plant
WP	Work Package
WPL	Work Package Leader

Executive summary

This document provides the INVADE project with a review of studies on end users of smart energy technology and tariff models. The report provides a thorough review of state of the art literature and previous studies on the role of the end user in relation to energy use. The results cover both qualitative and quantitative analyses on end users and energy use. It also provides a short overview of theoretical perspectives of science and technology studies (STS) that are useful for understanding user engagement with energy markets, business models, tariff structures, and technology and the basis of many of the contributions in the review as well as our recommendations.

The aim of the report is to provide INVADE knowledge and insight to the design and deployment of business models and smart energy technologies. It provides recommendations in four sections on 1) intervention and feedback, 2) introducing new technology, 3) segmentation and tariffs, and 4) vehicle to grid.

Findings indicate it is quite possible for customers to allocate flexibility, and that there are several ways of achieving it. Responsiveness (as indicated in most cases by consumption reduction) is typically in the range of 5-20%. The qualitative findings underline the importance of social learning when undertaking interventions into everyday life. Introducing novel business models or technology opens a window of opportunity, which must be exploited carefully to achieve engagement. Some selected findings:

- Novel information from feed-back and monitoring devices may become the root cause of a new, more cemented consumption baseline, which future interventions may have an even greater difficulty of changing. This means monitoring can lead to new barriers of behaviour change.
- New monitoring devices in the household initially open a window for social learning. After learning has happened, devices fade into the background. After saturation is reached intervention becomes more cost intensive.
- If routine change during the initial phase of solution domestication does not happen, changes will likely dissipate. A return to normal may be observed.
- Attention must be paid to symbolic aspects of microgeneration. Some users are above all oriented towards “doing the right thing” (environmental or societal motivation).

- The significance of prices and tariffs should not be underestimated. Variable prices and feed-in tariffs have proven effective incentives in some instances, and small but favourable setups can be included for added effects.
- Possible segments include sceptics (i.e. the elderly), pragmatists (focused on low hanging fruit) and enthusiasts (early adopters, adopters with social or environmental motives).
- Monetary gains interests, ecological concern and technology interests were also found to be viable inroads for recruiting end users.
- In the cases where acceptance of smart charging was negative due to desire for high flexibility in mobility, even programming capabilities for charging was not found to improve acceptance.

1 Introduction

The energy sector is currently undergoing rapid change. With the introduction of smart energy technologies and novel business models, the role of the end user of electricity is evolving quickly. The introduction to the electricity sector of novel technological solutions and business models, like within any planning project, is often conceptualized with an "imagined user" (Ivory 2013, Throndsen 2016) at the core, as the real user is still not existing. This report takes a closer look at the task that technology designers and developers of smart energy technologies and market devices face, when they have to make many of the design related decisions based on assumptions about prospective users and what they can learn from past studies of users. In short, the report examines the role of the user in the INVADE project and in the smart grid in general, to inform WP9 on how to make smart energy business models relevant for end users.

The overall aim of the INVADE project is to enable the introduction of increased shares of renewables in the grid. This poses increased challenges with balancing the grid. A way to improve balancing capabilities, is to make end user consumption in the grid more flexible. A way of meeting this challenge, in line with the goals of the INVADE project, is to have end users introduce local generation capacity like solar PV or local storage capacities like batteries, employing Vehicle-to-Grid (V2G) capacities, and adding flexibility control to household appliances. The end goal is to leverage these capacities to meet rapid changes in supply and demand.

Allowing this change to come about means changing the way users relate to their electricity consumption on a household level. Further, it also means that it is necessary to coordinate the many, small contributions that arise from end users providing flexibility or becoming prosumers. The main goal of WP9 is to deliver viable business models empowering this coordination to make sure that every, small stakeholder contribution meets its potential value for both the grid and the end user. The contribution of this report is to inform designers of business models in WP9 on ways to keep user needs in mind when designing these business models. Considering user needs and desires are necessary to create business models that do in fact provide incentives and value (monetary or other) for actual customers. In the end, ensuring that households are provided sufficient benefit as stakeholders within the business models implemented by WP9 will, in turn, ensure large scale adoption of the energy services delivered by INVADE.

This report examines the role of the user in the INVADE project and in the smart grid in general, informing WP9 on how to make smart energy business models relevant for end users. In Chapter 1 we first define the role of the electricity end user in the INVADE project and describe why there is a pressing need to have an expanded view of end users when designing and delivering business models in INVADE. This chapter also revisits the use cases in the INVADE project to focus on the ones most relevant for examining the role of end users. Chapter 1 finally describes the method of the literature review and the selection criteria for the papers that were included.

Chapter 2 introduces the theoretical background that informs the analysis. To this end, some of the theoretical basis within science and technology studies (STS) are presented to establish a general understanding of how technology appropriation and practices of energy consumption occur in the everyday life of end users. The theoretical concepts that will be presented is that of socio-technical imaginaries (briefly mentioned in the introduction above), in addition to theories of technological script, domestication of technology, and energy practices.

Chapter 3 presents a review of scientific contributions, both quantitative and qualitative, related to end users in the smart grid. Finally, chapter 4 engages in a discussion about the implications of the review and summarizes some recommendations for WP9 and the INVADE project in general about what must be taken into consideration when designing markets and business models for energy service provision aiming to meaningfully include end users and households.

1.1 What is the role of the end user in the INVADE project?

According to the overall approach methodology described in the INVADE proposal, the project will develop, and through testing within large-scale demo pilots, adapt a platform for leveraging storage and demand side flexibility in the grid. The success of this is dependent on end users partaking in a novel market coordinated by Smart Energy Service Providers (SESP) dealing in the timely coordinated dispatch of storage and end use flexibility. Within such a market, novel business models that consider multi-dimensional value of storage and that are empowered by big data analytics can help increase returns on investment for individuals and communities investing in storage and offering up flexibility, as either prosumers or conventional consumers. The end user in the INVADE project is one that is able and interested in learning about and investing in production or storage capabilities or repurposing their use of home appliances and

Electrical Vehicles (EVs), either manually or by automation, and to participate with these resources within the framework provided by their local SESP.

However, this means that end users must be called upon to make such realignments in the first place, since participation usually is voluntary and contingent on the right incentives. The incentives may be monetary, but, as this report will consider in more detail, they may also be more compounded and stem from other sources entirely relating to social, environmental and/or cultural aspects. Since monetary incentives, at least in a short perspective, may be quite small compared to investment costs, combination effects between many kinds of incentives must be identified and exploited. Importantly, incentives related to social aspects are made even more relevant by the fact that the business case of smart energy service provision is based on network technology. As with any network technology, the more resources are networked, and their capabilities made leverageable, the more the benefits of participation (and thereby any conventional, monetary incentives) are increased.

Realigning end user's relationship to their electricity consumption and subsequent behaviour patterns is a challenging task. Electricity consumption is by itself often experienced as invisible, or in fact, doubly invisible, as Burgess and Nye (2008) has described it. First, the connection between local consumption and regional or national production is not straightforward. For instance, the connection between Norwegian consumption and coal generation on the European continent is not immediately apparent, as has been made increasingly apparent by a debate surrounding the trade in certificates of origin on electricity generation in Norway. Second, households do not experience using electricity as such; electricity use arises as a side effect of doing housework, cooking, cleaning, transport, or of getting information and being entertained.

Since the liberalization of the energy market of the 90's, expectations have seen end users as market conscious and interested in optimizing electricity consumption and cost. Users were imagined as (i.e. it was assumed by system designers that they were) interested in keeping themselves up to date about prices on electricity and swapping electricity providers routinely to get the cheapest electricity. The result today, for Norway, is that few swap providers very often, but also that the consequence of doing so is hardly considered worth even the extremely low transaction cost of navigating a website and clicking a mouse button. In short, the achievement of the electricity market liberalization was probably lower prices, but one did not see the rise of electricity conscious end users (Karlstrøm 2014).

The INVADE project addresses the potentially shifting role of end user in the market from one of energy sink, to a market for energy service provision, where end users can themselves partake as providers. In general, making end users more electricity conscious and enrolling them in a system of service provision is now made more feasible with the introduction of smart metering.

Though considered more necessary than sufficient within any developed smart grid vision, the introduction of smart meters is heralding perhaps the greatest change in the electricity system since 1990. Introducing smart meters and the subsequent technologies to exploit increased communication and measurement capabilities can make electricity more visible for consumers. Smart metering makes it possible to aggregate and provide data about consumption, and to give users an overview of the hourly consumption of the household. This makes it possible to cross-reference consumption data with market prices in real time. For the users, this may entail needing to pay more attention to the timing of their electricity consumption and consume electricity in a more “responsible” manner (Throndsen 2016). The (re)introduction of power tariffs may also further increase incentives for end user behaviour change according to price signals. For users to be able to respond in a timely and manageable fashion to these changes in the electricity system and still be able to continue with their everyday lives, they might need some tools. A short overview of the possibilities introduced by such tools as suggested by the INVADE project is outlined in the following subchapter.

1.1.1 Use Cases in the INVADE project

The focus of WP9 is to enrol and make coordinated use of flexibility assets in the grid in order to balance the increasing share of intermittent renewables, at the same time as appropriate value for large and small stakeholders is assigned to the provision of said flexibility. Flexibility assets include demand-response (DSM) of loads, storage systems, local production, and electrified transportation at the site of end use. This pool of flexibility is potentially quite valuable since they can provide balancing to a grid that includes intermittent generation, ensuring stability and operability of the system and possibly enabling the disburdening of public investment needs in the grid. The challenge from an electricity systems perspective consists in how to assign the value of this flexibility, effectively turning it into a commodity that end users will want to trade with. The active participation of end users in prosumption, self-consumption of local generation, and the use of residential or community storage can, with the systematic application of big data analytics, Internet of Things-capabilities and visualization techniques, be exploited and operated as Virtual Power Plants (VPP). The INVADE project’s aim is to create a flexibility management system to be used by a flexibility operator to provide flexibility services in the grid. The flexibility operator leverages flexibility assets in a flexibility market by the employment of a business model as designed by WP9, tying in the different assets by offering to trade their flexibility, creating value.

The cloud-based flexibility management system and its attendant business models will be tested through demonstration pilots and four distinct use cases. Use case 1 and 3 include mobile energy storage using EVs to implement V2G-capability, and distributed storage using individual batteries at the household level for demand response and flexibility management are the most relevant for end users and is therefore the focus of this report.

Use case 1 is linked to demonstration projects in Norway and the Netherlands, where a heterogeneous composition of up to 75 EVs will be detailed during the project. Use case 3, focusing on distributed energy storage across multiple households, will showcase in Norway making use of at least 25 households (some including EVs as well) with batteries in the range of 5-10 kWh.

More specifically, the Norwegian demonstration, focusing mainly on use case 3, is in the Triangulum Smart City & Communities area in Stavanger. The backdrop is the prospect of rising energy prices due to great investment needs in the grid infrastructure in the future, including the introduction of power tariffs by the end of 2019. Norway also has the highest EV density in Europe. In this respect there will be a focus on both unidirectional and bidirectional flows between houses and grid, including boilers, batteries, PV installations, network capable energy management tools, and various novel tariffs (i.e. power tariffs). The pilot will make use of big data analytics to aggregate data and provide individual households with information, feedback and DSM capabilities.

The second demonstration, pertaining to use case 1, is in the Netherlands. Through the local companies GreenFlux and ElaadNL, possibilities of vehicle-to-home (V2H) or vehicle-to-grid (V2G) capabilities will be explored. This pilot outlines three domains, the home, the work-place, and the public (i.e. a city street or a shopping mall). Each domain provides different business cases. The goal is to use local energy locally, and benefit from the often-lower prices of intermittent electricity generation.

1.1.2 About this report and review selection method

With the use cases described in the previous section as the departure point, this report is based on a literature review of empirical contributions that describe end user engagement with similar technologies, services, and business models as the ones that feature in INVADE use case 1 and 3. The literature review was conducted in the database of Elsevier, one of the leading publishing houses on social science energy research. The theoretical background is provided for a general understanding of user engagement with novel technology and knowledge, but the review is multi-disciplinary with results provided across the fields of e.g. economy, anthropology, sociology, psychology.

The review is based on a literature search that was conducted using concepts that are central to the INVADE project, such as *smart, energy, solution, business model, user, multi-sided, battery storage, demand response, demand side management, cloud, service, prosumers, V2G*, and *EV*. The contributions were selected based on a close reading of the abstract to ensure relevance to the topic of this deliverable. Importantly, many of the contributions were based on simulations and modelling, all of which have been ignored in the subsequent literature review. The focus of this review is on solutions that have been tested in real life, with real users, and which have provided experiences that have some bearing on the creation of business models for the INVADE project.

Some of the contributions provide insight into business model creation besides having studied users, for instance by expert interviews. These contributions have been included where appropriate (for a thorough review of business models pertinent to INVADE see D9.1 Review of existing business models and storage technology database). Before commencing with the review of empirical basis for our user analysis, a short introduction to some central theoretical concepts that may aid in building a basis for recommendations is provided in the following section.

2 Theoretical perspectives on end use of electricity and the everyday life

Four theoretical concepts are introduced that provide insight into how users interact with new knowledge (i.e. business models) and technology, taking into consideration the existing framework in which users are already posited, in the setting of everyday life. Electricity consumption takes place within the confines of this everyday life, and consequently this is where much of the efforts of WP9 will be aimed.

First, **practice theory** is introduced, which views technology interventions as a smaller part of already existing and slowly changing energy cultures. In this perspective, for technology or a new business model to be taken into use, they must become part of practices that make up everyday life.

Second, a related perspective introduced is that of **domestication theory**. This is a useful tool to keep count of practical, cognitive, and symbolic aspects of technology or business model appropriation processes. These may be utilised in user evaluation by gauging users' motivation for appropriation, learning and know-how, and concerns of self-representation when technology is appropriated and put into use. Only subtle differences exist in the appropriation of a technology or for instance a business model, which both deal with issues of knowledge, convenience, and identification.

Third, the concept of **technological script** is introduced. Script is written into technology and read and interpreted by users, and the theory thus has a view to the link between design processes and end use. It is a useful tool in aiding evaluations of whether technology design has been successful or not, and on what terms success should be measured. The concept of script is equally applicable to for instance a business model. For instance, the design of a business model takes into account who customers are, what their needs are, how to engage the customer, how to capture value, and an overview of the value-chain (Baden-Fuller and Haefliger 2013, see also Illieve et al. 2017). Any answer to these questions will be part of the script that makes up the business model.

Finally, the closely related concept of **socio-technical imaginaries** is introduced. It can be employed to conceptually explore how development and implementation of technologies can be made more robust by reflecting over imagined (i.e. assumed) use and users in the design process, and how such assumptions ultimately affect the final design.

2.1 Practice theory

Practice theory mainly considers consumption a consequence and not a cause, as «consumption occurs as items are appropriated in the course of engaging in particular practices and that being a competent practitioner requires appropriation of the requisite services, possession of appropriate tools, and devotion of a suitable level of attention to the conduct of the practice» (Shove & Walker 2014, also see Warde 2005, Shove 2003, Schatzki 2010). In other words, it has its focus on individual competency but also to a large degree on physical objects. Practices are considered as the "site" of the social, or nexuses of saying and doing, and that the act of saying and doing within these nexuses reproduce, transform, and perpetuate the practices they carry. Its goal is to analyse what happens when people and material things come together, keeping in mind that this is a constantly ongoing activity. It approaches from the point of view of the many practices, for instance, in a household. In terms of WP9, practice theory can be used to understand how practices within households can and must change to fulfil end users' specific roles in participating in the pilot, and that participating in the pilot is not itself the cause of change.

Energy use takes place within energy cultures comprised of a wider suite of practices that define everyday life. Everyday life is made up of tasks, many of which do not necessarily involve evaluating energy consumption even though they may relate to energy consumption indirectly. Such tasks are aimed at cooking, cleanliness, cosiness, and otherwise routines of the mundane. For end users, evaluating electricity consumption vis-à-vis undertaking such tasks is mainly secondary, as the tasks exist simply according to their own necessity. Practices are what defines the doing of these tasks. Practices are often embodied, meaning we don't actively employ cognitive skills to do them: we just do them. As such, practices are often routinized.

Traditions within technology design and development guided by market theories of neoclassical economics has shaped much of our understanding of end users as rational actors who actively seek out and employ all available information and technology to make as beneficial decisions in the energy market as they are able to. This is contrary to practice theory findings. An important aspect of the customer focus is that even though more and better information often may be relevant in an appropriation phase, defined as it often is by thinking and selecting, it may be of less importance in a use phase, which is mainly oriented towards doing. Use phases occur when interventions of a technological or informational kind are in the past. Everyday life occurs, and tools and gadgets enter a background existence in which they "just work".

As we have already seen, electricity itself is invisible to users. The practices that take place within the home have arisen partially because of and in parallel with other, tightly interwoven practices of everyday life. This is what makes people easily able to think in an abstract manner about issues like electricity consumption and how to reduce it. However, when they attempt to incorporate routines (new practices) and action plans in the flow of everyday life to achieve this, they immediately bump into a whole new set of considerations and priorities (existing practices). This is the graveyard of arbitrary energy consumption behaviour change endeavours.

To more fully understand what electricity consumption is about (perhaps because we want to change it), rather than thinking about users as rational individuals, we can explore ongoing practices that cause electricity to be consumed. Then, as these practices are better understood, the real value of electricity consumption comes to the fore. Examples of this are elaborated in section 3 below.

2.2 Domestication theory

Domestication theory is a way of analysing technology appropriation processes by paying attention to 1) practical, 2) cognitive, and 3) symbolic aspects (see Silverstone et al. 1992, Berker et al. 2006, Sørensen 2006, 2013). In short, evaluating 1) practical aspects, determine what a new technological artefact or a novel piece of knowledge can be used for, if and when we are allowed to use it, or the appropriate way of using. Then there are 2) cognitive aspects, governed by if we know how to use it, understand what it is for, or if and how we can learn or be taught by someone how to use it. Finally, the 3) symbolic aspect determines among other things identity markers, or the ways in which technological artefacts can be used to signify to others one's values and concerns. This grants us the perspective that technology use has attached to it values and meanings, which may or may not be visible and interpretable to others. This last point is of course crucial with respect to creating the right kinds of incentives for participation in INVADE pilots by end users when monetary incentives cannot be relied upon alone. As the symbolic aspect underlines, technologies enter into social life and become part of our relationships with other people, including issues of rule setting and guideline provision. This means that value and meaning is assigned to for instance an electric vehicle or a solar panel rooftop rig visible to the neighbours.

It is not an accident that the term itself, domestication, is the same as the one used to describe the process of taming wild animals and putting them to work for us. It is a process. It takes time, skill and knowledge. It provides meaning and identity (i.e. “farmer”) to those that engage in it. Importantly, it is a two-way street, because the way the animal works changes our lives as it displaces our world, both in intended and unintended consequences. Analyses looking at developing relationships between human and technical elements in this way are said within science and technology studies to maintain symmetry, which is useful to avoid emphasizing too much on just the human aspect of for instance animal husbandry. This ensures maintaining the analytical relevance of both parties’ concerns.

2.3 Technological script

When studying end users and technology within science and technology, a common point of entry is by looking at how things are designed, as it is considered to influence how things end up being used. For this a framework has been adopted, that simply put analyses technology as if it were text. This is not straightforward since for 200 years already the analysis of text has been subject to a debate on where we might find the meaning of the text. For instance, is it to be found within the text itself, or is it produced as it is read? Within the field of hermeneutics, which is where this debate has its roots, the most common answer to the question of meaning is that it arises as a synthesis of the reader’s preconditions and the intended message of the text. When analysing the intersection of technological artefacts and human beings, the same question regarding meaningful use can be posed. This has led to what is known as script theory (Akrich 1992, Akrich & Latour 1992).

In short, we can say that designers shape technology in such a manner that instructions for proper use is embedded within the design. This is often what is referred to as “good design”, or what one with design parlance might refer to as a high degree of affordance. The thing presents itself in a way that more or less immediately reveals to the user how it is meant to be used, what it is for, and the role of the user in relation to it. The script is a program for action, the program the user relates to when engaging with machine or artefact. When the artefact leaves the hands of the designer and is placed in the hands of users, they have some freedom over whether to follow the script, change it, or even oppose it altogether. These are cases then, in which the user employs anti-programs. The relevance for WP9 is evident in the following example, which also sheds some light on how domestication and practice theory features in everyday life:

Consider an energy monitoring device which has been placed on the kitchen counter of a (stereo) typical household. The husband in this case follows the script and considers it a source of relevant and interesting information on how to further relate to energy consumption. The wife considers the object in the way of other kitchen activity and finds its appearance unappealing. She nevertheless bears with her husband for a while, since she notices him finding it interesting and meaningful. Besides, improving energy consciousness in this day and age is considered a noble goal, and she is not above learning a thing or two about energy consumption herself. However, after a while the battery dies. The husband does not despite his initial interest go out of his way to change the batteries. The monitor does connect to the outlet with a cord, but there is no outlet where it is currently placed, and the cord is not long enough to reach other outlets. The outlets that do exist within reach are already occupied by a coffeemaker and a toaster. The wife takes advantage of the situation and, employing an anti-program, places the now dead monitor in a drawer. This is, incidentally, where the story of many energy monitoring devices end.

2.4 Socio-technical imaginaries

From the above example it is evident that users have some influence over objects beyond the intentions of designers, whose responsibilities are often limited to designing for ideal scenarios. This active role of users in meeting technology evidences that they are not simply passive or rational. Often there are conditions outside the realm of user and designer both that explain the success, or lack thereof, of an artefact in doing what it was supposed to. Still, shaping technology is about making choices on behalf of the user in advance of the use situation. The concept of socio-technical imaginaries (Jasanoff and Kim 2009), as well as what has been described as imagined lay persons (ILP) (Maranta et al., 2003), can be considered that which influences assumption made on behalf of users by designers of technology and policy alike. This is hardly controversial, as any design activity must necessarily be guided by some level imagination, if not at least some basic assumptions to move things forward. This is of course the case with WP9 and the INVADE project in general.

2.5 Summary of theoretical perspectives

Though admitting the role of imaginaries in influencing technology innovation and development processes, their sheer necessity for such processes to achieve momentum at all cannot be underestimated. Technology development is about making choices on behalf of users and of the future of society. Woolgar (1991) has classically described the designer as someone who "configures the user", an act whereby a frame is created for correct use. With this in mind, it is possible to say that technology itself can have a normative capacity. If technology does have normative capacity, it means that it can implement guidelines, for instance, for how electricity should and should not be used.

The subject of this report, smart energy technologies and their attendant novel business models, can be described as normative in this way. The basis of the norms carried by technology (for instance the imperative to reduce peak consumption) has an origin. This is perhaps what went missing in the gap between end users and the designer of the energy monitor on the kitchen counter in the example from subchapter 2.3. The example underlines that in most cases, "users are not simply victims of bad performance or beneficiaries of cunning design" (Berker 2012). Smart energy technology can be a way of configuring users according to greater principles of energy markets and policy. But for norms to have any kind of ordering force they must resonate. So then must technology, if it is to carry norms.

The goal of this chapter has been to underline the importance of the role relatively stable norms and convention play in design of technology and its subsequent use. The following chapter will consider several examples of empirical studies on electricity consumption, and what results have been achieved with a wide variety of interventions. First an overview of quantitative results in the form of several review studies is presented and thereafter, a view to the more qualitative approaches.

3 Studies on user practices and energy consumption behaviour

The following is a review of relevant empirical research related to the prospective role of the end user in the use cases of INVADE. The goal of WP9 is to include end users as flexibility assets through a business model that assigns value to end user flexibility, thus making it lucrative for end users to offer it up. This is a novel feature of the energy system that can help solve the challenge related to a higher share of intermittent renewables in the grid, but it is also tied to some challenges related to changing user behaviour and making users adopt novel technologies. Intervening in the household to change energy consumption behaviour or introducing new technologies that may circumvent such intervention is historically tied to ambitions of energy efficiency or consumption reduction. This is not directly a goal for the INVADE project or WP9, which is more interested in singling out and making use of flexibility. However, for this flexibility to become available, it is often necessary to "free up" already ongoing consumption. Much of the dynamic, of efforts related to making energy visible for end users, can therefore be instructive for WP9.

3.1 The feasibility of "freeing up" flexibility

Attempts to solve the challenges linked to the double invisibility of electricity follows a main trend of trying in different ways, though most often through the provision of information and visualization techniques, to make it more visible. Hereunder we also find different kinds of measures such as energy labelling of houses and appliances, simple graphs on electricity bills comparing consumption over time and season, face-to-face meetings in the form of energy counselling, inspections aided by infrared cameras in order to show where heat escapes, and of course the often-revisited energy monitoring device in the form of a screen, placed more or less prominently within the home, showing consumption and prices in real time. These are just a few examples of different ideas that have been attempted thus far.

The underlying assumption is usually that by giving the customer information this will make the customer more rational. Rational users in the historical sense has meant that users respond to price signals and thereby function as efficient consumers from the perspective of the energy system by vacating hours of peak load with high prices, thus saving money for themselves. In the sense of the WP9 platform, rational means that end users respond to offerings made on their potential flexibility, and by providing it they will receive remuneration. Both are predicated on the user receiving, through some kind of platform, information on which they can act.

A relatively early and apt example of the effect of simple provision of information exists in a study by Wilhite and Ling (1995). The study is based on an observation of a considerable overconsumption within Norwegian domiciles. Furthermore, it observes the fact that the electrical bills of the time provided very little information. Finally, the study hypothesizes that providing more feedback in the form of information about consumption would lead to more rational consumption. The study tests this hypothesis by developing an experiment in which they distributed new kinds of electric bills on a bimonthly basis. The experiment, which was allowed to proceed over three years, investigated effects of added information on three different groups vis-à-vis a control group. The first group received their bill more often. The second group received bills more often, with the addition of some information that graphically presented consumption history compared with last year. The third received bills more often with more information and graphs, in addition to energy saving advice.

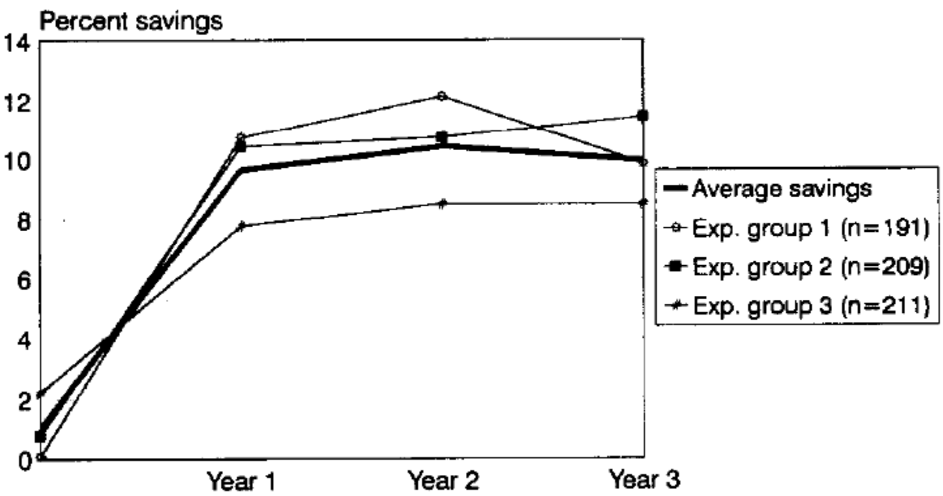

Figure 1: Introducing information in the electricity bills was shown by Wilhite and Ling (1995) to impact energy consumption

The impact energy consumption is shown, in this last figure, as savings in percent across three different groups. All experimental groups conserved approximately the same amount (there were no statistically significant differences in consumption among groups). The study concluded that this intervention led to changes in behaviour resulting in electricity consumption reduction of about 10% compared to the control group, and that the main ingredient for success was increased frequency of feedback. This shows that even with quite simple intervention considerable effects may be created. In conclusion the authors recommend that bills should be provided more often, and that the more often they come, the better. The bill needs to provide information that sparks interest in one's own consumption patterns. The bill also ideally needs to contain some form of comparative standard, and provide a basis for comparison, for instance with earlier consumption.

When considering the possibility of "freeing up" consumption of electricity at the household, there are several quantitative review studies that sum up the effects achieved by pilot projects implementing various technologies providing information or intervening in consumption behaviour. Darby (2000) reviewed results from 38 studies from the previous 25 years (n=3-2000). These studies varied greatly both in terms of technology used, size of pilot, and design. Across these many and varied approaches however, a clear trend was observed as the average reductions in consumption were as much as 5-20%. She found direct feedback is preferred over indirect, and that in-house monitoring is better than information across the bill.

Another study reviews results from social and environmental psychology, where Abrahamse et al. (2005) looked at 38 studies (n=4-1811). Here was made some remarkable findings, foremost among them that an increase in energy knowledge did not need to impact consumption levels. They also found that reward systems were effective, albeit only for a short while before fall-back occurred. Feedback was found to have an effect; however, in the case of low-income groups, increased feedback could lead to increased consumption. Another interesting finding suggested that long-term feedback was not necessary if one single case could create a strong enough impression, as cognitive dissonance could result in lasting change in consumption behaviour. Otherwise, they noted that hourly pricing generally led to shifts in consumption but not reduction. Finally, they have a comment on generalisability. Problematically, often these studies include test subjects that are highly motivated due to the experiment effect. The numbers on energy savings found by Abrahamse et al. (2005) were all within a range of 4-20%, much like the findings of Darby (2000).

Another review was done by Fischer (2007). Here, 26 feedback pilots in 11 OECD countries were investigated. These were all examples of studies examining experimental projects, or so-called model projects. The main trend in these results was that end users were able to reduce consumption with amounts in the range of 1.1-20%, more commonly in the 5-12% range. Fischer concludes energy behaviour change is indeed possible and adds some recommendations for those who would so endeavour. First, there needs to be a degree of freedom of choice in the form of feedback, and there should be an interactive element. More feedback is always better. Finally, solutions should offer to show in detail a breakdown of the consumption of individual household appliances.

A final example of these kinds of studies is found in a review by Delmas (2013), dealing mainly with quantitative studies from within the purview of behavioural studies and economics. This is one of the more accomplished studies of its kind and uses data from 156 field experiments with a total of 524 479 U.S. based participants measured at times between 1975 to 2012. The authors find an average energy consumption reduction across all these studies of 7.4%. They also make some recommendations. First, individually targeted feedback works best, for instance in the form of energy audits, or in other words, a kind of feedback that involves a high degree of user involvement. Peer-comparative feedback, comparing different users together, was found to not work well, probably due to the inherent difference in households as perceived by end users. Moreover, tendencies were observed that suggested monetary feedback could lead to increased consumption, partially described by what they call the “licensing effect”. This is a term from economics, meaning that when users realize how little a service costs they use it more since, after all, they are paying for it.

In summary, these studies, which are quantitative in nature, indicate a flexibility potential from consumption reduction alone to be around 5-20%. However, there is an issue with generalisability in many of the studies reviewed, and the question needs be posed what would happen outside the experimental setting, and what might be the role of the experimenter effect. We are also unable on the basis of these studies to say anything about how flexible customers would like to be, even though it is evident that they are able to forgo a part of their consumption and that this could contribute to an increased flexibility potential. Additionally, much is left out about what we can expect in a long-term perspective, and if changes that are implemented will hold over time. Many of these studies lack a control group, and in many cases the consideration of what was going on before the experimenters arrive at the scene leaves much to be wanted. There are also cases where weighting for seasonal variation or socio-economic background is absent, as well as a clear indication of the randomness of selected participants. Of course, all of this is hard to accomplish in as much as it is the lived life that is the subject of experimentation here. Finally, the existence of a kind of glass ceiling at 5-20% seems puzzling when one takes into consideration if it might be possible to achieve this number only once, or if the effects of interventions may stack, and if such is the case, when a new stack may be taken out.

These are all important considerations to include when designing, implementing and scaling up solutions within WP9 and in the INVADE project in general. However, in order to get a better grasp of these uncertainties the following subsections will provide insights from qualitative studies. This provides a fuller picture of how to deal with challenges of energy consumption behaviour and practice change.

3.2 An in-depth look at energy monitoring technology use

An increasingly sizable body of qualitative research has been undertaken the last 10-15 years on what happens in households when new kinds of feedback technologies are introduced. It looks in greater detail at what happens when such technologies are introduced besides the average effects across larger populations. These approaches reveal much of interest, even though they cannot give generalizable answers on how users react. Instead they point toward potential challenges and opportunities. Some of the opportunity related to the roll-out of novel energy technology and pricing schemes were outlined by Throndsen and Ryghaug (2015). Interviews with pilot participants revealed that the introduction of the smart meter in tandem with the prospect of novel ways of pricing electricity consumption opened a window of opportunity for realigning participant's engagement with energy technology and energy politics. The smart meter in fact became a way through which end users could materially engage with the politics of energy consumption. These findings address some of the concern found among technology and policy designers that people will be passive and unwilling to relate to new developments in the smart grid. The study found that participants, far from being passive, were easily engaged in the reasons behind and possibilities embedded in the new metering technology. However, the results suggest that letting users "go cold" within the pilot project setting could lead to this engagement resulting in reluctance rather than constructive co-production. The technological design in this study relied too much simply on the smart meter itself and was too slow to provide any other benefit for end users in introducing any change in their consumption practices. The result is an effort that caters little for any kind of user engagement that goes beyond a strictly rational, economic motivation. This is a challenge since this motivation alone might not be enough to topple the heavily routinised everyday life of households.

In short, as technology and novel business models bring with them a kind of change, the way people respond to it is not straightforward. This suggests that the processes by which novel technology and business models in the electricity system re-arrange people's relationships with their energy consumption can be better understood.

Skjølsvold et al. (2017) identified that relational re-arrangement comes about in the four dimensions of knowledge, material, social, and routine re-arrangement. The first, *knowledge* re-arrangement, underline how technology itself does not determine outcomes as some people simply use it to gain new knowledge about their domestic energy system (with all its different appliances). Still others use the new knowledge to rest assured that their consumption and electricity cost is so low that they need not worry about it at all – ultimately leading to a kind of disengagement. In the case of *material re-arrangements*, one-off investments may be undertaken, for instance adding a heat-pump, retiring old appliances, or lowering thermostats. *Social re-arrangements* were often made in parallel or on top of the knowledge and material ones, sometimes to mount a surrounding framework more supportive of those changes. This would take the shape of new modes of internal control or setting new rules (manually enforced or delegated to automation), for instance in the form of not doing laundry while cooking dinner. This had in many cases the potential to create tension related to already existing gender roles in the household, as men are most involved in designing and implementing such rules. As the authors underline, this points to an important design and technology development challenge: how to design smart energy technologies that do not only cater for individuals, but which opens for engagement across household members with different interests, needs and skills (ibid:6). This is connected to the final point regarding re-arrangements of *routines*, as monitoring represents quite a potent intervention in the beginning of trials, but after a while becomes more and more "backgrounded" as its presence becomes a normality. New routines that have survived thus far might be along for the duration, but after this backgrounding occurs, additional routine change by way of the monitor is more cost intensive.

A classic example from recent times, the findings of which adding bolster to the conclusions in the above, is found within two studies about the use of in-house monitoring devices in the U.K. (Hargreaves, Nye and Burgess, 2010 & 2011). Too often studies of energy interventions do not employ a longitudinal perspective, limiting our insight into what works and why. In this study participants had the opportunity to choose between three panels that they could install at home, so called Solo-monitors. These are of the kind that work by placing an optical reader over the diode of the meter. The studies are based on a thorough investigation of 15 householders' experiences with these monitors for more than a year.

First the authors examined what motivated participants to be a part of the experiment. This revealed that some were in it for economic reasons, others due to environmental concern, and yet others were simply driven by a desire to become better informed about their own consumption. Participants' ambitions were then coupled with several challenges posed by the monitoring devices. To begin with, those interested in economic gain were rather disappointed in learning the small potential for savings that the monitors revealed. This is, as we have seen, not an uncommon problem. Often more information in this context just teaches people how cheap electricity is, leading them to consume more with good conscience. The environmental indicator in the monitoring devices provided values in CO_2, something that led to confusion for many as they realized the abstractness of such a measuring unit. This was not better in the case of those who wanted to become better informed, as they were likewise unable to grasp the information provided in kWh. In general, participants missed a relevant basis for comparison. When it comes to the kind of information people would prefer the monitor provide, almost everyone selected monetary feedback, i.e. pounds sterling, and this was preferred to CO_2 and kWh. Another classical finding is that everyone reports being rather interested in the monitor in the beginning, after which interest deteriorated over time.

Regarding the use of the monitor itself, this revealed first of all that the main user of the monitor was the man of the house. This is recognizable in other studies as well, as energy and economy often are the domain of the man in the household, and he connects with this information in what is often regarded as being in a rational manner (see Strengers 2013 for an interesting discussion on the effects of the Resource Man on energy technology in the household). A widespread type of usage that was found, was of the kind that aimed at making energy use in the house more relational. This means that users compared the electricity use of different household appliances, linking them to the practices within the household. However, it also meant that the monitor was used to say something about the consumption patterns of the other occupants in the home – in other words, in a kind of surveillance mode.

This evidences that the monitor was indeed used, but these studies also say something about what it meant for user behaviour. The monitor became part of new behaviour in different ways. Most importantly it was reported used for something called "using it hot". This means that people used the information from the monitor to establish and learn about what was normal consumption levels for their household. If something seemed out of order, or if consumption was regarded being too high, people would walk around the house turning appliances on and off to cross reference their consumption levels with the real time information in the display. In this manner they were able to gauge how consumption was spread out across different appliances, and thus they were able to make the electricity consumption of services visible to a certain extent.

This implies a behaviour that of course is quite rational, but what makes it more interesting is that it implies the users have an idea about what constitutes normal use levels in the household, and that this is something that with some motivation and the aid of an energy monitor can be self-taught (in line with domestication theory, discussed above). Users in this pilot did in fact describe an initial learning period where the monitor played an important role for them to get acquainted with the electricity consumption in their own household. By tinkering with the monitor and the household appliances users were able to establish a baseline for normal, acceptable consumption behaviour. The practice of “using it hot” was therefore about trying to keep consumption below the new, acceptable standard – not uncommonly a few points’ percentage below the previous level. This gives credence to energy monitoring devices as a crucial part of end users’ learning about their energy consumption practices.

Many of the surveyed users reported about increased planning of routines. Some started having energy meetings where acceptable amounts of showering were negotiated upon. Some reported an increased interest in renewable energy and micro generation, without it necessarily leading to any kind of investments into such technology. Some reported about a more comprehensive kind of planning, where the monitor entered into a larger project oriented towards changing lifestyles. A few reported about spill over effects, where the budding interest in energy saving was manifested in other arenas, that of mobility for instance, and they would engage in lobbying activity towards friends and extended family with the aim of making them use less energy as well. With regards to the goals of the WP9, this type of learning about and socialization of technology should be explored in order to enrol users.

A problem was pointed to by several participants, however, and this was that the monitor did not necessarily lead to positive experiences in family negotiations about electricity consumption. Since the monitor not only visualizes what appliances are used but also makes evident who uses them, this could lead to considerable conflict. This could play into already existing conflicts or create new ones and was not always conducive to using energy smart. At the same time many said they did not change their behaviour because they could not base new decisions on any kind of meaningful basis of comparison. It was indicated that a comparison with earlier consumption could be useful, but also in terms of what their consumption meant in a bigger perspective: what it meant in terms of aviation, industry, transportation, etc.

When the follow-up study was done a year later, an expected observation was made. Many households had completely discontinued their use of the monitor. Others reported they used it differently. The interest in the information it provided was simply deteriorating, and the monitor was not gauged as often as before. The participants explained it as being due to sheer laziness, forgetfulness, or a gradual slipping back into old habits. A somewhat more concrete explanation offered by some was that the monitor stopped providing new and relevant information. In the beginning, the monitor represented a form of constructive nagging, it was a foreign object making loud proclamations about consumption. Despite this, the information was considered novel and possible to learn from. After a while, the learning potential in the information provided was considered exhausted, indicating a challenge related to the continued relevance of energy monitoring technology. Sooner or later, there exists a real danger that a saturation point will be reached. Nevertheless, this begs the question if it is not possible to consider the effect of the monitor justifiable in some cases if it led to lasting behaviour change. On the other hand, an energy monitoring device does seem like a costly solution for a few months of learning, but if there are other interventions, for instance by way of automation, introduced together with the monitor, this might ensure a more lasting effect. At the very least, a window is opened by the monitor, in which a new program can be introduced.

In summary, it is evident that in-house monitoring devices has some effects, but also that the extent of changes are limited. Firstly, many said they believed the lion's share of electricity consumption in the house was necessary and unavoidable, and that it would be impossible to change use connected with this. What they are really saying is, of course, that they are unwilling to manually change their every day practices. Furthermore, when people use their monitor to establish a baseline this must be considered as a fine tuning, rather than a deep lifestyle change. This new baseline, or "new normal", becomes part of a story in the household about what can be considered justifiable use. Everything below the baseline is deemed normal, and everything above it deemed a waste. Different households establish different baselines, entirely independent of whether consumption was already high or not (Hargreaves, Nye and Burgess 2011).

3.2.1 Segmentation

When engaging with the challenge of the diffusion of technological solutions it is difficult to avoid mention of the classical work of Everett M. Rogers (1962) in which he posited that adoption of innovations usually follow a bell-shaped curve. As a novel innovation enters into the world, it is first taken into use by innovators and early adopters, both small and elite groups of technologically savvy people that on the curve make up about 15% of the total population. The rest of the population, about 75%, are made up of the early and late majority, along with the laggards. However, it is not always given that a technology will reach all 100% of the population, as the innovators and early adopters may turn out to be the only ones who, in the end, ever pick some new technologies up. Often this is not a problem unless one has to do with a network technology. Network technologies are, by their very nature, technologies that provide the most benefit when an as large a part of the population as possible are users. This is usually the case for any kind of information and communication technology, like cell phones and the Internet.

The kind of technology that is the subject of this report is one such technology, as the goal is to enable the coordinated leverage of many small sources of intermittent and flexible resources for the benefit of large groups of users. This poses the question of how to address end users in the later stages of the bell curve mentioned above, in order to ensure that the necessary critical mass of actors can be enrolled in smart energy networks to make them effective enough. As noted by Strengers (2013, see also Throndsen 2016) much of the smart grid technology developed in pilots today, are conceived by experts imagining users that are almost as proficient and knowledgeable in technology as themselves. In other words, they run the risk of misrepresenting the population and developing smart grid solutions that might not be feasible on a very large scale (Throndsen, 2016). This is a challenge taken seriously by INVADE and WP9 especially where emphasis has been put on defining solutions that are able to realize value for end users in many ways, and not just for highly technologically competent Resource Men (Strengers 2013).

To achieve this, it is necessary to realize that there are qualitative differences between users and groups of users, but also try to learn something about what defines these differences. As the previous literature review shows, a large part of the participants that have already been taking part in smart grid pilots and that have been studied, are within the segment of typical early adopters. Even so, some attempts to discern qualitatively the difference in user segmentation have been made, for instance in the example from the U.K. above (Hargreaves, Nye and Burgess, 2010 & 2011). As indicated in those findings, initial exploration of motivation for participation showed that monetary interest, ecological concern, and technological interest are all viable inroads for recruiting end users. Other studies have found these three concern areas to figure prominently as well, for instance in the case of Throndsen et al. (2017a, described in more detail in subchapter 3.4), who found that local conditions related to energy or environment can motivate certain individuals to consciously flag their values and political standpoints through the prominent placement of micro-generation capacities on their roof-tops, in plain sight of their community peers. In one case, participants interviewed had not even looked at the displays or web-portals provided to them in order to gauge their electricity production and were happy to simply have made the investment and installed the panels.

Another notable example was provided by Throndsen and Ryghaug (2015) in their study of a smart grid pilot in Norway, where focus group interviews revealed that it was possible to separate users into three groups much like the innovation adoption bell curve mentioned above. The focus groups were provided hypothetical examples of tariffs in the future grid. One example was a choice between a very volatile time-of-use (ToU) tariff, where rush hours were expensive but large gains could be had by avoiding them. The other choice was a ToU-tariff that was less punishing during rush hours but had somewhat higher costs the rest of the day compared with the volatile one. The second example was a choice of two kinds of power tariff. The first was one where the household had agreed to be subject to demand-side management (DSM) of large loads in return for a low overconsumption tariff. The other was one where the household had opted out of DSM but would have to pay double during overconsumption.

First of all, this revealed that all variants of the two tariff structures had some appeal, and that three, more or less, well defined groups of end users could be discerned. There was one group of what the authors referred to as “enthusiasts”, who were more than happy to fulfil the common expert imagined role for the user in the smart grid. They would feel confident in their ability in handling technology and programming skills, and by this merit alone would prefer the most volatile models and the ones with DSM. The reasoning behind this was that they could fully automate consumption in such a way that they could reap the greatest benefits. In the other end of the spectrum were the “skeptics”. They were less confident in their technological abilities, and that of others, and thus the general development in society that the smart grid signified. They were worried that they would be forced to adopt technology with which they would not be proficient and suffer the consequence of this in the form of economic losses. In the middle of these two groups were found the “pragmatists”. The reasoning behind this posture was that most of the energy consumption in the household, perhaps as much as 70%, could be managed quite easily with simple monitoring and control systems (i.e. smart plugs, etc.). In this way, steep prices and overconsumption could be avoided without detriment to quality of life due to excessive concerns about electricity consumption. Finally, it can be noted that no one was of the impression that electricity cost would seriously concern “the common Norwegian”, as prices in that country have been very low.

Finally, another example of segmentation was found by Throndsen et al. (2017b) when studying the enrolment program for a PV pilot in Trøndelag, Norway. In this case the energy company doing the pilot advertised for pilot participants and interested customers were able to apply for this through a questionnaire on the energy company’s web site. Of the over 1700 respondents, about 100-200 or so would also provide information that they deemed relevant to the recruitment, in an open section of the application. Information about occupation, what other kinds of technologies they owned and that they thought pertinent to the PV pilot, as well as what motivated them most, money or the environment were found. These findings are reproduced in the figure below.

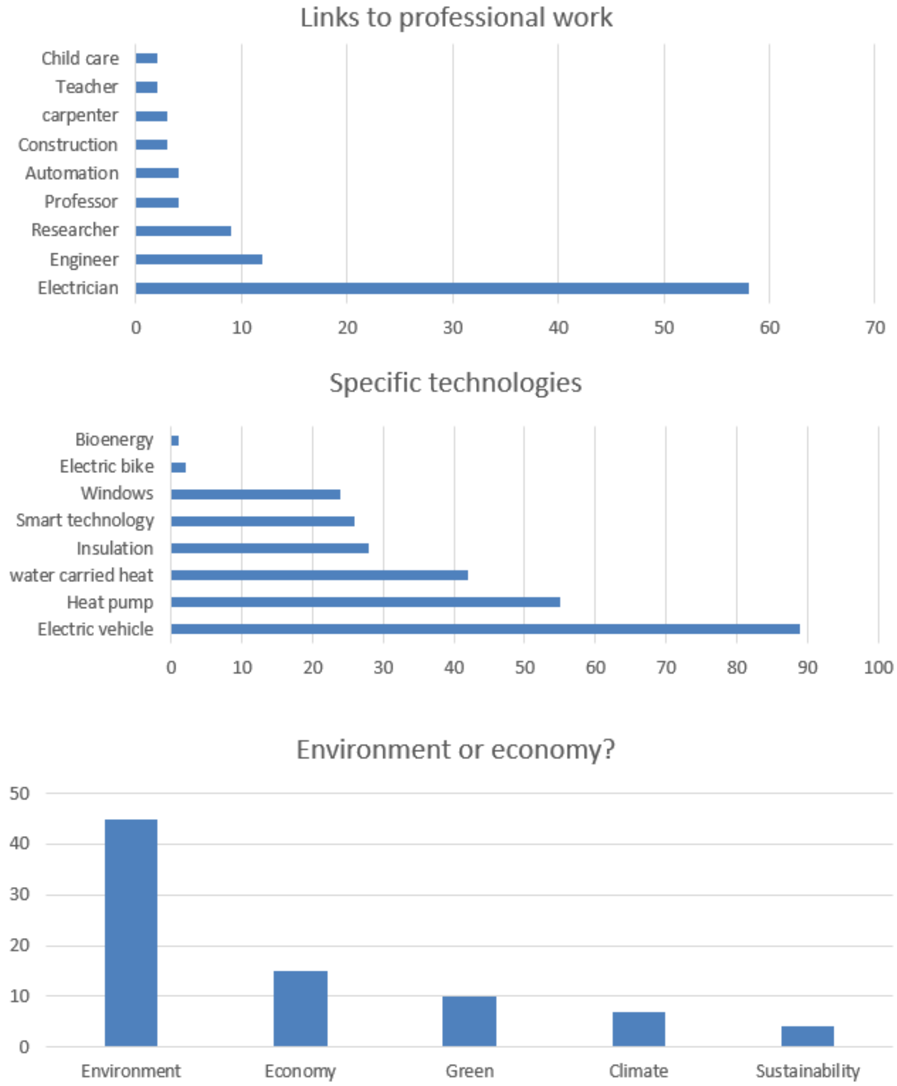

Figure 2 Mentions of motivating factors for self-describing as a "good" prosumer, then mentions of specific technologies in the respondent’s possession. Finally, mentions of respondent’s professional work. All results from the “other” box.

As we can see from Figure 2, a large majority of respondents would represent themselves as more motivated by environmental issues than economic ones. In the second and third charts, we also see evidence of what this means in terms of owning or emphasising technology and what kind of profession the respondent has. Figuring quite high on the list of technology mentioned is of course the electric vehicle. Smart technology is also mentioned, along with more conventional – but not irrelevant – kinds of technology like insulation and water heated floors. Among the professions mentioned, a clear overweight are electricians, engineers and researchers. Interestingly, working with children also seems to be counted as relevant when the concept of the prosumer is invoked. This implies that those that are most heavily drawn to participate and engage with these projects are technology forerunners or otherwise professionally inclined to engage with related issues of these kinds of technologies (i.e. the environment, climate change, etc.).

3.3 Perspectives on energy services and end user uptake

In Germany a study of utilities' efforts into renewable energy found that while having viable business models for RES on the utility side, utility managers did not see customer-side renewables as an attractive future market. Paradoxically though, many utilities were still offering products for distributed and residential renewable electricity generation (Richter 2013). The offers ranged from consulting services, direct investment grants for PV, and even full "rent-a-roof-packages" in which utilities install the PV system and then pays rent to the end user for the roof space. In this sense, small scale renewables represented a disruptive technology for utilities, who do not have a viable business model for making a profit with them. Some of the reason was suggested to be because of cognitive barriers in management (Chesbrough 2007, in Richter 2013), but also that from their perspective small-scale renewables were not cost competitive to conventional sources or utility side renewables (Christensen et al. 2011, in Richter 2013). Suggestions on how utilities could solve this range from seeking external partnerships to establishing separate ventures that are focused specifically on renewables.

Some studies have looked at what possible shapes exist for such ventures. According to Parag and Sovacool (2016), there are two main paths down which we can envisage energy end users travelling in the near future. Both entail the introduction of the prosumer, but in the first instance large numbers of users make use of micro generation technologies such as solar PV to empower themselves by managing their energy production and consumption autonomously. This segment is not expected to become very large however, since the users belonging to it would need to be able to exploit geographical, technological, and economic conditions in order to install sufficient capacity and storage, in combination with smart monitoring and control capabilities, in order to make such investments worthwhile. The other segment which is envisaged to be much more feasible, is one in which users are connected to a grid, but still change from being passive consumers to active contributors to the grid, supplementing or even competing with utilities and energy companies. The authors suggest four ways by which energy markets could become more prosumer-oriented by identifying three possible models: peer-to-peer, prosumer-to-grid and prosumer community groups (see figure 3, models a, b and d).

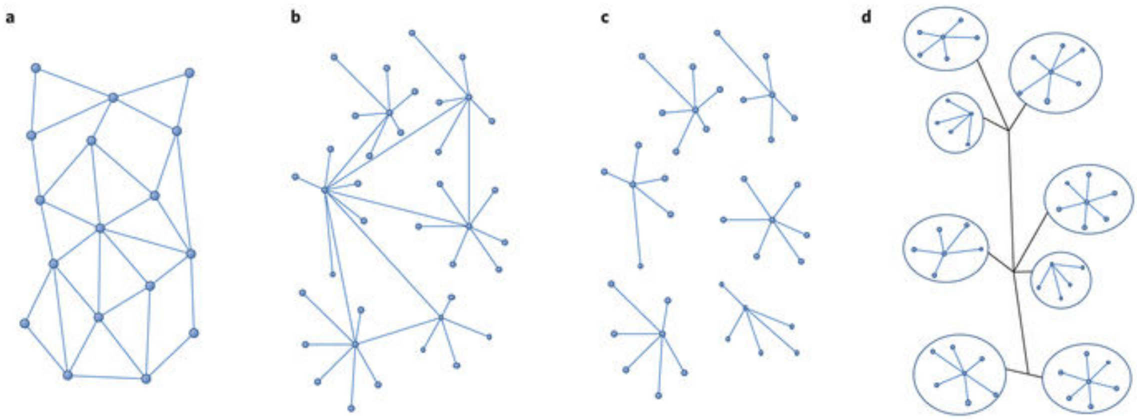

Figure 3 a, Peer-to-peer model. b,c, More structured models involving prosumers connected to microgrids. These entail prosumer-to-interconnected microgrids, in which prosumers provide services to a microgrid that is connected to a larger grid (b), or prosumer-to-islanded microgrids, in which prosumers provide services to an independent, standalone microgrid (c). d, Organized prosumer group model, in which a group of prosumers pools resources or forms a virtual power plant. Dots represent prosuming agents; lines represent a transaction of prosuming service; circles represent an organized group of prosumers. Figure from Parag and Sovacool (2016).

The first kind of market is organic and unstructured to a degree, and governed as autonomous, flexible peer-to-peer networks, but who pay for grid utilization through tariffs. Parag and Sovacool (2016) mention the Netherlands-based Vandebron as an example of how this structure has been utilized. Here, a platform was launched that enable end users to buy electricity from local farmers. A similar model was launched in the UK in 2015 by start-up Open Utility, which deliver a peer-to-peer platform called Piclo that enables renewable generators to set the price for their electricity and sell it to local commercial energy consumers. In early 2015, Open Utility had 25 producers signed up in Piclo. Backup power is offered by an electric utility to maintain reliability.

The second kind is a more structured kind of model, which relies on brokerage systems for prosumers within microgrids. The microgrid can operate both in island mode and connected to the main grid, and incorporate prosumers via prosumer marketplaces, prosumption brokerage systems and predefined participation rules. In this respect the authors emphasize the NOBEL (Neighbourhood Oriented Brokerage Electricity and Monitoring System) project, which has as its aim to help network operators improve energy distribution efficiency. It works by suggesting a brokerage system for communicating energy needs among individuals directly to large and small-scale energy producers including shopping malls, industrial parks, and the likes. (see Linnenberg et al. 2011, Marqués et al. 2010, Karnouskous et al. 2010, and Parag 2015, in Parag and Sovacool 2016). In such systems, users are also able to adapt their consumption or production in return for financial benefits (see Corn et al 2014, in Parag and Sovacool 2016).

A third kind suggested takes the shape of community organized prosumer groups, which is more organized than peer-to-peer networks but less so than prosumer-to-grid models. This kind of model is suggested to be ideal for smart city environments, presenting opportunities for local organizations or neighborhoods to manage their own energy situation. Communities in this model can pool their prosumption resources to generate revenue for their own benefit (see Gelen et al. 2013, in Parag and Sovacool 2016). The Enco Group, one example of this, provides electricity to 2 million customers in the Netherlands and Belgium via a software platform that allows using dispatchable resources as a virtual power plant.

Another look at the Netherlands was done by Geelen et al. (2013), examining the role of end users as co-providers in the electricity grid. The study looked at how technology development allows households to become producers by implementing microgeneration in the examples of Texel Energy and Grunneger Power. These are cooperatives that aim to balance supply and demand to optimally utilize locally produced energy. Apart from these two, the authors survey a range of pilots in the Netherlands to gauge the feasibility of including the end user as a co-producer of the energy system. They gauged the capabilities of end users in terms of microgeneration, storage, smart appliances, smart meters, time variable prices and contracts, as well as monitoring systems. They offer advice on how each of the topics may be viewed to enable the integration of end users. In the first case, that of microgeneration, they emphasize how production should be matched to consumption, or otherwise sold back to the grid for a feed-in-tariff. This will in turn make it possible to rapidly cover local spikes in demand through automated signals to the site of the end user from the operator.

The authors mention the PowerMatching City project as a pilot that has tested this concept, where several houses are enrolled in a VPP. This is done with a technology platform provided by PowerMatching that matches supply and demand, with the aid of a micro-cogeneration plant that produces electricity and heat-as-by-product. Bergman and Eyre (2011, in Geelen et al. 2013) point out that different user behaviour patterns are likely to ensue due to the introduction of micro-generation. The range of behaviour includes misuse, disappointment, disillusionment, and rebound effects, fit and forget scenarios that engender no change, some instances of increased energy awareness, indirect benefits, and double dividends. Still, other studies have found a reduction in 6% due to solar PV and some load shifting accomplished by the aid of monitoring devices (Keirstead 2007, in Geelen et al. 2013). Positive but non-uniform effects such as awareness increase, and behaviour change has been found to result from micro-generation, as well as shifting consumption patterns due to information about solar energy availability (Dobbyn and Thomas 2005, Herrmann et al. 2008, Kobus et al. 2012, in Geelen et al. 2013).

Positive effects from participation in micro-generation pilots in Norway was found in a study by the MATCH[1] project where in the municipality of Hvaler and the region of Trøndelag had enrolled numerous household into various PV programs (Throndsen et al. 2017a). In the first case, in Hvaler, the findings indicated that end users were interested initially because of specific local conditions shared by all inhabitants, namely a single, somewhat under dimensioned grid connection to the mainland, and the slight feeling of energy insecurity that this entailed for the population. Enrolling in the PV program initiated by the local municipality, the energy company and the university college of a nearby town was viewed as a positive way for individual households to contribute to solving energy issues challenging the greater community. In qualitative interviews, most respondents dismissed economic incentives as contributing heavily to their decision to enroll. Reports indicated the people of Hvaler committed to investments in micro-generation mainly because of the perceived social value of the panels on top of their roof physically represented. In this way, visible PV participation could be viewed as the identity marker of a conscientious citizen of the community. Similarly, in the region of Trøndelag, though economic incentives were scant even after harnessing support from the energy agency and the likes, people reported the main reasons for investing in rooftop PV to be a technological forerunner, and as someone who was conscious of and taking a visible stand toward the challenges of the world.

[1] See www.match-project.eu

Energy storage at the household, though physically less visible to the outside world, is perhaps one of the keys to enabling efficient local micro-generation, as surplus energy can be stored in batteries or as thermal heat in boilers. This also enables users to draw electricity from the grid at favourable times. The effect on behaviour linked to storage technology is similar to the case of micro-generation, however it is important to remember the invisibility of these technologies. This makes it necessary to include various possibilities to retrieve updates and information from them, for instance displays providing information about state of charge or performance, to bring them to the foreground (Geelen et al. 2013).

Smart appliances are also mentioned as aids for users in the smart grid, as they are capable of programming and automation, thus making it possible to run them at favourable time. Through programming, the appliances can be given schedules for when they can decide themselves to start operating, for instance when tariff signals tell them it will be cheaper. Geelen et al. (2013) mention the pilot project in the Netherlands called the “Jouw Energie-moment” (Your energy moment), where they provide an energy management system that can predict the best moments for energy consumption, enabling smart appliances to operate based on this. A study on the effects of these appliances on behaviour found that they cause households to shift demand of the washing machine away from the evening peak, but that they do their laundry more often when electricity is locally produced. Unsurprisingly, users of automation shifted demand the most (Kobus et al. 2015).

Finally, smart meters and dynamic pricing (or time-variable pricing) can convey the fact that electricity does not cost the same at all times to the consumer. The underlying assumption for this is of course, as mentioned above, that the shifting prices and informing end users about their variation incentivizes load shifting. Providing stick but also carrot, this reality becomes beneficial for end users who own production capacity, as they can sell electricity when prices are high. The authors point out several studies that have shown the effect of variable prices on behaviour. Faruqui et al. (2010, in Geelen et al. 2013) has shown that load shifting was reinforced by an informative in-home display, and that this effect grew stronger with a prepaid electricity program. This point highlights where new business models can stand to gain in causing greater effects in the future, even though it may be limiting to only focus on price. Importantly, response of end users to variable pricing varies across end user segments (Breukers and Van Mourik 2013, in Geelen et al. 2013).

Geelen et al. (2013) also mention monitoring and control systems, an area already covered extensively in this report in the above. The authors do however make some interesting notes on automation of monitoring and control. As the energy market becomes more complex, the end users are benefiting from more and more automation. In the PowerMatching City project, users can interact with a minimum amount of preferences including a thermostat for space heating, and operating modes of dishwashers and washing machines, while the rest is left to an automated algorithm that anticipates and reacts to the supply and demand conditions in the grid. However, this caused end users to report that they felt they missed a sense of control and feedback that would enable them to change their behaviour, and that this was something they very much wanted to do. According to the authors, this could lead to a missed opportunity in increasing awareness with end users.

Geelen et al. (2013) provide some general design recommendations based on these experiences. Monitoring technology should be able to provide insight into the operation of the smart home energy system, in turn enabling users to change behaviour based on this insight. Another point is that display devices should be goal driven interfaces rather than static feedback devices, as this will enable users to make tradeoffs and interact with smart energy systems (Geelen and Keyson 2012, in Geelen et al. 2013). A goal may as an example be how to charge an EV within a period of low cost. Users need actionable feedback, so they can understand if they are meeting the goals, or if not, how they would need to respond in order to do so. Finally, information about the electric power system at community, city, or regional levels allows users to react to the needs of the electricity grid. Community level feedback provide users with an impetus to coordinate energy production and consumption with other households. According to these findings, users are willing to exhibit this kind of engagement.

3.4 EV smart charging and user acceptance

When it comes to V2G and smart charging, contributions in the scientific literature is so far quite sparse, as the technologies themselves are new and not widely adopted. Even in countries where EVs are highly proliferated, most of them are as of yet incapable of functioning in storage mode for the grid because of a lack in bidirectional capacity (i.e. power only goes into the car's batteries). Some contributions have been made however, and this subsection reviews a few of them.

Firstly, Will and Schuller (2016) report from a German analysis of 237 early adopters, analysing relevant factors for acceptance of smart charging. Notably, since the technology is currently still immature, the authors were not able to study users with hands on experience with smart charging concepts. This is not uncommon in this vein of research, as scholars sometimes find themselves ahead of actual developments, albeit with a clear picture of the conceptual shape of technology and its potential. The study thus examines opinions held by early EV adopters on a hypothetical concept of smart charging.

The findings of the analysis reveal a high acceptance of the concept of smart charging, and the importance of communication g benefits to end users. This is not to be mistaken for personal benefits, because in fact these early adopters reported they were most concerned about the benefits to the grid and to society overall. This includes concern for grid stability and integration of renewable energy sources, which were found to be the strongest influencers of acceptance. One aspect negatively affecting acceptance was found to be desire for individual and flexible mobility, and the provision of customization possibilities of charging had little noticeable effect.

Interestingly, the analysis revealed that money was not an important influential factor. Users expected varying compensation, which on average amounted to about 20% of their monthly individual charging expenses. Nine other factors were tested without significant results. In conclusion the authors suggest that the tariff design *itself* needs to communicate public benefits, which users can leverage by restricting their mobility and flexibility. Suggested modes of feed-back are information on balancing power or carbon emissions reduction, and one radical idea is to allow aggregators to charge according to end user's contribution to such factors.

In another study by Schmalfuß et al. (2015) a 5-month field trial was undertaken with 10 EV drivers comparing conventional charging with smart charging. Interviews and questionnaires sampled before and after testimonies from participants gauging motivation, attitudes and willingness to use smart charging were assessed. Not just finding a high degree of acceptance (even though it was indeed found), this study looked in qualitative detail at responses, which ranged from "'awful' to 'great' and from 'poorly developed' to 'worked without any problems'" (ibid:69). Importantly, Controlled Charging (CC) was feasible for users if they were able to plan the charging process and configure settings, and since the system rewarded setting limits to charge state, many end users willingly offered up their flexibility in favour of mobility and spontaneity. This trade-off was characterized as a learning process according to cognitive aspects of domestication theory discussed in the above. Many participants did not feel like they needed to be curtailed however, and this was explained as a lack in transparency of the system design, also noted to be important by Will and Schuller (2016).

When it came to motivation Schmalfuß et al. (2015), like Will and Schuller (2016), discovered financial incentives to be not important as motivator. Again, ecological and societal concerns were more important, and that drivers were experiencing a well-being connected to "doing something good", along the lines of symbolic aspects of domestication. In succession, the greatest motivators were environmental friendliness, contribution to grid stability, green energy supply, and lower financial cost. Users reported they felt a sense of cost when experiencing reduced flexibility, less spontaneity, the need to plan ahead, spending time adjusting settings, and less range due to limiting their charge state. This then becomes a balancing act between range anxiety and implementing experienced reward. Finally, in terms of behaviour change, the authors found this was dependent of previous charging habits. Those who seldom charged before smart charging was introduced charged more often, those who plugged in every day continued to do so, and some people would avoid charging when there was no reward given by the control system.

4 Findings and recommendations

The review makes evident that there is potential for freeing up flexibility at the place of the consumer. However, in order for the potential to be unlocked, certain preconditions need to be in place. Section 3.1 summarized several quantitative reviews of many kinds of interventions, ranging from a more frequent and informative bill to comprehensive monitoring systems. Results showed that energy consumption can be reduced in the range 5-20%. Even though energy reduction itself is not the overall goal of the INVADE project, these results are instructive in that they provide evidence for the responsiveness of end users to different kinds of energy related measures. The qualitative review finds that overall that **social learning is the most important aspect** of intervention, and in this context "social" must be considered as containing technology as well as people. Interviews with pilot participants revealed that the introduction of new technology in tandem with the prospect of novel ways of pricing electricity consumption opened a window of opportunity for realigning participant's engagement with energy technology and energy politics. Processes of implementing new technology or business models constitutes a possible re-arrangement of users' lives.

Several recommendations were identified as important when considering how to enrol the end users, and they are summarized in the following. The main findings deal with four areas of interest for WP9: 1) intervention and feedback, 2) introducing new technology, 3) segmentation and tariffs, and 4) vehicle to grid.

4.1 Findings on intervention and feedback:

- The electricity bill has proven a relevant medium for reaching customers. It needs to be timely, frequent, and must provide information that sparks interest, for instance by way of comparison of periods. Feedback must be actionable.
- Direct feedback is better than indirect feedback, and in-house monitoring is better than information on the bill.
- Feedback should be individually targeted, specific, contain possibilities for freedom of choice, contain an interactive element, and provide detailed breakdowns of consumption of individual appliances.
- Low income groups are vulnerable to licensing effects, meaning that more information about consumption can lead to increased consumption.

- Reward systems may be effective but are vulnerable to "fall-back effects" in the longer term, as they lose their effect.
- Hourly pricing to some degree leads to shifts in consumption, but not necessarily reductions in electricity use.
- Feedback over the long term is not always necessary. A single, impactful impression leading to cognitive dissonance can cause long term change.
- Peer-comparative feedback, i.e. comparing different users together, was not always found to work well. Comparing users is tricky, as they can reject the foundation of the comparison.
- Feedback at community, city or regional levels were found interesting by many, meaning that they would like to know that actions taken are significant contributions to greater society.
- Monitoring devices can without further follow-up become the root cause of a new, even more heavily cemented consumption baseline, which future interventions may have an even greater difficulty of changing. This means monitoring can lead to new barriers of behaviour change.
- The intended user program of any pilot must be thoroughly planned and executed in such a manner that a new normal is established that corresponds with the aims of the intervention.

4.2 Findings on introducing new technology:

- New monitoring devices in the household initially open up a window for social learning (Sørensen 2006, 2013), as the device is found useful for learning about consumption.
- After learning has been accomplished, devices fade into the background. There are limits to what a device can achieve before a level of saturation is reached and effects of intervention becomes more cost intensive.
- Knowledge re-arrangements can lead to licensing effects (as mentioned above). More knowledge can actually lead to disengagement (i.e. when people learn that electricity is cheap and/or certain practices are unproblematic).

- Material re-arrangements (i.e. new devices or appliances) can be considered success factors but may simply represent a one-off change of implementing a new system, after which the customer disengages (the change of no change).
- Monitoring devices help users learn about consumption. What they do with new knowledge is highly contingent.
- Social re-arrangements are associated with more lasting change, as they affect practices in the household by implementing new rules through both the domestication of new material objects and negotiating new practices.
- When new material objects and social re-arrangements in the form of practice changes, this may lead to re-arranging of routines. If this survives the initial window of opportunity opened up by the intervention they may represent lasting change.
- If change in routine is not implemented during the initial phase in which new objects and rules are domesticated, changes will likely dissipate and a return to normal may be observed.
- Findings often implicate the man of the household as the main change agent, fighting a lonely battle against the rest of his family. This has been identified as posing a challenge for lasting changes in household routines and practices and identifying ways of engaging more members of households as change agents should be emphasized.

4.3 Findings on segmentation

- Users were found to be highly differentiated across segments, and designers should be careful to avoid designing only for users highly proficient and skilled in technology. Possible segments include sceptics (i.e. the elderly), pragmatists (focused on low hanging fruit), and enthusiasts (early adopters, adopters with social or environmental motives).
- Monetary gains interests, ecological concern, and technology interests were all found to be viable inroads for recruiting a share of end users.
- Tariff structures have to be seen in relation to segmentation. Technologically proficient end users prefer volatile price models that benefit a high degree of automation.
    - Users less proficient in technology or less knowledgeable, interested or able to manage their consumption may prefer flat price structures.

  - Tariffs will have distributive effects and may potentially reaffirm unwanted social stratification.
- One must pay attention to symbolic aspects of microgeneration. E.g. some users are above all oriented towards “doing the right thing”.
- Location and context matters: enrolling people into smart energy pilots often have to do with specific, local energy or environmental issues. These issues can be identified and leveraged in order to provide meaning, significance and possible identity markers to prospective users.
- The significance of prices and tariffs should not be overestimated. However, variable prices and feed-in tariffs have proven effective incentives in some instances, and small but favourable setups can be included for added effect.
- There is a tension between automation and manual demand response. Some users reported they felt their efforts at effecting change in behaviour became less meaningful with more automation. This means that too much automation can constitute a risk of reducing user engagement in some cases.

4.4 Findings on vehicle to grid (V2G)

- There are few studies available, but existing studies suggest high acceptance among users for smart charging.
- Engagement mainly found to originate with concern for society’s benefit (for instance grid stability), and not one’s own personal gains.
- If acceptance was negative due to desire for high flexibility in mobility, even programming capabilities for charging was not found to improve acceptance.
- While users expect some remuneration for smart charging, 20% of total charging expenses were often found to be enough.

4.5 INVADE-specific recommendations

Based on the literature review and the findings in the above, this section highlights three key considerations for business model development within the INVADE project. The concrete challenge with implementing and reproducing the findings outlined in this report at the site of regular end users in their everyday lives, is that they often are derived from demo projects with a highly involved, small number of early adopters. The goals of such projects are often explicitly inclined towards implementing smart technology with a high degree of user involvement. Projects and calls focused on smart energy technology are often predicated on an often-stated need for engaging end users and making them into an increasingly "active" part of the energy system. As active, engaged or involved, a customer is envisioned that eagerly employs solutions in order to be as flexible and rational as possible. As this report has highlighted, along with several other studies critically examining the so-called "need" for active end users in the smart grid (see for instance Throndsen 2017, Strengers 2013), a number of challenges are associated with this. The following is an attempt at describing an option which does not necessarily rely on involving and rendering "active" every end user or customer in a potential market. Such a goal may in fact be impossible to achieve, and a business model that relies too heavily on having all its customers involved and engaged at all times could become extremely resource intensive, as well as possibly meeting tough challenges in realising goals and potential. Thus, the three main considerations for an "everyday" smart energy technology implementation scheme, and which is considered important for solutions and business model development within INVADE, is outlined as follows:

- First, a high degree of automation may be preferable to a high degree of involvement, simply because, as stated in section 3.2.1 about segmentation (and elsewhere in the review), many users are slow to adopt cutting edge technology. The success of the business model should not rely on having every customer completely engaged.
- Second, a degree of involvement and customer side customisation and programming capability should be made possible in order to cater to early adopter, super user segments that *are* interested in this, as indicated in the review above.
- Finally, while automation may solve many problems for customers and make their lives easier, one of the main messages in this report is that such automation almost never is implemented "automatically". Users will still need to allocate some effort for implementing and running-in new systems.

In conclusion, an approach that says "this will be taken care of for you" may be a better than "you will have full control". Many customers will not know what having this "control" entails and are not ready for or interested in it. In a worst-case scenario, when giving customers more control they may experience it as more work. Even when automation takes over certain amounts of work in the home, time must be given to allow for a transition during which users "give up" certain practices to the automation. This is a process that cannot be automated.

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