RESPOND

DEMAND RESPONSE FOR ALL

Integrated Demand REsponse SOlution Towards Energy POsitive NeighbourhooDs

WP3 User Engagement Process

T3.2 User engagement approach

D3.2 RESPOND USER ENGAGEMENT STRATEGY

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EXECUTIVE SUMMARY

The RESPOND project aims to fill the gap between the ongoing Demand Response (DR) initiatives often focusing on the biggest customers with high energy demand and households with small demand. The objective of RESPOND is to design, implement and test Demand Response solution for small dwellings which, acting like a large group, can also provide valuable services to the grid avoiding peak hour stress while benefiting from cheaper and cleaner energy.

To demonstrate these solutions, RESPOND is developing a Demand Response programme/solution (including a mobile app) that is going to be tested at three pilot sites selected in different countries and with distinctive characteristics. Inhabitants (households) living in these pilot sites will be engaged to take part in the trials to prove the suitability of the concept proposed.

The users' active engagement with the RESPOND mobile app (and the RESPOND DR programme in general) is essential for the success of RESPOND. For this reason, this deliverable presents a set of recommendations on how to ensure user engagement, which make up the RESPOND user engagement strategy. The recommendations are the outcome of RESPOND Task 3.2 *User engagement approach*.

The user engagement strategy recognizes that energy consumption of households is closely linked to households' everyday life and everyday practices. Therefore, it is important to design DR solutions and a mobile app that consider this complexity and ensure that the developed solutions fit in with the existing practices and do not cause inconvenience to households by opposing their daily practices.

Based on a comprehensive literature review of existing studies of energy feedback and DR solutions, and founded on the theoretical framework of social practice theory, a number of specific recommendations on how to ensure user engagement are developed (see Chapter 6 for details):

- **Involvement of users in final design:** A well-functioning and easy-to-use mobile app is key to ensure user engagement. This goes for the user interface as well as for the functionalities "behind" the mobile app user interface (e.g. programmes for automated DR response). For this reason, experiences and input from the prospective users at the pilot sites will be involved in the final designing of the mobile app. This will be done on basis of focus groups carried out in RESPOND Task 3.3.

- **Option for overriding DR automation:** The RESPOND platform includes elements of automated remote control of parts of the households' energy consumption (e.g. space heating in the Aarhus pilot). In addition to providing options of relevant user pre-settings (e.g. minimum and maximum temperatures for the automated heating control), it is important to include a functionality that makes it easy for the users to override the automated control. This provides the users with control and is essential, as experiences of inconvenience or discomfort related to the automated control schedules otherwise could jeopardize the households' continued participation in the DR programme.
- **Appliance-specific consumption data and real-time feedback:** To support households' active engagement in changing their consumption patterns, appliance-specific consumption data should be provided. Furthermore, information should be provided as (close to) real-time feedback, as this supports cycles of experiential learning.
- **Timely and personally tailored DR action recommendations:** The mobile app should include a module that makes it possible to provide the users with timely and personally tailored DR recommendations. Practical and "hands-on" recommendations on how to change practices (e.g. time-shift consumption) are important to users and their continued engagement. This can be done through push-notifications on the mobile phone. It is important that the information is delivered timely, not too frequently and to some extent is tailored to the characteristics of the individual household.
- **Simple data presentation:** The presentation of energy feedback and DR information to the users via the mobile app should be simple and avoid too technical terms. Also, the presentation should ideally be graphical as this supports the users understanding of the information.
- **Neighbour comparison:** To support the continued engagement with the RESPOND DR programme and the mobile app, the neighbourhood approach of the RESPOND project will be exploited through a mobile app feature making it possible for the households to follow their own DR performance and compare this to their neighbours. This acts as a performance score based competition.
- **Local competitions and use of social media:** Further utilizing the neighbourhood approach of RESPOND, a competition should be created among the RESPOND households on who's performing best. It is suggested to make a competition about "who's able to achieve the highest share of locally-produced RE in their own energy consumption", which relates to the above-mentioned DR performance score. This will work as a reward system. Also, the RESPOND mobile app should make

it possible for the individual household to share its "local RE-share performance indicator" via social media. Together, these two initiatives can fuel competition among the local RESPOND households.

- **Hands-on demonstrations:** It is recommended to consider arranging hands-on demonstrations (e.g. a "home party") at the beginning of the RESPOND validation phase at each pilot site. Here, the local RESPOND households can meet and get demonstrations of the mobile app and the related devices; how they work and how to perform DR actions etc. This supports the dissemination of knowledge and competences related to practices of time-shifting energy consumption.

Together, these recommendations make up the RESPOND user engagement strategy.

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ABBREVIATIONS AND ACRONYMS

CKN	Community Knowledge Network
DR	Demand Response
IE	Indoor Environment
IHD	In-Home Display
IoT	Internet-of-Things
ToU	Time-of-Use (pricing)

1. INTRODUCTION

Demand Response (DR) solutions might be the key to unlock the environmental objectives set by several actors, including The European Union. Lowering energy consumption, CO_2 emission and ensuring an increasing share of renewable resources in the energy system are the core of most policies and road maps towards a more sustainable future. A core element in such plans is allocating the energy consumers[1] (citizens and households) an active role through demand response and energy feedback – solutions often seen as part of the so-called *smart grid* or *smart energy system*. While smart energy solutions have been discussed since the beginning of the 21st century, the technical attributes of the smart energy system evolve rapidly, and new developments include higher levels of involvement and cooperation of the users. In such developments, understanding how users engage with smart energy technology and how they use energy becomes a central element. The objective of this deliverable is to understand user engagement with DR solutions, and in doing so, develop recommendations for design of user feedback and engagement with DR solutions.

In this deliverable, which is an outcome of Task 3.2 *User engagement approach* in WP3, a discussion of the potential and limitations of user engagement with DR solutions will be presented, resulting in a set of recommendations that can be implemented when designing the practical solutions in the RESPOND project.

Chapter 2 gives a short introduction to the theoretical framework of this deliverable, which in particular draws on the work of social science scholars within practice theory. This is followed by three chapters (3-5) that detail three themes (meaning, competences and technology) that are important to take into consideration when designing user engagement in relation to DR solutions. These chapters combine literature reviews of (mainly) practice-theoretical studies of energy consumption and smart energy interventions with analytical observations on the implications for how to design DR solutions that are workable and engage the users. This feeds into Chapter 6, which translates finding and recommendations of Chapter 3-5 into an outline for the user engagement approach in RESPOND. Finally, Chapter 7 provides the overall conclusions of the deliverable.

[1] In this deliverable, we will use the terms ”(energy) consumers” and ”users” interchangeable.

2. THEORETICAL FRAMEWORK

This chapter presents the underlying analytical and theoretical approach of this deliverable, which is based on the social practice theory approach.

While DR solutions, as part of smart energy, often have been perceived and implemented as purely technical or infrastructural projects, it is key that such solutions should also include knowledge about the consumers and the everyday practices that the solutions are integrated into.

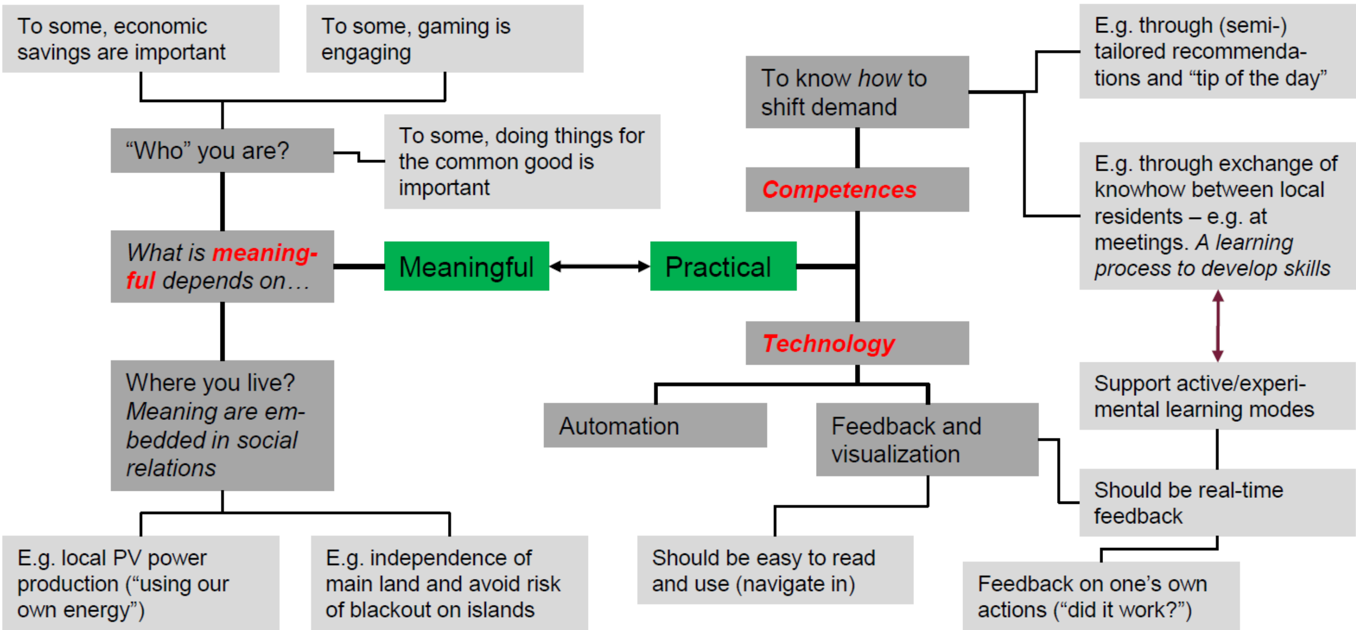

FIGURE 1: VISUALIZATION OF THE RESPOND USER APPROACH (WITH SELECTED DESIGN CRITERIA, WHICH IS DETAILED FURTHER IN LATER CHAPTERS OF THIS DELIVERABLE)

In relation to this, two **key criteria** can be set up for DR solutions to be successful and to work in practice (see Figure 1):

1) The solution should be "meaningful" to people
2) The solution should be easy to use and interact with for the users, i.e. practical or workable.

These are, of course, rather generic observations, but important to have in mind when designing DR solutions. The latter criterion (practical solutions) can be divided into two sub-characteristics that together determine the (experienced) workability of a given DR solution: The technological design and the users' competences or knowhow related to operating the DR solutions (see Figure 1).

The two key criteria are closely intertwined; e.g., the way in which people ascribe meaning to a certain technology, such as DR solutions, is determined by, among other things, their technical proficiency and know-how. Furthermore, what is perceived as meaningful to the users is also determined by a diverse and complex set of socio-economic parameters and individual (but culturally derived) dispositions. As an example, some people might find DR meaningful because of economic benefits, while others might denote environmental benefits as their main motivation for engaging with DR solutions.

2.1 Social practice theory as theoretical framework

Social practice theory situates practices as the place of the social, and as Andreas Reckwitz [1] argues, practices are therefore the smallest unit of social analysis. Simplified, social practices can be defined as people's "sayings and doings", situated in a specific space and time. On one hand, practices are constituted by rules, purposes, beliefs and practical understandings [2] and are performed as embodied habits. Following Reckwitz, individual people are "carriers of practices" who produce and reproduce practices through mentally and bodily embedded routines [1]. While Theodore Schatzki [2] contributes to the understanding of practices as the site of the social, he also elaborates on the linkages of such – in other words: What constitutes practices and how they are carried out? [3]

Especially Alan Warde [4] and Elizabeth Shove and colleagues [5, 6, 7, 8] have contributed to the understanding of how practices are constituted. Shove et al. [6] argue that practices are constituted – or held together – by the following three elements: materials (artefacts), meaning (images) and competences (skills). Materials represent objects, tools and infrastructures, while meaning represents cultural conventions, expectations and collectively shared meanings and, finally, competences represent knowledge and embodied skills (ibid.). This deliverable will be built around these central elements of which practices are produced and reproduced. As Pantzar and Shove stress, new practices are "(…) new configurations of existing elements or of new elements in conjunction with those that already exist" [8].

With special focus on consumption, Alan Warde [4] argues that performing practices always entails consumption of, for instance, energy and materials. Consumption is therefore a moment in almost every practice [4, p. 137]. In order to understand consumption, one must therefore understand the practices; i.e. understand the elements that constitute the specific practice. With reference to Schatzki, Warde defines the elements as: understandings, procedures and engagements (slightly different from the elements identified by Shove and colleagues). In other words, it is necessary to understand "(…) why do people do what they do?" and "how do they do those things in the way they do?" [4, p. 140]. The point about consumption as an integrated part of performing everyday practices is also made by Shove and Walker [7], who recognize that "energy is used not for its own sake but as part of, and in the course of, accomplishing social practices" [7, p. 47].

The objective of RESPOND Task 3.2, and the RESPOND project in general, is to develop DR solutions that can assist in balancing energy demand and supply through time-shifting consumption, including overcoming problems of peak demand. The RESPOND approach to DR differs from many previous projects by having a distinct neighbourhood-approach that focuses on balancing local energy generation and consumption. At the same time, the RESPOND DR solution will integrate automation and third party services in the design (e.g. weather forecasts in predicting demand etc.).

By employing a neighbourhood approach, RESPOND does not only focus on the supply-side needs (e.g. related to intermittent RE power generation), which has otherwise been criticised by social practice theorists for ignoring the close connection between the demand and supply sides of the energy system [9, 10]. In practice, many of the households taking part in the RESPOND site demonstrations are individual prosumers or they have local, collectively-owned RE power installed in their neighbourhood.

Another critique from a practice theory perspective is that demand-side management approaches, like DR, often rely on an approach that Shove [9] has termed the ABC-model. ABC is a shortening of Attitude, Behaviour and Choice. Strengers [10] adds a "D" to the model for Demand. According to the ABCD model, the demand-side solutions should be based on an analysis of attitudes, values, choices, opinions, barriers and drivers that are ascribed to the end-users (ibid). Such an approach contains the assumption that demand can be changed by mapping the ABCD of end-users, and hereafter applying the right strategy. This is due to the assumption that people's behaviour is determined by their attitudes (e.g. their "environmental values"), and that people make conscious and deliberate decisions (choices) with regard to what they do on basis of their attitudes (combined with knowledge, e.g. about the environmental impact of a certain behaviour). However, Strengers and Shove (among others) criticise this ABCD approach for neglecting the dynamic and evolving nature of practices. Instead of seeing the demand for energy as an outcome people's active and rational choices and their individual attitudes, the practice theory approach recommends to understand the demand as an outcome of practices that are performed by individuals, but essentially are collective in nature. In other words, practices are shared by people and their performance is dependent on many different elements, including – for instance – technical aspects like how energy-demanding products are designed.

Related to this, Strengers also questions the general tendency to think of the energy consumers (e.g. householders) as "micro resource managers", when engaging in strategies of demand shifting or reduction [10]. Such an assumption builds upon the before-mentioned notion that consumers essentially are rational and autonomous "decision-makers", who on a daily basis make decisions about their energy consumption based on information they are given (e.g. as smart meter feedback). What this model is missing is, again, the fact that:

1) Energy consumption is the outcome of people doing daily practices that are shaped by many other concerns than energy consumption as such (e.g. comfort and convenience) and
2) That people's daily energy-consuming habits are dependent on a range of different elements and are not a result of deliberate and rational decision-making.

Based on the above considerations, the key observations from the practice-theoretical approach, which will form the basis for the following analysis and the design of the RESPOND user engagement strategy, are:

- Energy consumption is an outcome of people's (the "consumers" or "the users") daily practices, e.g. cooking and cleaning.
- People do not in general think specifically about energy consumption (it is just part of their daily doings)
- The daily practices (and thereby the energy consumption) are constituted by a wide set of elements, which in this deliverable is categorized as: materials (e.g. products and technologies), meanings and competences.
- Following from this, providing information alone is not sufficient to make people change practices in general. It is also important to include the role that meanings and competences play for the practices people perform (and the related energy consumption).

In the following three chapters, we will further elaborate how meaning, materials and competences are each co-shaping the daily practices and energy consumption of people. Also, each chapter includes a discussion of what has been learned from previous energy feedback and DR studies and trials. The three chapters inform the design of the RESPOND user engagement approach presented in Chapter 6.

3. How to engage residents through making DR meaningful?

In this chapter, focus is on strategies that can make DR meaningful to end-users. Theoretical and empirical research will be presented and recommendations to specific initiatives will be developed. In doing so, focus will be on the role of economic savings, "doing something good" for the environment or the neighbourhood, social competition and normative social influence. The potential and limitations of these different approaches will be discussed and, as part of this, specific initiatives will be presented. Also, the role of Indoor Environment (IE) is also explored, as this is important to address to ensure that DR solutions are meaningful to people.

A central part of understanding and explaining user-demand and behaviour is associated with the notion of meaning. In practice theory, meaning is regarded as a central element in every practice, and it is therefore important to unfold the concept of meaning and how it can be understood and used when implementing DR solutions. In the following, focus will therefore mainly be on how practice theory can shed light on the importance of meaning and help develop appropriate and effective interventions.

3.1 Economy and price-incentives

Within the smart energy and smart grid field, "saving money" is often expected to be a key incentive to make people change habits and energy consumption. This also applies to many demand response approaches which advocate various forms of dynamic pricing schemes as key to promote time shifting of consumption. However, as previously pointed out by several theorists from the practice theory field, there has certainly been a tendency to over-estimate how effective dynamic pricing is as an incentive to make people change consumption. This said, a review study by Kessels et al. [11] shows that if designed correctly, time-of-use pricing schemes can have an effect. Important characteristics of an effective dynamic tariff scheme are, according to this study:

- **Simple to understand:** It should be simple for people to understand the dynamic price scheme. This means that it should not involve too many time intervals with too fluctuating prices. Similar findings were found in a Danish study [12] of households participating in a Time-of-Use (ToU) price scheme involving both static and dynamic ToU pricing. The static ToU scheme divided the day into a limited number of time intervals with fixed prices, while the dynamic ToU pricing was based on the market price at the Nordic electricity market Nordpool, which changes hour by hour. The study showed that while the participating households in general got used to the static ToU pricing and, over time, adopted new routines in order to time-shift electricity consumption to low-price hours, they all ignored the dynamic ToU pricing as they regarded it to be too complicated and inconvenient to follow.

- **Timely notifications of price changes:** If some kind of dynamic ToU pricing scheme is applied, it is important to notify households of price changes in a timely manner; i.e. not ”too late” or ”too early”. A German smart grid project (eTelligence) tested people's reactions to what was termed ”Bonus” and ”Malus” events associated with very low prices (0 ct/kWh) and very high prices (120 ct/kWh), respectively [11]. These events happened on days with excess of wind power (bonus) or days with particular low generation of wind power (malus), and prices were announced day-ahead. The trial showed that users reduced their consumption at malus events with up to 20% and increased it during bonus events with up to 30%. Here, however, the frequency of these events probably plays an important role for the householders' long-term acceptance and reaction to the prices.
- **A considerable effect on their energy bill:** Finally, if the householders are expected to take active part in (manually) shifting their electricity consumption, it requires high price spreads. This in particular applies to dynamic ToU pricing schemes, whereas also more limited price spreads can have an effect in static ToU pricing schemes.

3.2 NAÏVE PSYCHOLOGY AND NORMATIVE SOCIAL INFLUENCE

When people explain their own behaviour, they tend to rely on so-called *naïve explanations* [13]. Naïve explanations is a concept from psychology and refers to individuals' conception of their own behaviour and mental process (ibid.). Put simple, naïve explanations – and naïve psychology – refer to the verbal explanations that individuals give when asked about why they do what they do. When explaining behaviour, people are subject to a so-called introspective illusion, in which they "(…) see others as more conforming than themselves" to existing norms [14, p. 585]. Through five empirical studies, Pronin et al. [14] find that this introspective illusion occurs in domains ranging from consumption to political views. When explaining behaviour, people therefore state that they are less susceptibility of social influence than others. In a study of energy conservation [13], a survey in California was conducted among 810 participants examining the impact of social influence. One result of the study was that while the participants rated beliefs of saving the environment, benefits to society and saving money as the primary reasons for their own measures to save energy, the strongest correlation and indicator for behaviour was their beliefs about "what other people are doing" (ibid.). The study uncovers the effect of social influence and the importance of social surroundings for energy consuming behaviour. In other words, what the individual thinks that other people might do or not (e.g. with regard to sorting waste) has a more significant influence on his/her own behaviour than his/her personal (stated) values (i.e. attitudes) with regard to environment, money saving etc. This is termed the **normative social influence** and indicates a general tendency for people to accommodate to what they believe are the common norms and existing practice within a community. Or in the words of Nolan et al. [13, p. 913]: "communicating a descriptive norm – how most people behave in a given situation – via written information can induce conformity to the communicated behavior". Normative social influence has been utilized in different feedback trials, including the often-cited American OPOWER Home Energy Report letters [15]. Here, the American utility company OPOWER had positive experiences with sending their customers a letter that compared their electricity use to that of their neighbours. In this way, the individual household could see if their electricity consumption was above, similar to or lower than the average of their neighbours' (including a comparison with the "efficient neighbours", i.e. the electricity consumption of the neighbours of the 20th percentile with lowest energy consumption). The trial showed an average energy reduction of 2.0%.

Other companies are offering similar feedback solutions providing social comparison, such as the Energy Grader provided by RESPOND partner DEXMA (see Figure 2).[2]

FIGURE 2: DEXMA ENERGY GRADER APP

The normative social influence can be utilized in RESPOND by comparing the individual household's energy performance to the average of its neighbourhood and the average of the most efficient homes,

[2] See: https://www.dexma.com/energygrader/

respectively. The figure below shows a preliminary proposal on how such a comparison could be made through the Mobile App associated with the RESPOND DR programme.

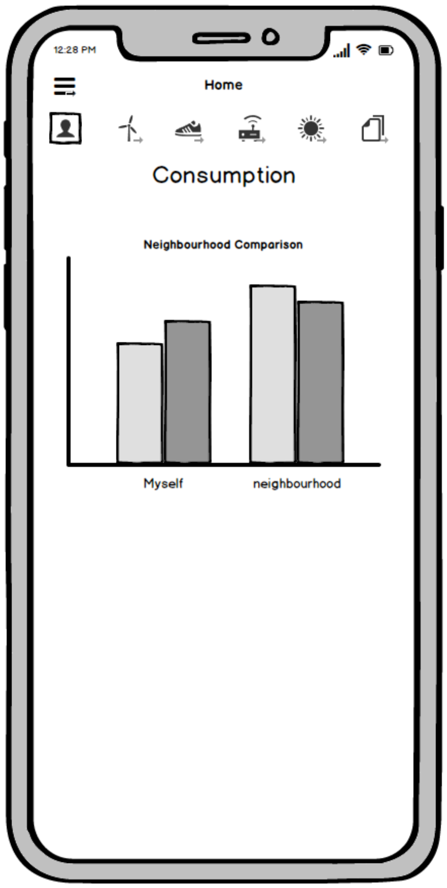

FIGURE 3: NEIGHBOURHOOD COMPARISON IN RESPOND MOBILE APP (MOCKUP)

Despite indications of a relatively high impact on behaviour from campaigns incorporating normative social influence, most energy initiatives and campaigns are still based on "**classical information provision**" about consumers' individual consumption behaviour and the general virtues of saving energy (e.g. saving money or saving the environment). Previous studies have shown that campaigns supplying information about consumption can be useful, but also entail pitfalls that eventually lead to limited results.

In a study examining the supply of environmental information and its influence on consumer behaviour, Bartiaux [16] challenges the paradigm of consumer rationality and policies that such methods depend on. Based on a survey conducted in Belgium, Bartiaux concludes that information about environmental protection is not "taken in" by the recipients, neither is it transformed into changed practices. Furthermore, Bartiaux shows that households that are better informed about environmental issues are not behaving in a more environmental-friendly way than other households. In the same study, participants were subjects to expert advises concerning saving energy, but these recommendations were rarely followed.

Another study conducted by Hargreaves et al. [17, 18] found similar results. Set in the context of UK, a 12-months study of householders and their interaction with real-time feedback on their domestic energy consumption via in-home displays was carried out. Through qualitative interviews, the study concluded that while feedback on energy consumption increased the participants' knowledge of electricity consumption, this did not translate into changed behaviour on energy demand [18]. One of the reasons for this was that at the same time as awareness was created about which specific practices that resulted in which specific energy demands, this awareness also proved to the participants how difficult it was to change many of these practices to save energy (e.g. if the energy demand is related to essential or cherished activities such as preparing dinner or watching television). Again, this points to the importance of better understanding the everyday practices that energy consumption is the outcome of.

3.3ENERGY CONSUMING HABITS

As already pointed out in Chapter 2, domestic energy consumption is the outcome of householders performing everyday practices like cooking, making a home comfortable or washing clothes. Further, energy-consuming practices are deeply embodied by the individual through their frequent repetition and thereby reproduction. This means that such practices are often performed without much consciousness from those who perform the practices. Thus, in the previous-mentioned study by Hargreaves et al. [17, 18], the participants first became aware of their energy-consuming practices when information was supplied.

Furthermore, the energy-consuming practices were difficult to change for the participants as they were deeply anchored in everyday life (ibid.). When discussing how to change or ”break” energy-consuming habits, Sahakian and Wilhite [19] therefore turn to the importance of **distributed agency**. The concept of distributed agency refers to three elements that are particularly important for how daily practices are constituted (or ”shaped”) and performed: The body, the material world and the social world. Rather than focusing only on information, attitudes and beliefs as the main drivers behind practices and how they change, the concept of distributed agency argues for the importance of identifying how practices are rooted across each of the three elements. Supplying information with the purpose of affecting domestic energy consumption thus needs to apply a holistic view on relevant practices. While addressing one of the three elements in some situations might cause the wanted change, addressing all three elements will be more efficient when habits are to be changed or broken. The element of *the body* refers to both cognitive and physical dispositions. This includes embodiment of knowledge, which has been produced and is reproduced through experience. Simple awareness building around e.g. saving the environment is therefore not enough to make a change. Creating new practice through the active and bodily engagement of people in new practices can therefore be a more effective approach; for instance providing ”hands-on” demonstration of how to do practices in a less energy-intensive way (e.g. washing clothes at lower temperatures). The second element identified by Sahakian and Wilhite refers to *materials* as represented by the material things that surround us (e.g. electrical appliances) as well as the general infrastructure (e.g. smart grids). Materials directly interfere with energy-consuming practices in that they respond to our actions. Furthermore, materials are often ”scripted”, which means that they prompt certain uses and excludes others. An example of the latter is when appliances like television sets or washing machines are set in ”high efficiency” mode as default, which leads many users to use this setting, which results in higher energy consumption. However, the relation between technologies and the users is a two-way relation; technologies can shape and change practices, but at the same time practitioners can change the technology and sometimes work against the scripts of the devices. The last element identified by Sahakian and Wilhite is *the social world*. This entails norms, values and institutions, which can both be tacit and explicit. Campaigns aimed at changing or reducing domestic energy consumption have typically addressed this element through information, education or ”awareness-raising”. But introducing new norms and values does not necessarily contribute to change in practices.

In highlighting the importance of distributed agency, Sahakian and Wilhite put forward a set of recommendations when appealing to change domestic energy consumption. First and foremost, they recommend identifying how individual agency is distributed across each of the three elements. Thus, policy and campaign interventions must adopt a broader scope and consider the complexity of the different social practices that might be connected to domestic energy consumption.

Sahakian and Wilhite [19] propose applying methods of social learning when appealing to change domestic energy consumption. Using the examples of professional athletes who train for a sport, Sahakian and Wilhite argue that engagement with new practices is key. Thus, Sahakian and Wilhite point towards demonstrations as a fruitful and effective way to stimulate practices.

3.4 Caring about the indoor environment

The (perceived) indoor environment is an essential element of home life and home practices, and it is important to address to make DR programmes meaningful to people. The indoor environment is made up of several physical, chemical and biological factors, often divided into the four main groups:

- Thermal environment (e.g. the feeling of heat, cold and draughts)
- Atmospheric environment (e.g. perceived air quality, pollutions like chemical compounds and particles, odour and volume of fresh air supplied)
- Acoustic environment (e.g. noise, vibrations, perception of speech and sound)
- Visual environment (e.g. lighting and glare).

Since Europeans spend around 90% of their time indoors, the indoor environment affects occupants' comfort and health significantly. For instance, in a Danish questionnaire survey, house owners living in single-family detached houses stated that they are interested in, and concerned about, the indoor temperature and air quality, and that it is an important element in caring for each other in the family [20]. The survey also showed that just because residents can follow their heat consumption on a mobile app, it does not mean that they actually do it.

This opens for an opportunity to increase the value as perceived by occupants of the RESPOND mobile app by including not only information about energy, but also information about their indoor environment, based on selected measured indoor parameters. Today, several relatively cheap sensors exist that can monitor relevant indoor environment parameters, e.g. temperature, relative humidity, CO_2 and VOC, particles etc. These measurements can simply be made available for the occupants, but they may also, if analysed and assessed up against certain standards, lead to meaningful/valuable feedback to the occupants that can help establishing a more comfortable and healthier indoor environment. Furthermore, if the measurements are made available for the building manager, s/he may be able to take better care of the building constructions, e.g. act if the humidity is high in a dwelling, and in that way reduce the risk of building damage and mould problems due to high humidity.

In Europe, approximately 40% of the total energy consumption is used in buildings. Establishing the preferred indoor temperature level with heating/cooling and an acceptable indoor air quality by mechanical ventilation are responsible for a major part of the energy used in buildings. Here, demand response can be utilized within heating/cooling and ventilation of buildings to reduce CO_2 emissions and energy costs at both utility and consumer level. During demand response control, some of the indoor environmental parameters (room air temperature or CO_2 concentration) are allowed to either increase or decrease to time-shift energy consumption. Hence, the demand response is a bargaining process between energy cost savings and acceptable impact on indoor environmental quality.

Time shifting energy use to reduce peaks by demand response actions should preferably not be noticed as a poorer indoor environment by the occupants, or at least it should remain within an acceptable range [21]. This range may not be the same for all occupants.

The thermal environment has been studied thoroughly during the last 100 years. Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (EN 7730 [22]). Different quality levels of design criteria for the thermal environment are often based on the thermal comfort indices PMV-PPD (predicted mean vote – predicted percentage of dissatisfied), which link together air temperature, radiation, air velocity and humidity, levels of activity and thermal insulation of clothing.

The thermal comfort indices PMV-PPD were developed by P. O. Fanger [23] based on laboratory studies with human subjects assessing the thermal environment under controlled conditions in climate chambers. Therefore, the PMV-PPD indices may be suitable for application in controlled office environments, but perhaps less suitable for homes where residents may have other individual preferences for temperature conditions, and the assessment of temperature may depend on other criteria than in an office environment. For example, residents may make a trade-off between the quality of the indoor environment and other concerns such as economy and energy consumption, which can lead to a decision that allows some rooms to be cold during winter and warm during summer. Occupants' different preferences should be utilized rather than treating everybody as the same. Some people may find the temperature acceptable only within a narrow range, whereas others are more willing to live with some thermal discomfort if it means other benefits, like saving money.

Some recent studies suggest that the comfort levels in dwellings may be influenced by personal preferences, which supports that the situation in dwellings is less rigid than that of offices. Therefore, to get the most out of demand response, and thereby the highest energy saving/shift in energy use, individual preference needs to be exploited. Information about what people are willing to accept may be revealed by communication/user feedback via the RESPOND mobile app.

To ensure a long-lasting appeal of the RESPOND DR platform, special attention shall be paid to user experience. To make DR approaches time-shifting energy used for heat/ventilation more meaningful for occupants, it needs to be done in such a way that the IE is not affected in a way that is perceived negatively.

3.5 Highlights

Based upon the above, the following "key messages" can be inferred with regard to the role of meaning as an element in energy-consuming practices and in changing these through DR programmes like the one carried out in RESPOND:

- If variable (dynamic) prices are used as an incentive to time-shift energy consumption, the price scheme should be simple, include timely notifications of price changes and relative high price spreads.
- When asked, people rate environmental concerns (e.g. "saving the environment") higher than social influence in explaining their own behaviour and domestic energy consumption, however …
- Studies show that the normative social influence, i.e. the tendency of people to confirm to norms that they believe other people follow, is a stronger predictor of energy behaviour than personnel beliefs or stated values.
- Policy, campaigns and initiatives should focus on practices rather than on individual beliefs.
- Energy feedback increases households' knowledge of their energy-demanding behaviour, but does not necessarily lead to changes in practices.
- Domestic energy consumption is the outcome of routinized practices.
- When designing interventions aimed at changing practices, and their related energy consumption, it is important to identify and include all elements that constitute practices (materials, meanings and competences)
- In order to promote new practices, hands-on demonstrations of how to do everyday activities in a better way (more energy efficient or time-shifting consumption) are important. This can be done in different ways, e.g. through practical and tailored advices communicated timely via a smart phone app.
- DR programmes should not compromise residents' experienced indoor environment, as this would jeopardize their acceptance of these programmes.
- Including information about the indoor environment (and recommendations for improvements) in DR solutions can be part of making these solutions meaningful and engaging to people.

4. How to engage residents through developing competences for DR?

When considering how users engage with DR solutions, as those developed in the RESPOND project, it is important to highlight competences. Providing feedback to users on energy consumption, with the aim of affecting domestic energy consumption, is not a straight forward process. Here, knowing how to act and change consumption is an important skill of the users. Following Shove et al. [6], competences refer to both knowing how to do a practice and the practical enactment of a practice.

Knowing how and what in a specific practice is often implicit to the person, who performs the practice and does this with little thought on how s/he is actually doing it. A classic example is biking, which is something that most people can do – but it is almost impossible to explain to others how to do it. At least in a way that can help others to learn how to bike. Learning to bike takes a lot of practical training. This said, some types of knowledge can more easily be described through, e.g., written instructions and thereby be transferred to others.

Based on studies of energy consumption, Kirsten Gram-Hanssen [24] contributes to a further clarification of competences, and their relation to knowledge, that play a role in social practices. Gram-Hanssen distinguishes between: 1) Know-how and embodied habits and 2) Institutionalized knowledge and explicit rules (Ibid.). The first category refers to knowledge as know-how, which is learned by doing and often through socialization (biking could be an example of this). Such competences are embodied and entail forms of knowledge that allow individuals to perform routinized practices in their everyday life. The latter refers to knowledge of the type of “knowing what”. Important here are rules, principles and instructions. This type of knowledge is easier to codify (i.e. generalize or describe with words in order to confer to others), and could be e.g. technical knowledge on how to operate energy devices etc.

In the following, focus will be on the role of competence in practices of energy consumption and in relation to reducing or time-shifting these. Just like meanings and materials constitute elements of a practice, competence is active in the constant development of practices.

4.1 Transferring knowledge from one context to another

One way of gaining competences is “learning by doing”, which happens continuously and often without our notice. Learning by doing is therefore often referred to as embodied knowledge [6]. Transferring knowledge from one context to another typically implies that knowledge has to be processed in some way. In relation to demand response solutions using feedback monitors, much policy has aimed at transferring knowledge on how to shift or reduce energy by promoting various types of signals to users. In doing so, knowledge has been codified and processed, so that the outcome on the monitors show consumption in e.g. graphical terms or using smileys. Though, this processing of knowledge relies on the assumption that the users' will understand and take in the knowledge presented, and hereafter develop competences in order to act in line with the information given (e.g. save energy or time-shift consumption). Shove, Pantzar and Watson [6] contest this and highlight that while knowledge can be transferred from one specific context to a new one, the obtainment of knowledge is not a straight forward process (ibid.). They argue that when knowledge is transferred, it is re-embedded into a pool of existing knowledge, and the abstraction of knowledge from this pool is dependent on the specific context and the set of competences that the receiving users poses. Abstraction and transferring of knowledge are possible, but it must be acknowledged that certain barriers or limits are present.

Individual know-how is essential for how new knowledge is understood and turned into new competences, but know-how is unequally distributed among people because it relies on their prior experiences and practices. Some individuals are better equipped to "decode" the presented information because of prior experiences. Designers of DR solutions therefore have to take into account the context and who are going to engage with the feedback. If users are properly prepared, e.g. through previous demonstrations and practice-based learning, they are more liable to obtain the knowledge on how to use e.g. feedback technologies. Ideally, users should be integrated into the process of design and testing.

Competences for the performance of a specific practice, and thereby the transferability of knowledge, are dependent on how other specific practices relate to this specific practice. If users have gained know-how for one practice, which has certain similarities to other practices, the potential for this know-how to be successfully obtained in other similar practices is higher. In relation to the RESPOND project, know-how on how to use and engage with feedback provided via a mobile phone app is therefore dependent on the users' existing know-how related to the use of technologies such as mobile phones and ICT in general. Competences thus act differently compared to other elements of practices, in that it can travel between practices by the means of abstraction followed by "de-coding" by individuals. In this perspective, the ability to decode is a competence in itself, which is based on previous practices and the know-how related to these.

4.2 COMPETENCES IN EVERYDAY LIFE

Relating practices and competences to households' daily management of energy consumption, Sarah Royston [25] examines how individuals manage heat flows in the domestic sphere, and how competences influence this. Royston finds that know-how is of importance to individuals when they manage heat flows in the domestic sphere. Royston defines know-how as an individual capacity to act in a specific context. Royston argues that know-how is experience-based and highlights three aspects that stimulate the development of new forms of know-how. First is the aspect of *life course*, as life-changing circumstances influence how people develop know-how. Here, Royston finds that child-birth is an important example, and that becoming a parent leads to a new range of experience-based know-how. For instance, ensuring comfortable temperatures for small children often imply new competences such as knowing when it should be cold or hot. Demand response solutions thus need to incorporate the importance of life course through making the design applicable to people in various life phases. Related to this, Royston argues that changes to household composition also affect the development of know-how created among the inhabitants. Know-how can be perceived as negotiated in social practices and when for instance new inhabitants move into a house, they will enter the ongoing development and negotiation of know-how. Secondly, *material arrangements* influence the development of know-how. Royston argues that when individuals move from one house to another, and thus experience changing material arrangements, new forms of know-how will be developed. As material arrangements, houses are embedded with certain know-how, which the individual orientates towards. Old houses thus have a certain script in relation to e.g. practices of heating, as old houses often are less well insulated. Moving to a new house thus implies that the individual must orientate towards new ways of performing practices. Thirdly, *shared conventions and understandings* play an important role. Within households, the household members typically share a certain convention about what is normal and desirable (e.g. with regard to heating).

All this show that know-how is something rather complex that is essential to our daily performance of practices. In practical terms, this means that exposure to e.g. response demand solutions is important for the individual to develop the necessary know-how to engage with these solutions. This could be done as "hands-on" demonstrations that make visible to the prospective users how to use the new technical solutions (e.g. the mobile phone app).

4.3 DIFFERENT FORMS OF KNOW-HOW (COMPETENCES)

Burchell et al. [26] examine the role of knowledge in relation to policy interventions aimed at reducing domestic energy consumption. Taking a starting point in a critique of mainstream policy interventions relying on education and communication as means to transfer knowledge on how to reduce domestic household energy consumption, Burchell et al. emphasize the importance of so-called **know-how approaches**. These highlight that knowledge is often embodied through practical doings, experience and guidance. Empirically, Burchell et al. examine a UK smart community where initiatives relied on both literacy and know-how approaches. Literacy approaches refer to initiatives that provide the users with factual and general knowledge on energy and energy consumption. Such initiatives also provide information to the consumer about their own energy consumption as well as general information about "energy-friendly" behaviour. Burchell et al. argue that while such initiatives have gained most attention in policies towards reducing energy consumption, there is a need to focus more on know-how approaches, as these provide consumers with experience-based know-how, and thereby are more likely to lead to the wanted changes and reductions in domestic energy consumption. This critique of literacy approaches is in line with the previously mentioned critique of the ABC model provided by Elizabeth Shove [9] and others. Burchell et al. [26] found that while know-how approaches produced most changes in energy consumption, such approaches were also the most resource intensive and difficult to scale up. In opposition to this, literacy approaches produced less change, but were less resource intensive and easier to implement on a large scale.

As mentioned, in their empirical study, Burchell et al. [26] examined how households in a local community in the UK responded to both literacy and know-how approaches. The interventions consisted of: Energy consumption monitoring, community-based consumption feedback, weekly email communication, a web forum, community workshops, home visits and working with a primary school and library and collaborating with local groups and experts. Of the specific interventions, home energy audits proved to be the most effective, which again highlights the importance of know-how approaches that engage the users in practical knowledge. During the home audits, the householders were exposed to thermal images of heat loss and provided with a list of go-to actions, which could reduce their energy consumption, and which proved to be a valuable tool. On basis of the study, Burchell et al. distinguish between three different (although interrelated) forms of know-how: First is know-how in form of suggestions or *alternative ways of doing things* (e.g. energy-saving ways of cooking). This also include experiments that householders can try out, and thereby investigate their own consumption. Secondly, know-how can be *practical skills* that are required to perform a certain (energy-saving) practice. Such know-how makes it easier to perform practices correctly. Third, and last, know-how can be thought of as *scripted knowledge* embedded in materials or technologies. These three understandings of know-how can be useful when developing policy that aims at reducing or shifting energy consumption.

Turning to the literacy approaches, which were also included in the smart community project, Burchell et al. [26] found that providing householders with weekly emails was valuable. They therefore highlight that providing communication to householders can have a positive effect. However, the content of the communication matters – and descriptive information about the households' energy consumption should ideally be combined with suggestions or recommendations that are specific, concrete and tailored to the local context. Thus, Burchell et al. argue that the most successful approaches towards developing competences valuable to reduce energy consumption are those that combine literacy and know-how approaches. In practical terms, such initiatives can consist of home visits, demonstrations and thermal imaging combined with regular emails and communication campaigns.

4.4 Learning and sharing knowledge on how to reduce energy consumption

Like Burchell et al. [26], Simcock et al. [27] argue that providing information to users about energy consumption can have an effect, but that it must be adapted to the specific context. Information therefore works best, if it comes as personalized advices with which the users can engage. Furthermore, Simcock et al. argue that the timing of *what information* is provided *when* is essential. For instance, if information is provided in relation to a home renovation, knowledge provided on energy consumption is more likely to become adopted by the residents and develop into new competences.

In their paper, Simcock et al. [27] seek to understand how learning and information sharing is a factor in establishing knowledge on energy consumption in the domestic sphere. Simcock and colleagues find that factors influencing users' perception of information can be split into three: First is factors that are related to the **content and form of the information**, which is provided. Second is **perceptions of the source** that provides the information, and third is the **process through which information is communicated**. Using this framework, Simcock et al. found that when providing feedback on energy consumption, this must be contextualized in order to be useful for the users. Such a contextualization can be through providing feedback on the overall energy consumption of the households as well as individual appliances.

Furthermore, users regard feedback on *how to take action*, given their specific situation, as useful information. Following this, the users in the Simcock et al. study found that it was more useful to them if energy consumption feedback was delivered as costs rather than as energy units consumed (e.g. kWh). This finding suggests that users make sense of energy consumption through concepts that they already know of and can relate to; thus, most people have experiences with the costs of energy consumption, while they are unfamiliar with energy units. Furthermore, the participants expressed interest in feedback that made them able to compare their own consumption to others, as this made them able to understand their own consumption relatively. Regarding feedback that also provided advices on how to reduce or shift consumption, the participants valued that such were personalized and, e.g., took into consideration the physical character of the home, and also the actions that the participants already made (e.g. not recommending actions that they already performed, such as turning of light in rooms not used). In the same regard, information which took into account what the participants already knew were highly valued. Regarding the format of feedback, participants highlighted that feedback should be easy to understand. The participants valued language which was not overly complex and did not use too many technical terms.

The trustworthiness of the source of the information provided was also important. Close relatives, such as friends and family, were ranked as the most trustworthy by the participants. Organizations such as charities and local councils were also seen as trustworthy. Contrary to this, profit-making companies were perceived as untrustworthy. Another factor that influenced the perception of the source of feedback was expertise, which was ranked high by the participants. Expertise is different from the notion of trust, as expertise relates to the competence of the sources, and not their (perceived) honesty. The participants valued that feedback on energy consumption should be accurate, and in relation to this, experts were seen as being able to provide detailed and specialized information. However, while some participants valued formal professionals and experts, others valued informal experts such as personal experiences from other peers (who they regarded to be competent regarding the subject). Following this, websites on which participants could share their experiences were valued high. Reasons for valuing close relatives were that these could provide practical tips and experiences which were highly contextualized and tailored to the situation and needs of the person receiving the advices.

Relating to the third factor in their framework, Simcock et al. [27] examined the process through which feedback was provided. Their study showed that the participants wanted to have an active role in the feedback provided, and they did not see themselves as passive; they wanted to engage with and negotiate the feedback that was provided. The process of feedback is important for understanding how knowledge is transferred from one context to another (cf. the previous section). Processes that rely on top-down approaches were perceived as patronizing and disempowering by the participants. In such approaches, the users had feelings of frustration. The process of providing feedback should therefore actively involve the users; interactive feedback processes were regarded the most useful, as this provided the users with the opportunity to control and select the flow of feedback and allowing them to adapt this to their personal and specific context.

4.5 Different types of users with different competences and interests

Similar findings are presented by Murtagh et al. [28] on basis of how 21 households used and engaged with monitors providing feedback on electricity consumption. Their main finding was that the use of monitors varied greatly between households, which points towards the importance of looking at the wider social and physical context when providing feedback. Focusing on monitors that were installed inside the home, the so-called In-Home Displays (IHDs), the authors also found that the use of these was limited six months after installation. Furthermore, they found that previous information and knowledge about energy consumption influenced the use of the IHD. The use and engagement with IHDs were interpreted within the existing knowledge that the householders had. Based on their findings, Murtagh et al. developed three archetypes of users and their reasons for adopting and engaging with IHD. The first type is the so-called **monitor enthusiast**, who loves the monitor and sees money savings as the main driver for engaging with it. These users actually changed their practices over time and gained awareness and knowledge on their own energy consumption. Also, this type of users typically (already) invested a lot of time and effort into energy conservation more generally. Typical for these users was that they had the resources necessary to adopt new and energy saving practices, namely time and personal flexibility. However, there was found no specific pattern with regard to household income for this group. The second type of users were the **aspiring energy savers**. They all expressed interest in energy savings, but varied greatly regarding which actions they undertook. This was the largest group of users (represented about two-thirds of the participants in the study). For this group, reducing energy consumption was motivated by financial gains, but also by a desire to save energy, which was seen as something morally and socially right to do. Acting on reducing consumption though seemed more difficult for this group, and they expressed concerns that engaging in such actions would compromise the care and well-being of their family. The last type of users are referred to as the **energy non-active**. This group was aware of the environmental impact of energy consumption, but was not motivated by this. In contrast to the other types, this group had a much larger energy consumption and was relatively homogenic in that they all were low-income households. They argued that reducing energy consumption was only motivated for financial reasons, but at the same time they argued that they would not reduce their energy consumption, as they did not find this necessary. As these three distinctive groups show, perceptions and actions towards reducing energy consumption vary greatly among households.

In relation households' interaction with energy feedback and smart energy devices, **gender** plays an important role. This is shown by various studies, such as a recent study by Gram-Hanssen et al. [29], which argues that energy consuming practices within smart homes are gendered. While men are more interested and motivated by technical appliances, women tend to be more environmentally concerned and engage in action towards this. As argued in another section of this deliverable, visions of the smart home tend to rely on notions of the so-called resource man [30]. Gram-Hanssen et al. [29] therefore argue that in order to achieve a successful adoption of feedback technologies, women need to be included.

Gender is not the only important division, and in an examination of perceptions of the smart home market across Europe, Balta-Ozkan et al. [31] find that people express concern of differences in technical proficiency. The concern is that a heavy reliance on technology will exclude people who are not technical proficient, such as the elderly.

4.6 THE ROLE OF COMMUNITIES

Burchell et al. [32] find that engagement with feedback monitors tends to be limited and usually fades out over time (see also [33]). The same can be expected to happen for other communication platforms, such as websites and mobile apps. This emphasises that knowledge and know-how provided via feedback can lead to reductions in energy consumption, but the mere supply of information alone will not work in the long run. In their study, Burchell et al. [32] investigate what role community-oriented action and communication can play in energy campaigns. They also found that the extent of engagement with feedback varied greatly among the users within a community, but they also found that the users who did interact with the provided feedback made significantly larger changes in their consumption than the users who did not participate. The same applied to the level of knowledge, as those who had developed higher levels of knowledge on energy consumption also were those who took part. Burchell et al. conclude that engagement with the monitors supported and mediated energy-saving practices, in which participants experimented around their house, which contributed to knowledge as know-how and new ways of doing. In this process, weekly e-mails with recommendations on how to take action were important. The study though also showed that engagement with feedback is a time-consuming activity, which must be taken into consideration.

With regard to the impact of community-oriented action and communication, the study found that this approach can prolong the users' engagement with feedback. This is due to the users getting a feeling of being part of something that extends the boundaries of their individual home and family. Burchell et al. [32] therefore argue that **policies and initiatives should create narratives of community action**, rather than narratives based on the "smart home utopia" that typically addresses the consumer as a rational and utility maximising individual (i.e. the resource man). Based on their findings, Burchell et al. recommend that feedback on energy consumption should be given as feedback plus communication. If communication is channelled out through a trusted organization in the local community, this can increase engagement with feedback and make it more durable. The communication should furthermore focus on how to take actions, including context-tailored tips and advices on how to reduce or shift energy consumption. In relation to communication, it is furthermore important that this is provided on a regular and ongoing basis. In such, mobile phone apps can prove sufficient, as they can provide timely alerts and notifications tailored to the specific household.

An alternative approach could build upon community knowledge networks [34]. Such an approach recognizes that knowledge and competences are context-dependent and situated, and that one must understand the practices they are embedded within. According to Catney et al. [34], users already possess different forms of knowledge about everyday life and energy practices. If new knowledge then has to be provided to the users and made meaningful and useful to them, it has to build on the existing network. Some communities are better than others to tackle challenges of energy consumption due to their economic, organizational and social capital. Community Knowledge Network (CKN) approaches are specifically occupied with notions of knowledge, which play an important role in shaping practices. Catney et al. define a CKN as "The constellation of people, organizations, material objects, information, practices and relations through which knowledge is shared and articulated within communities and between their members" [34, p. 510].

4.7 Energy Monitoring as a Separate Practice

Zooming in on the phenomenon of energy monitoring itself, Foulds et al. [35] find that the way people use and interact with feedback data, like through monitors or mobile apps, can be regarded as a practice in itself. A practice, which focuses on measuring and identifying trends of energy consumption. An interesting aspect of this "monitoring practice" is that many of the skills and competences that are required to measure energy consumption are transferred to the material arrangements, which will do the actual calculations of measuring household energy consumption. In other words, many of the actions that people would otherwise have needed to do in order to measure and calculate their own energy consumption are allocated to the technologies and related algorithms (e.g. energy meters, servers and mobile apps). However, it still takes cognitive skills to understand the data presented through feedback solutions. This involves cross-checking data and making analysis of these – or, in more general terms, identify what is important and what it means to the household. Foulds et al. argue that both the process of measuring and the process of identifying imply that users learn about energy consumption. This highlights that the performance of energy monitoring, as a separate practice, results in the users gaining competences and know-how about energy consumption. Foulds et al. furthermore argue that competences and know-how related to energy monitoring can become transferable to other practices in everyday life that involve processes of measuring and controlling. For people to be able to perform the monitoring practice, different sets of know-how are needed to enable the user to interpret and analyse the monitored feedback data.

Since the practice of energy monitoring is distinct from other practices in everyday life, monitoring itself does not necessarily lead to users taking action and making changes in everyday life in order to save og time-shift consumption. This helps understand why a sole focus on energy monitoring is not sufficient. This said, Foulds et al. [35] conclude that energy monitoring enables users to better understand their own energy consumption, and thus improve opportunities for reducing energy consumption.

Similar results are found in a study by Buchanan et al. [36]. Examining how users engage with and respond to energy monitors, Buchanan et al. find that feedback can provide both a psychological and conscious visibility of energy consumption. Transforming energy consumption from something invisible to something visible can furthermore prompt users to learn more about their energy consumption, and thus develop new knowledge and competences related to this. Energy monitors make the invisible visible and allow users to become familiar with their own energy consumption, e.g. being able to detect appliances that consumes electricity, but they do not use or need. After receiving the energy monitor, participants start conducting their own investigations in their homes, trying to figure out which appliances use how much energy. The energy monitor was thus used as a tool to identify so-called "greedy" appliances, and was by many participants seen as an eye-opener. Buchanan et al. therefore describe the energy monitor as a learning tool, which through processes of experimentation helps increase and develop knowledge around domestic energy consumption.

4.8 Highlights

Based upon the above, the following "key messages" can be inferred regarding the role of competences as an element in changing energy-consuming practices via feedback and DR programmes.

- Competences (skills) play an important role in shaping practices, and thereby energy consumption, and in the use of feedback and DR programmes.
- Competences (know-how) are transferable between practices, and for this reason it is recommended to build DR solutions that call for competences like those implied in the performance of other practices (e.g. using a mobile phone app DR solution, as most people are acquainted with using such apps).
- Competences (e.g. for use of smart phone apps) differ between people, which needs to be considered.
- Individual competences can (and will) often differ between individuals within a household, which implies differences in, e.g., how easy the individual household members will find it to use DR and feedback solutions. For this reason, asymmetries will sometimes develop in which some members of the household will be more familiar with managing feedback and DR solutions than others, which can cause conflicts within the household about who is controlling what (and how).
- In order promote (develop) the competences needed for using feedback and DR solutions, it is recommended to use "hands-on" demonstrations that make it visible to prospective users how to use the new technical solutions.
- DR solutions should include easy understood, concrete, timely and tailored (personalized) recommendations on how household members can change practices in order to time-shift (or save) energy.
- Community-based approaches can prolong the users' engagement with feedback and DR.
- Feedback data helps people to better understand their own consumption patterns, but this does not necessarily lead to changes in practices (here, specific recommendations on how to change practices can be a help).

5. How to engage residents by making DR designs technically workable?

This chapter focuses on the technical setup and design of the DR solutions. Demand-side management strategies, including price schemes, energy feedback and direct load control, attempt to engage users through different designs and technical system setups. Examples of such include feedback and visualization using in-home displays (IHD), in which users can monitor and/or control the domestic energy consumption. New and more modern technical designs include IOT features and are often connected to other devices in the household, such as lighting, locks, entertainment etc. One of the discussions in literature of the technical design and setup includes how users interact with the actual products. Some users might prefer a simple setup, which is easy to control and understand, while more Do-It-Yourself-minded users prefer a design in which they can engage actively and make changes.

In other words, the materiality (technical set up) of DR solutions is central. In RESPOND, the technical setup consists, among other things, of a smartphone app, which allows users to view their own energy consumption and compare this with the consumption of others as well as monitor the historical development of their own consumption. The technical setup presents the total household consumption and the consumption broken down to a number of individual appliances. The utility is furthermore able to send customized advices to the users, and thereby engage in a more direct form of communication.

The technical setup in RESPOND is only one example of a technical configuration within the emerging smart energy and smart home market. These products range from smart metering solutions to complex smart home technology, which allows monitoring, control and managing of energy consumption in the domestic sphere.

In the literature, the role of materials, such as the smartphone and its corresponding feedback app, has been covered extensively. Elisabeth Shove and Gordon Walker [7] argue that when studying practices of energy consumption, it is important to understand the material arrangements, which influence and constitute practices. Material arrangements can be defined as something that enable and constrain certain practices [37]. This is a two-way process: while DR solutions will prefigure certain practices within the household, pre-existing practices will also prefigure how users engage with DR solutions. The technical design of DR solutions is therefore important for user engagement.

Before going into details on how the technical design of DR solutions plays a role for how these are used, we will first give a short introduction to how materiality plays a role more generally in shaping people's energy-consuming everyday practices (next section).

5.1 Materiality in everyday life

Focusing on everyday practices, Gram-Hanssen [38] points to how routines emerge, develop, break and change with the introduction of technology. However, this happens through an interplay with other aspects of the everyday life, so the adoption of new technology is not a linear process (see also [39]), and the social organisation of everyday life is just as important for changes in routines. This said, the role of technology is substantial, and throughout history, the introduction of new technologies in the domestic sphere leads to changes in routines and energy consumption. Shove and Southerton [40] present an example of this in their study of the introduction of the freezer in homes. Tracking the use and perception of the freezer throughout history, Shove and Southerton show that the introduction of the freezer in the domestic sphere changed existing routines and practices related to cooking and shopping. For instance, instead of shopping groceries daily, people (at that time mostly housewives) started to bulk shopping, i.e. shopping for several days as the groceries could now be stored in the freezer and refrigerator. Also, fruits and vegetables in season could now be frozen (and in this way saved for a long period), which gradually replaced previous practices of food preservation, e.g. making jam, pickles etc. However, the process of the integration of the freezer into the home was not linear, and the use of the freezer has also changed throughout history. Shove and Southerton's study also shows how material arrangements adapt to the local context and surroundings, e.g. differences between socio-economic groups of families. In the words of Shove and Southerton: "Despite its persistently white disguise, the chameleon-like freezer takes on the spots and stripes of its surroundings" [40]. Similar to the freezer, Gram-Hanssen [38] also finds that the introduction of another white goods, the washing machine, in profound ways changed washing routines in Denmark with new notions of convenience and cleanliness to follow. Such studies show two important dynamics related to the introduction of new technology in the domestic sphere: First, technology responds to its surroundings, and its use thereby changes with regard to its social context. Second, technical devices are – through their design – scripted in certain ways that prompt certain uses (and make others difficult).

In a study of heating practices and householders' interactions with thermostats, Gram-Hanssen [38] shows that while this technology is scripted (thermostats should be in the same position and closed when airing), heating practices and the use of technology are open to individual interpretation. Thus, the interviewed families performed heating practices in different ways, and while some had the thermostat in the same position all the time, others turned it up and down regularly. This shows that the use of technology is deeply dependent on meaning and competences. Changing or breaking routines are dependent on competences and know-how, and how individuals ascribe meaning to technology is also key in understanding the adoption of technology in the domestic sphere. In other words, when designing new technologies, it is important to investigate the existing practices and how new technical solutions best fit into these.

5.2 THE EFFICIENCY OF ENERGY FEEDBACK AND THE ROLE OF TECHNICAL DESIGN

In general, smart meters have become widely distributed in European countries, and so have the features of this technology. Here, the legal framework of EU works as an important driver for the roll-out of smart meters; particularly the *Directive on Internal Markets* from 2009, which is part of the *Third Energy Package*. This directive demands member states or regulatory authorities to work for an optimisation of the use of electricity to promote energy efficiency, e.g. through introducing intelligent metering systems. The directive demands that at least 80% of the national customers shall be equipped with intelligent metering systems by 2020, if a long-term cost-benefit analysis shows a positive result. [41]

Smart meters allow a two-way communication in which feedback is send to the households. Much of this new technology is built upon a rationale of making energy visible [42]. In a Belgian study, Wallenborn et al. [42] examine how households use smart meters installed in their own home. The authors find that smart meters installed in the domestic sphere can be useful in changing the residents' perception of electricity consumption. These findings are similar to the ones found in other studies [e.g. 17, 18]. Wallenborn et al. [42] also find that the use and engagement with smart meters are dependent on the individuals' existing interest for energy savings. This underlines the importance of meaning.

More interesting is whether smart meters provide energy savings. In an extensive literature review, Sarah Darby [43] examines empirical studies to find out what is known about the effects of feedback on individual energy consumption behaviour. With a focus on gas and electricity consumption, Darby investigates the effect of studies from North America, Scandinavia, the Netherlands and the UK. Concerning smart meters, which Darby defines broadly as *direct feedback*, it is found that energy savings range from 5-15%. Darby does not examine the role of the technology attributes in smart meters use, but develops a set of recommendations for the future of feedback. First, Darby highlights how social and educational background influence the effectiveness of feedback. Second, smart meters are a good option in relation to visualization of the consumption of individual appliances. Compared to periodic billing-feedback, the smart meter furthermore provides a good perception of actual consumption, but historical feedback needs to be added to provide persistent and long-term user engagement. Darby concludes:

”Persistence of savings will happen when feedback has supported ‘intrinsic’ behavior controls – that is, when individuals develop new habits – and when it has acted as a spur to investment in efficiency measures. People may need additional help in changing their habits – this is where well-thought-out energy advice can be of use. Where feedback is used in conjunction with incentives to save energy, behavior may change but the changes are likely to fade away when the incentive is taken away” [43]

The quote underlines how feedback can only lead to persistent energy savings if habits are changed or broken.

While some studies problematize the extent to which energy feedback provides energy savings – several of these have been referenced in the previous chapters – others are showing more significant results. In addition to the above-mentioned review study by Darby [43], another example is a Danish trial studied by Grønhøj and Thøgersen [44], which achieved savings of 8% through providing feedback on overall and appliance-specific energy consumption (historical and realtime). Opposite to other studies [e.g. 17, 18], Grønhøj and Thøgersen argue that feedback empowers individuals to take actual action and thereby lower their energy consumption. In the light of this variety in empirical results and conclusions, it is interesting to further explore what role the technical attributes of feedback technology plays.

In a study by Sami Karjalainen [45], the most successful ways of presenting energy feedback (on a smart meter) were investigated through qualitative interviews. Based on how individuals perceived different types of feedback, the analysis concluded with a set of recommendations for feedback technology. Particularly important, they found that **consumer involvement** in the design process was essential for the development of efficient technical solutions due to the diversity in prospective users’ preferences and perceptions of technology. For instance, this could be done by examining how users understand energy consumption and technology. More specifically, they found that consumers valued feedback which provided historical presentation of costs, appliance-specific consumption and comparison with their own prior consumption. Bringing these recommendations into the context of RESPOND, the developed DR solution must therefore account for the various meanings and competences that users ascribe to the technology. This includes considering the users and their practices.

Another study by Corinna Fischer [46], based on a comprehensive literature review, provides important insights on how to design feedback solutions that works efficient. Similar to the study by Karjalainen [45], Fischer highlights the role of **computerized feedback** as being more efficient than previous “analogue” forms of feedback (e.g. letters). In her review, the studies that presented the best effects all relied on computerized feedback, which allowed the user to view historical consumption and compare to the current consumption, but also included the opportunity for providing advices to the users based on their actual consumption. **Appliance-specific consumption data** also provided better results, and in most cases **frequent feedback** was most successful. While studies where feedback was given frequently showed better results, Fischer highlights that high frequency is not enough. The same is evident when uncovering the influence of the duration of the feedback programme; here, Fischer found no indication that long-term interventions provided better results than short term. In line with practice theory, Fischer though underlines that **long-term interventions** contribute to the formation of energy-saving habits, and therefore can prove to be more useful and robust.

Regarding the way data is presented, Fischer [46] found no empirical evidence of which graphical presentation that was most successful. In relation to the presentation of historical energy comparison, Fischer found that such an approach was useful – especially when consumption was **compared to the energy performance of neighbours or similar households**. This shows the effect of social influence once again – also when dealing with the technological attributes. In conclusion, Fischer draws out the following design recommendations in relation to the setup of the most successful technical feedback solutions:

- Feedback should be based on actual consumption
- Feedback must be given frequently (daily or more often)
- Feedback should engage households through interactive design and personalized opportunities
- Feedback should involve appliance-specific consumption data
- Feedback should be given over a long period
- Feedback should involve historical and neighbourhood comparison
- Feedback should be presented in an understandable and appealing way

5.3 Why the complexity?

Since energy consumption can be regarded as ordinary consumption related to routinized practices, uncovering the effects of feedback and how to properly design feedback solutions imply examining how technology is incorporated into already existing practices. In their 2011 study of 21 Belgian households with smart meters installed, Wallenborn et al. [42] find that while smart meters changed the participants' perception of energy consumption, changes in practices were more difficult to achieve. Wallenborn et al. conclude that major reasons why participants did not change practices were related to the importance of skills and technological know-how. A lack of skills on how to work the smart meters meant that participants did not engage with the smart meters, and therefore did not change their energy-consuming practices. A general conclusion, which can be drawn from this study, is that when smart meters enter the domestic sphere, they enter into a process of existing energy-consuming practices. The use of a smart meter therefore depends on a range of elements, including understandings. Based on their study, Wallenborn et al. offer some recommendations that designers should take into consideration when designing and implementing smart meter feedback solutions. In relation to skills and competences, their findings indicate that men generally are more interested in technology than women, and therefore a gender divide arises in operating and engaging with the technical solutions. In order to counter this, it is recommended that smart meter solutions are integrated into existing appliances which most people already use. A good example of such could be the mobile phone, which is a technology that many people already are familiar with. Another way of giving meaning and acquiring competences to engage with smart meters is to use graphical illustrations, which are easier to understand. This must be combined with expert advice on consumption and how to reduce or shift it. Though, one pitfall in doing so is the possibility of a counterproductive effect that people will consume an appliance even more if they find out that it does not use much energy. Somewhat surprising, and contrary to other studies, Wallenborn et al. do not recommend real time solutions, as these are too difficult for users to understand. As the study by Wallenborn et al. shows, the layout and design of smart meters are important, because it prefigures a certain use.

5.4 Automation and the Risk of Losing Control

Many demand response approaches (as well as smart home solutions in general) involve a certain degree of automation, which is often regarded as the ideal design approach as this should avoid households being bothered by having to make active changes in their daily routines. However, there can be downsides to (too much) automation, as a study by Davidoff et al. [47] highlights. The authors examined how smart home technology, and the increased simplicity and control that this technology offers, effected the everyday life of American dual-income families. The participating families experienced a feeling of loss of control, because of the "(…) complex and rapidly changing logistics, that result from integrating and prioritizing work, school, family and enrichment activities" [47]. As a response, the families addressed this loss of control with strategies to increase the flexibility of their everyday life. Automated solutions must consider and ensure the flexibility of daily routines and everyday life. As part of this, energy management technologies must be designed so they can incorporate themes such as deviations from daily routines, improvisation, breakdowns, conflicting goals and responsibilities between family members. Davidoff et al. acknowledge that incorporating these themes in a technical design is difficult, but argue for the importance of this as households might eventually give up using this kind of technologies if such considerations are not accounted for.

Christiansen and Andersen [48] get to similar findings and argue that individuals prefer to be in control of their own environment. This challenges home automation systems, as those incorporated in DR solutions. In their study, the participants cared about exercising control in their own home and expressed that activities such as switching the light on/off at home involved meanings of nursing and caring for others. In the light of such findings, Christiansen and Andersen suggest a shift in the discourse surrounding energy management technologies. Instead of focusing on simplicity and efficiency obtained through automation, the discourse should focus on identity and understandability. Doing so will give people a feeling of engaging and interacting with technology, in which they are in control.

Another implication of automation is the new form of labour that it creates. Knowing and explicating your own routines, avoid changes in your daily doings (which could conflict with automated schedules) and being interested in and developing competences for managing the DR technology thus become key to achieve energy savings [49]. Automation requires data from individuals, e.g. on their daily routine time schedules, which means that users will have to spend time on providing this. Furthermore, the focus on simplicity and "one-touch-solutions" is often related to an increase in the number of devices that are needed for the automation (e.g. gateways, smart plugs etc.). An increase in automation might therefore result in a higher energy demand, and more energy management appliances are possibly needed to manage this complex system. As Strengers and Nicholls [49] put it: "It is somewhat ironic then that the smart home may necessitate 'doing more with more'". The narrative of convenience and simplicity might therefore legitimize even more energy demanding appliance, and thus increase energy consumption.

5.5 ENGAGING WITH ENERGY MANAGEMENT TECHNOLOGY

In the following, users' perception and engagement with energy management technologies will be in focus, and empirical studies of such will be highlighted.

Industry visions of users' engagement with technological solutions, such as smart meter feedback and smart homes, often imply a vision of the end-user as a technological competent person – i.e. the type of person that has been termed a resource man [49]. Technological solutions, such as the ones implemented in the RESPOND project, imply activities of monitoring and planning. In the monitoring process, end-users are assumed to have the necessary skills to interpret and also make use of the data, which is presented on the monitor or smart phone. However, the existence of the resource man is contested. Thus, Verkade and Höffken [50] find that users are able to interpret data from feedback, but have more difficulty in transforming this into actual changes in practices. Furthermore, it was shown that the effect of interpreting data was quite time-limited, as users were more attentive to the feedback in the beginning, but did not continue to be so.

Successful planning of energy consumption opens the possibility for time-shifting demand (e.g. peak-shaving). Such aim is also essential in the RESPOND project, and the prospect of energy planning is therefore essential to uncover. Verkade and Höffken [50] examined the potential for peak-shaving through feedback and automation. Their findings show that some household practices were easier to shift than others. Especially practices related to the use of washing machine, tumble dryer and dishwasher were time-shifted. Common for these appliances is that they include automation of parts of the processes, and users are therefore able to postpone the practice of washing clothes or doing the dishes by use of e.g. timers on the machines. A similar finding was reached in a Danish Time-of-Use pricing study [12]. Other practices where though more difficult to change. Verkade and Höffken [50] point toward three themes, which made some practices more difficult to change than others. First, *natural rhythms*, e.g. of daylight, are essential with regard to whether some practices can be time shifted. Second, *organizational time rhythms* of the household complicate the potential for shifting energy consumption. This refers to the temporal ordering of activities in the households, such as specific and often fixed times for cooking and leisure activities. Third, the *household composition* had an impact on the possibilities for changes; e.g., seniors who were more at home during the day were better able to shift consumption than households with household members working outside home.

A third objective of Verkade and Höffken's [50] study was to uncover the possibilities for users to share experiences on reducing energy consumption. The participants were therefore encouraged to share knowledge on how to reduce and shift energy consumption with their neighbours. In support of this, an online platform was created. This tool was imagined as an energy community and a learning tool. The platform was though no success, as users were lacking the skills to properly use the platform. In sum, the findings of Verkade and Höffken show that the resource man does not in general exist in "real life" households. This has to be taken into account then designing DR solutions.

Another study on the user engagement with technology in energy management projects has been conducted by Goulden et al. [51] in a UK context. The authors apply a practice theory approach and uncover how domestic energy management technologies such as feedback and IHDs are used. The participants perceived such technology as something, which should be "backgrounded" in the domestic sphere. As one participant explained his use of the IHD: "*A quick glance, if you've got the time*" [51]. The participants preferred a design, which made the presentation of consumption simple to read and understand – e.g. through graphical presentations and colour schemes. Though, like in other studies, the engagement with the energy management technologies decreased over time. Also, the participants preferred that technologies incorporated recommendations and advices.

5.6 DIFFERENT SCOPES ON ENERGY MANAGEMENT TECHNOLOGY

The literature on smart home technology is extensive and several studies have uncovered the effects of energy feedback and associated technologies. On basis of a literature review covering 150 scientific articles concerning smart home technology, Wilson et al. [52] conclude that studies of the smart home can be categorized into three different groups. The first group represents the functional view, in which the smart home is seen as the means to achieve better life. This part of the literature has focused on how smart home technologies can contribute to make the everyday life in the domestic sphere safer and easier (convenient). The second group of literature represents an instrumental view. This part of the literature focuses on the possibilities for reducing and shifting energy consumption. With a strong focus on technological features, this part of the literature typically adopts an understanding of the user as a rational micro resource manager, which has also been highlighted in previous sections. The third group of literature focuses on the smart home as part of a larger socio-technical system. This part of the literature investigates how smart home technology is used “in practice”, and how people ascribe meaning to technologies. The literature review of Wilson et al. shows that most studies so far have focused on smart home technologies in a functional and instrumental view. In recent years, more studies have though been uncovering the use and engagement with technologies in an everyday life context.

Wilson et al. [52] also map the challenges with the smart home technology identified in the literature. One set of challenges relates to the hardware and software issues that smart home technology entails. Important lessons here are that **smart home technology must be reliable**, which implies that it must not fail or do unpredictable things. Another part of the literature focuses on design issues related to the technology. Most important are issues of user-friendliness, security and privacy. Concerning the user-friendliness of the technology, the overall findings point towards that users prefer technology which is simple, looks like familiar appliances in the domestic sphere, is concealed from view and is providing recommendations and advices on how to engage with one’s own energy consumption. These studies highlight that smart home technologies involve a **risk of overpowering the users** with too complex information and solutions, which implies the risk of users refusing the technology. However, preferences for the design of technology are context dependent, and involvement of the users in the design process is therefore always key. A third challenge expressed in the literature concerns the process of domestication (i.e. how households adopt and integrate new technologies into the household). The focus of this part of the literature is to examine how technology is used and understood in everyday settings. Many of the themes studied here have already been mentioned earlier in this deliverable. One important observation in the literature is that technology must be designed for a non-predictable everyday life.

5.7 How to design for everyday life

Hargreaves et al. [53] uncover how individuals use and adapt to smart home technologies. They furthermore develop a set of recommendations on how to engage with energy management technologies. Overall, they argue that technological solutions must be designed so that they are perceived as meaningful and functional by the users. This entails that designers and developers first and foremost must acknowledge that the everyday life is complex, and the use and engagement with technology is just so. Technology that is integrated into everyday life must reflect routines, breakdowns, compromises and conflicts, which are essential parts of everyday life. One design implication of this is that technology should not remove control from the users (see also section 5.4). Individuals prefer to be in control, and energy management technology must therefore co-evolve with the users. Simple technical solutions that allow the users to engage with technology in ways that give meaning to them are preferred, and can be a way of avoiding loss of control.

Building on the approach of domestication theory, Hargreaves et al. [53] highlight three types of work that are essential for users' and households' adoption of technology in everyday life: 1) Cognitive work, which is about users learning about the technology and its features. 2) Practical work, which is learning about how to use the technology, and 3) Symbolic work, which is about ascribing meaning to new technologies and how to incorporate these into the users' own identity. On basis of a study of 20 UK households, the authors identify core themes, possibilities and limitations for the adoption and domestication of energy management technologies in the domestic sphere. With respect to the cognitive and symbolic work, they find that individuals have established much of this even before engaging with the technology in question. In their study, the participants where asked about their motivations for getting a smart home technology, which means that they had already before the purchase of the technology had developed ideas about the meaning of the technology and what it should be able to do. As their main motivations, the participants in general ranked high a desire to save energy and money, along with interest in new technologies, protecting the environment and improved control over a complex home. At the same time, the participants also expressed concerns about the use of the technology. From the concerns expressed by the participants, Hargreaves et al. found that prior meanings and use of technology had an impact on how the participants regarded smart home technology. These included, among other things, concerns about automation making people lazy, the ability to control and maintain technology and trust in the technology.

Hargreaves et al. [53] also studied how the smart home technology were actually used. Several lessons and design implications can be learned from this. The software, which visualizes energy feedback and enables users to manage energy consumption, was solely installed on computers. In this process, the practical work of the domestication process sticks out, as the installation process created a technological competence gap. The technology and the accompanying software implied that only some users engaged with the technology, namely those who were already familiar with the operation of computers. Because of this gap, the software was afterwards also installed on smart phones, which resulted in more people using the smart home technology being trialled. During the initial use of the smart home technology, the participants found the cognitive and practical work difficult. This resulted in that they did not use the technology very much – and when doing so, they typically only used the functions with the simple settings (advanced settings were not used).

The study showed that in several households conflicts or disagreements could arise between competent users and less competent non-users. Furthermore, and in line with other studies, engagement with technology decreased over time. This was especially true with regard to the more advanced functionalities of the smart home technology. In the long run, the participants symbolically adapted their prior understanding and engagement with technology in general. This meant that their understanding of and engagement with the smart home technology were similar to that of more traditional systems, e.g. heating systems.

Overall, the participants expressed that the challenge to use and maintain the technology was considerable, meaning that it required much time from the participants. Furthermore, many participants questioned the need and use of such technology, and called for advices on how to use and operate it.

Based on their empirical study, Hargreaves et al. [53] developed three scenarios for the domestication of energy management technologies, which represent three different ways that these technologies are integrated into the everyday life of homes. First, a *successful domestication* involves that smart home technologies do away with the more advanced features, which make the technology too complex. Further, the design of the technology should be concerned with the non-predictable everyday life and address issues of meaning and competences. A second scenario was identified as a *precarious domestication*. This involved that while smart home technology was used, the extent of the use was small. These participants expressed that the technology was too complicated, and that learning how to use it took up too much time. A third scenario was the *rejection of the smart home technology*. Common for these people was that these participants were not regular users of neither computers or smart phones, and then the smart home technology was installed in their home, they felt that the technology took over control. The participants therefore resisted the technology.

In putting up these scenarios, Hargreaves et al. [53] recommend that such scenarios must be considered in the design process of energy management technologies. These scenarios act as typical types of domestication processes. If designers and policy advisers take this type of concerns into consideration, the most obvious pitfalls of the integration of energy management technologies can be avoided.

Based on their study, Hargreaves et al. [53] present a set of recommendations for the design of energy management technologies that can be transferred to the design of DR solutions in the RESPOND project. Overall, designers must consider to actively involve users in the design and development of these technologies. Furthermore, designers must create attention around the cognitive work related to the adoption of the technology in households. It must be clear to the users how the technology should or could be used, and it should also involve recommendations and advices on what measures to take as part of the DR actions. The user-friendliness of energy management technologies must also be sought. This should include a focus on interoperability so that technological appliances easily can work together. Similarly, it is recommended that multiple entry points for the control of the technology – including automated actions – are created. Doing so, individuals with different levels of technological know-how and experience can ascribe meaning to and use the technology.

5.8 Highlights

Based upon the above, the following ”key messages” can be inferred regarding the role of materiality and the technical design as an element in changing energy-consuming practices in feedback and DR programmes.

- Integration of energy management technologies into the everyday life of households is not a linear and rational process.
- Technology is part of social practices in everyday life and technology can change routines
- Technology is scripted towards a certain use, but the understanding and use of technology is open to interpretation.
- Engagement with DR solutions depends on meanings and competences.
- Feedback can change perception of energy consumption.
- Educational and social background influences the effect of energy management technology.
- Direct and computerized feedback provides the best results.
- Appliance-specific feedback provides wider perception of energy consumption.
- Presentation of historical feedback can engage users in the long run.
- Users should be involved in the design and implementation process.
- Technology should include advice and recommendation on how to use and engage with feedback.
- Frequent feedback provides the best results.

- Energy comparison with neighbours provides better results.
- Energy management technologies should be integrated into/with existing technologies.
- Graphical presentations of energy consumption provide better results.
- Users prefer to maintain control with energy consumption – automation can create troubles of loss of control.
- Energy management technologies must be flexible and be designed for unpredictable/non-routine events in everyday life.
- Everyday practices involving automation (e.g. washing machines, tumble dryers and dishwashers) are typically easier to time-shift.

6. RESPOND USER ENGAGEMENT STRATEGY

In this section, the RESPOND user engagement strategy is presented. The aim of the strategy is to ensure a long-lasting appeal of the RESPOND platform and to engage residents at the pilot sites to take part in the DR programme and change their consumption patterns. The strategy is theoretically based upon the perspectives presented in the previous chapters. It includes both recommendations on how to design the RESPOND DR platform and mobile app to make these attractive as well as suggestions for complementary initiatives to the introduction of the platform and mobile app and in support of the users' engagement with these.

6.1 INVOLVEMENT OF USERS IN DESIGNING THE FINAL DR SOLUTION

Perhaps the most important recommendation is to involve the expected users in the design of the final DR solution, including how to design the interface of the mobile app most effectively. Experiences from previous feedback and DR trials show that badly designed solutions (e.g. interfaces) are among the primary things that can put off the users and discontinue their interaction with solutions (see also section 5.2 and 5.6). If this happens, it is virtually impossible to make people engaged, and this should – obviously – be avoided. Especially if automation is involved, which in some cases might oppose the daily life and activities of the residents, it is important to ensure that the automation works "together" with the daily routines of the residents and is easy to override (see also later). In relation to this, the involvement of the users in the design process is essential.

The involvement of the users will take place as part of the RESPOND Task 3.3 *Detailing the user context and improvements of user interaction*. The main activity here is carrying out two **focus groups** at each pilot site; one focus group focusing on demand response in relation to electricity consumption and another focusing on demand response related to heating (including indoor environment aspects). The participants in these focus groups are recruited among the local pilot samples. At the focus groups, participants will be showed a mock-up of the smart mobile client and personal assistant app developed in RESPOND task 3.4. On basis of this mock-up, the participants will discuss:

- How they interpret the functionalities or features of the mobile app and DR solution?
- How they believe these functionalities will fit with their everyday practices? As part of this, special attention will be brought to elements of automation and how this relate to their existing practices?
- The participants' own suggestions for possible improvements of both the mobile app and the DR solution more generally?

The results of the focus groups (six in total) feed into the further development of the mobile app and DR solution.

The design of the focus groups – and how to carry them out – will be detailed as part of RESPOND task 3.3. The focus groups are planned to happen in Autumn 2018.

Another input for the user-anchored design of the RESPOND solution comes from the first mapping of the users' socio-demographic profiles and some of their energy-consuming habits that was part of RESPOND Task 3.1 (see deliverable D3.1). This mapping resulted in several observations that are important to consider in designing the RESPOND DR solution (e.g. differences in socio-economic and educational background and differences in household composition, the latter in some cases including housemates responsible for doing energy-consuming household chores).

6.2 EASY FUNCTIONALITIES FOR OVERRIDING AUTOMATION

The RESPOND DR platform includes automated DR control of certain parts of the residential energy consumption. One example is from the Aarhus Pilot in Denmark: Here, it is planned to automatically control the heat supply of the homes via remotely controlled thermostats on the radiators in the homes. Through automated control, the heat supply will partly be shifted from the morning peak hours around 6-7 am to the hours before and after these peak hours. In practical terms, it is planned to increase the room temperature of the homes slightly 1-2 hours before the morning peak and then reduce heating during the hours of the supply demand peak (which is high due to people having their morning shower). In other words, the room temperatures will slowly decrease throughout the hours of the morning peak. When the morning peak is over, the remote control of the radiator thermostats will return to the standard temperature settings, and in this way the standard temperature will be retained.

To ensure that the residents will accept this type of automated DR control, and ensure continued use of it, it is important that the control scheme is not creating inconvenience (discomfort) to the residents and that it is possible to override the automatic control if needed. Regarding the first, this should be done by providing the residents with the option of selecting **minimum and maximum temperature pre-settings**; i.e. the maximum and minimum room temperatures they would accept during the morning. This ensures that the early morning increase in temperature is not too high and that the temperature during the peak-hours setback is not too low for being comfortable to the residents.

In addition, it is important that it is easy for the residents to **override the automated control**, if needed. Ideally, it should only take one or two steps (“clicks”) on the mobile phone app to cancel the control. More specifically, it is suggested to include a “Cancel the automated heat control for the next 24 hours” button in the mobile app. In this way, the users can already the evening before cancel the automated control (as well as this can be done during the DR control schedule, e.g. if they feel it to be too cold in the morning). This type of functionality is essential to avoid unintended, bad experiences on the residents’ side, which might otherwise jeopardize their continued participation in the automated DR programme. Having this option to override the control gives the users a feeling of power or “being in control” of the automated actions, which is essential for also building their trust and confidence in the DR programme more generally. As part of this, it is crucial that it is easy to find and access the “override button” in the mobile app; it should not be “hidden” long down a list of sub-menus. Ideally, it should be available on the first (initial) page of the app.

Situations where the users need to override the automation can have many reasons. This is due to the observation that it is hard (if not impossible) to create automated control programmes of energy consumption related to users’ everyday practices and indoor environment, like in controlling heating and room temperatures, that do not involve a risk of incidents of user-experienced inconvenience. Even if the users have submitted their minimum and maximum temperature preferences (the temperature pre-settings), situations might occur where this will not apply. For instance, if the users depart from their daily routines due to holidays, friends/relatives visiting them or sickness. An example could be if a family has a visit of relatives or friends who stay overnight and sleep in the living room. In this case, it might be associated with discomfort if the temperature of the living room is increased during the night hours; thus, it would be relevant for the users to be able to override the automated control in such situations.

6.3 SPECIFIC DESIGN RECOMMENDATIONS FOR FEEDBACK SOLUTIONS

As the previous chapters have demonstrated (in particular, see section 5.2), a number of more specific criteria and recommendations for the design of energy feedback can be set up. Some of these are described in more detail in other sections of this chapter. In addition to them, the following recommendations should be highlighted:

- **Appliance-specific consumption data**: To support households' active engagement in changing their consumption patterns, studies advocate providing appliance-specific consumption data. This makes it possible for the users to get information about the energy consumption of specific appliances in the home as well as it supports learning processes where the residents can follow the direct outcome of experimenting with changing their use of certain appliance.

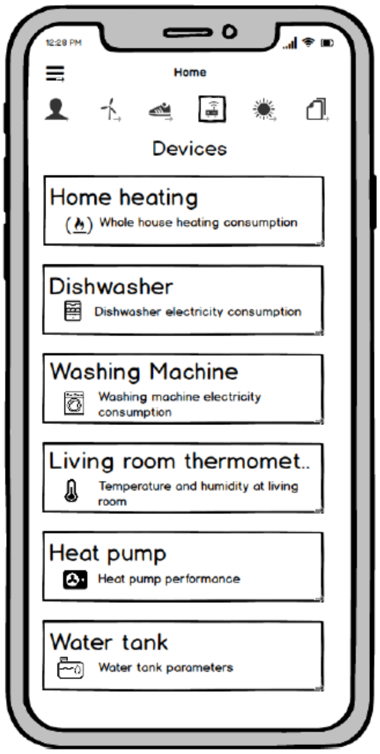

FIGURE 4: THE RESPOND MOBILE APP WILL PROVIDE ACCESS TO APPLIANCE-SPECIFIC CONSUMPTION DATA FOR A NUMBER OF APPLIANCES, E.G. THE DISHWASHER (MOCKUP)

- **Frequent / real-time feedback**: Studies also indicate the importance of real-time (or close to real-time) feedback, as this – like appliance-specific data – supports learning processes; lack of (close to) real-time feedback complicates the possibilities of monitoring the outcome of changing practices (e.g. of turning on/off certain appliances to see how this affects the power consumption).

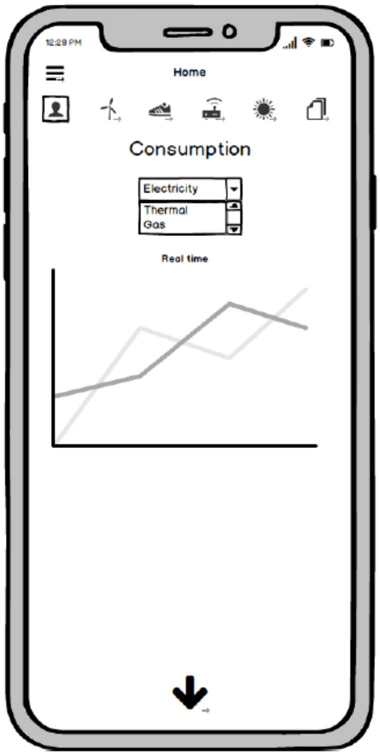

FIGURE 5: THE RESPOND MOBILE PROVIDES REAL-TIME CONSUMPTION DATA AT THE HOUSEHOLD LEVEL (MOCKUP)

- **Historical data and comparison to neighbour (similar) households**: Studies indicate that relative comparison of the household's current energy consumption with either historical consumption data and/or the consumption of neighbours/similar households is important. This helps the users to interpret their own consumption data (and how this change over time) as well as it can act as an important motivation for changing practices (c.f. normative social influence, see also section 6.5).

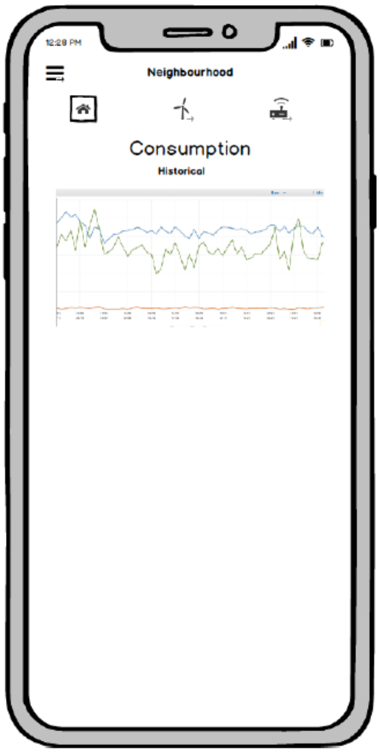

FIGURE 6: THE RESPOND MOBILE APP WILL PROVIDE HISTORICAL DATA (ABOVE) AND NEIGHBOURHOOD COMPARISON (SEE FIGURE 3) (MOCKUP)

See RESPOND deliverable D3.4 for a more detailed presentation of the RESPOND mobile app design.

6.4 TIMELY AND PERSONALLY TAILORED DR ACTION RECOMMENDATIONS

As shown in previous chapters (e.g. section 5.2), feedback studies indicate that supplying the users with recommendations on how to act to save or time-shift energy consumption can be important for ensuring real changes in practices and long-lasting involvement with the DR programme. However, it is important to design such recommendations in a way that the users find meaningful and helpful (as also pointed out in RESPOND deliverable D3.4, chapter 4). Otherwise, the recommendations can be experienced as annoying, which might eventually result in the users ignoring these or de-activating them (or, in the worst case, dismiss further participation in the entire DR programme).

The recommendations can be provided as "push notifications" on the smart phone. If so, it is important that the users can opt-out of push notifications, as some might be annoyed by these, which would jeopardize their continued engagement with the DR solution. However, if deactivated, it should still be possible for the users to access the messages through the mobile app.

Content-wise, the recommendations (notifications) should relate to specific actions that the users could perform to time-shift and/or reduce consumption. As the focus in this project is primarily on demand response and balancing local energy consumption and production, it is most relevant to provide recommendations related to time shifting. The content of the recommendations/notifications can further be defined as:

- **Notifications on *when*** it is relevant to increase/reduce own energy consumption (e.g. when the PV power generation is high due to midday sunshine). Can either be delivered as "now-and-here" notifications (i.e. concurrent with the RE power generation peak) or as warnings about upcoming peak generation events (e.g. a message sent the evening before a midday PV peak). Both types of messages can be relevant depending on how households typically organise and plan their daily activities. It can be part of the RESPOND project to test both approaches to get insights on what works best for the households.
- **Recommendations on *how*** the users can time shift their energy consumption. These should be specific and "hands-on" recommendations to support the users' development of competences in relation to DR and time-shifting consumption.

These two types of content can either be integrated (i.e. provided in the same notification) or, perhaps better, separated so that the notifications of *when* refer to further recommendations on *how* to time shift consumption to be found via the RESPOND mobile app. In this way, it is optional whether the user wants to access this information. In practical terms, this can be done by including a "link" in the "When-notification" to a page in the mobile app with further recommended actions.

Additional two recommendations for the design of notifications can be put up based on the reviewed literature in chapter 3-5 (these are also in line with the observations made in D3.4):

- Notifications (recommendations) should be **timely and not too frequent**: This means that notifications should be provided *only* if relevant and not "too late or too early"; a warning maximum 24 hours ahead of an event (e.g. low electricity prices) is recommended, as most households do not plan daily household chores much further into the future than on a day-to-day basis. At the same time, it is important to not overburden the users with too frequent notifications. A reasonable design criterion in this respect could be maximum one notification per day.

- Notifications (recommendations) should be **tailored to the individual user and household**: Redundant or irrelevant information are among those things that can annoy people and should be avoided. For the same reason, it should be possible to tailor the recommendations. Here, two types of tailoring appear important to consider in the final design: 1) For households with nobody staying at home during the morning/afternoon (e.g. due to paid work), it does not make sense on working days to send short-notice alerts (i.e. "now-and-here" notifications) with recommendations to change consumption right away. It might therefore be considered to include a question about whether household members typically stay at home during daylight hours on working days as part of the initial setting up of the mobile app. This information can then be used to target short-notice alerts on working days to only the relevant target group. 2) Also, notifications and recommendations should be tailored to the appliances available in the specific home. For instance, if a household does not possess a tumble dryer, it makes no sense to recommend it to use this in hours of peak PV generation. Again, it would be relevant to include questions about the stock of key white goods and appliances as part of the initial setting up procedure of the smartphone app.

To get the perspectives of also the prospective users on how to best design notifications/recommendations, this theme will be part of the previously mentioned focus group discussions in RESPOND Task 3.3.

6.5 SIMPLE DATA PRESENTATION INCLUDING NORMATIVE SOCIAL INFLUENCE

The feedback data presented to the households via the mobile app should be easy to read and understand. This includes **avoiding too many technical terms and language**. For instance, as mentioned in section 4.4, studies indicate that people in general are not familiar with technical energy terms such as kWh. Therefore, it is recommended to also present energy consumption in costs (e.g. the amount of euro the energy consumed corresponds to) and/or make graphical presentations that visualize the size of consumption (e.g. by comparing to others' consumption levels or to the historic consumption of the household). More generally, studies recommend applying **graphical presentations** such as bar or pie charts.

To evoke the positive effects of normative social influence described in section 3.2, the mobile app will include a section providing the individual household with a **neighbourhood comparison**. In this section, the energy consumption of the individual household is compared to the average consumption in the neighbourhood and the average of the 20% top-performers, respectively. The inclusion of the latter top-performers comparison is inspired by the American OPOWER trial [15], which included a similar category to avoid the so-called "boomerang effect"; i.e. that households with an energy efficiency already above average begin to increase their energy consumption as a response to the neighbour comparison showing that they have a relatively small consumption. By adding the category of "top-performing" households, most of the households above average will still find an incentive to improve their energy performance position relative to the "top-performers".

Previous neighbourhood comparisons have primarily focused on energy efficiency and total energy consumption. For instance, the above-mentioned OPOWER trial compared monthly total household energy consumption per household. This might also be relevant to consider in RESPOND in order to cover also the traditional theme of energy savings and increased energy efficiency. However, RESPOND focuses particularly on demand response strategies related to balancing local energy production and consumption, which makes it more challenging to create relevant and effective comparison methods. This has not traditionally been the focus of feedback trials, and this therefore calls for new and innovative ideas. One way to approach this could be to create an indicator of **the share of the individual household consumption supplied by locally produced renewable energy** (e.g. PV power). This could be calculated on daily, weekly and monthly basis, and the share of the individual household could then be compared to the average of the neighbourhood as well as the average of the 20% top-performers (i.e. those with the highest share of local RE). The households can when increase their individual shares of local RE by time-shifting some of their energy consumption to hours with high local RE production. In this way, the neighbourhood comparison would draw on normative social influence to create an incentive (or even competition among neighbours) for getting higher local RE-share percentages. The following figure illustrates the principles of this approach.

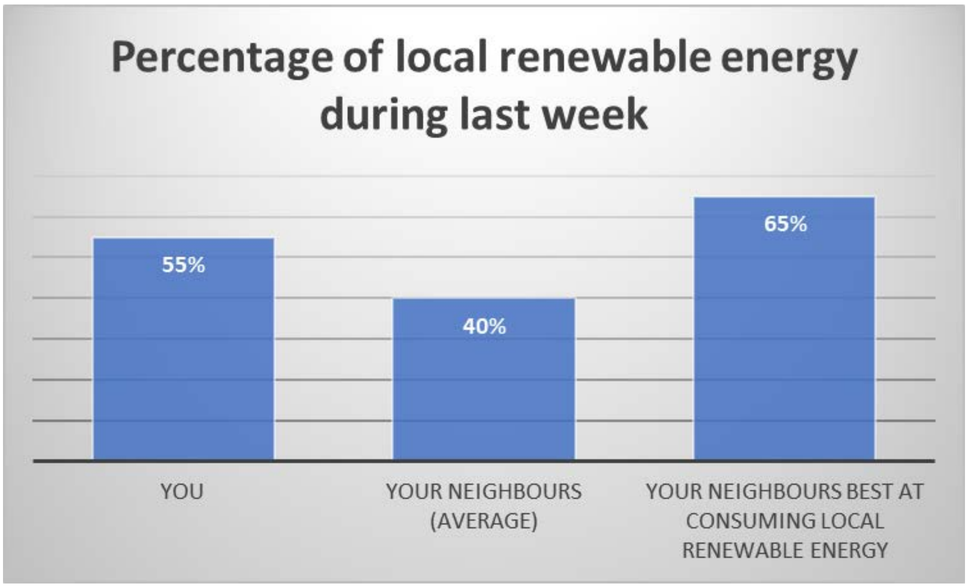

FIGURE 7: EXAMPLE OF HOW THE NEIGHBOUR COMPARISON OF THE INDIVIDUAL HOUSEHOLD COULD LOOK LIKE.

This neighbour comparison could further be supplemented with an **injunctive norm**, which conveys the social norm of having a high local RE percentage. This could be through verbal judgements such as “You are doing it great” (if the household percentage is among the percentage range of the 20% best performing households), “You are doing it good” (if the household percentage is above average, but the household does not belong to the 20% best performing) and “You are below the average” (if the household percentage is below neighbourhood average).

In addition to the neighbour comparison, it would also be relevant for the household to be able to compare with historic data (e.g. previous week).

The approach outlined above would apply to all three pilot sites, as a key objective of the RESPOND trial is to improve the utilization of locally produced RE power. A key challenge to this design is, however, to what extent the indicator of local RE share is a too abstract concept to the participating households. This needs to be explored further in the focus groups with the households carried out as part of RESPOND Task 3.3.

6.6 LOCAL COMPETITIONS AND USE OF SOCIAL MEDIA

A special feature of the RESPOND DR concept is the neighbourhood approach. This opens for the possibility of utilizing this approach productively in the user engagement strategy. One way could be to

create a competition among the local participants. Following the previous suggestion of creating an indicator for the locally-produced RE share (see section 6.5), this could be a competition about “who’s able to get the highest share of locally-produced RE in their own energy consumption?”. For privacy reasons, the individual households’ local RE shares cannot be published publicly, but each household could be informed about their individual position (e.g., “You are having the XXth highest RE share among your local neighbours in RESPOND – the top-performing household has a RE share of XX%”). This information should be provided via the mobile app. In this way, the individual household can follow its own (rank) position within the local community on a continuous basis, and it can also get information about the RE share of the best performing household (perhaps also the average RE share should be informed for comparison). This can act as a motivational factor to some households and create a competition of being the “best performing” household.

As the RE-share indicator will change daily (and even hourly), this should ideally be calculated as an accumulated indicator from the beginning of the trial and up to the current day. Also, it must be calculated over the same period for all households. This means that this feature of the mobile app cannot be activated before all households are ready and taking part in the trial (i.e. at the beginning of the validation period).

Ideally, a further improvement would be to add a feature in the RESPOND mobile app that makes it possible to **share the households’ individual RE-share performance result on social media** – e.g. Facebook. This could motivate more people to engage in the DR programme, as this adds visibility to their DR actions and the competition among the local households. The element of social recognition can be important to some individuals. Also, this could fuel the competition among neighbours further (given that these are already “friends” or contacts on social media) and/or trigger exchanges among the participants about practical experiences with the DR programme. The latter can support collective learning cycles and the spreading of layperson ideas and hands-on experiences on how to time shift consumption.

It should be considered to **award a prize** for the household achieving the highest level of RE in their energy consumption before a defined deadline. This could include some kind of reward, but could also be solely based on the “honour” of being the top-performing household. The prize could be awarded as part of a concluding (evaluation) event for the households taking part in the RESPOND project.

Finally, a technical note on the setup of the competition: In case the local RE source is individually owned (e.g. PV roof-top panels on individual houses like on the Aran Islands), this complicates the competition among households on RE-share. Since the installed power capacity (kWp) can differ much between homes, the participating households are not on "equal footing" from the beginning, and households with little installed power will find it difficult to get a chance for winning the competition. This would obviously be discouraging to these households. In this case, it should be considered to make the households compete in relation to a *relative measure* of the local RE-share instead; for instance, this could be the relative increase in the share of local RE in the individual household's energy consumption. In this case, the accumulated local RE share obtained during the validation phase (competition period) is measured in relation to the local RE share for a certain period *before* the start of the competition (a reference RE share).

6.7 Hands-on demonstrations

As pointed out by previous studies (e.g. see section 4.3), an effective way of engaging people and disseminate knowledge and competences related to practices of time-shifting energy consumption is hands-on demonstrations. One way that has proven effective (see e.g. Burchell et al. 2015) is to arrange a **home party** ("open house") meeting at the beginning of the RESPOND validation phase. Here, the RESPOND participants from the neighbourhood can be invited to visit the home of one of the participating households for a demonstration of the RESPOND DR solution. This should be done as a "walk through" of the key features of the mobile app. The meeting should also include a discussion of how the individual households can change practices to time shift energy consumption; e.g. possibilities and challenges related to this.

In addition to disseminating essential know-how related to the RESPOND DR solutions and energy time shifting, the home party will also support the creation of a "community feeling" around the RESPOND solution. This can be important for the success of the competition approach described in the previous section.

7. Conclusion

The users' active engagement with the RESPOND mobile app (and the RESPOND DR programme in general) is essential for the success of RESPOND. For this reason, we have developed a set of recommendations on how to ensure user engagement as part of RESPOND Task 3.2 *User engagement approach*. This deliverable is the outcome of Task 3.2.

The user engagement strategy, and its specific recommendations, is founded on the acknowledgement of how energy consumption of households is closely related to the complexity of households' everyday life and everyday practices. Therefore, it is important to design DR solutions and mobile apps that consider this complexity and ensure that the developed solutions fit in with the existing practices and do not cause inconvenience to the households by opposing their daily practices. Otherwise, this would create annoyance among the users and potentially jeopardize their continued engagement with the solutions.

The analysis of this deliverable is mainly built upon the theoretical framework of social practice theory presented in Chapter 2. In Chapter 3-5, we explored the role of meanings, competences and materials as elements in energy-consuming practices and DR solutions, and how these elements should be designed to support user engagement. On basis of the literature review presented in Chapter 3-5, a number of recommendations has been developed in Chapter 6, which makes up the user engagement strategy. In short, the specific recommendations are:

- **Involvement of users in final design:** A well-functioning and easy-to-use mobile app is key to ensure user engagement. This goes for the user interface as well as for the functionalities "behind" the mobile app user interface (e.g. programmes for automated DR response). For this reason, experiences and input from the prospective users at the pilot sites will be involved in the final designing of the mobile app. This will be done on basis of focus groups carried out in RESPOND Task 3.3. At two focus groups at each pilot site, a selection of participants from the pilot households will discuss a mock-up of the mobile app (see also RESPOND deliverable D3.4), including its DR functionalities. Based on the discussions, suggestions for specific adjustments to the final mobile app design are developed.
- **Option for overriding DR automation:** The RESPOND platform includes elements of automated remote control of parts of the households' energy consumption (e.g. space heating in the Aarhus pilot). In addition to providing options of relevant user pre-settings (e.g. minimum and maximum temperatures for the automated heating control), it is important to include a functionality that makes it easy for the users to override the automated control. This provides the users with (a feeling of) control and is essential, as experiences of inconvenience or discomfort related to the automated control schedules otherwise could jeopardize the households' continued participation in the DR programme.
- **Appliance-specific consumption data and real-time feedback:** To support households' active engagement in changing their consumption patterns, appliance-specific consumption data should

be provided. Furthermore, studies indicate the importance of real-time (or close to real-time) feedback, as this supports cycles of experiential learning.

- **Timely and personally tailored DR action recommendations:** The mobile app should include a module that makes it possible to provide the users with timely and personally tailored DR recommendations. Studies show that practical and "hands-on" recommendations on how to change practices (e.g. time-shift consumption) are important to users and their continued engagement. This could be done through push-notifications on the mobile phone, indicating when to time shift consumption, and including suggestions on how to do this. However, it is important that the information is delivered timely, not too frequently and to some extent is tailored to the characteristics of the individual household (e.g. what appliances the household has installed).
- **Simple data presentation:** The presentation of energy feedback and DR information to the users via the mobile app should be simple and avoid too technical terms. Also, the presentation should ideally be graphical as this supports the users understanding of the information.
- **Neighbour comparison:** To support the continued engagement with the RESPOND DR programme and the mobile app, the neighbourhood approach of the RESPOND project will be exploited through a mobile app feature making it possible for the households to follow their own DR performance and compare this to their neighbours. This can be done by developing an indicator ("score") of the share of the individual household's energy consumption supplied by locally produced renewable energy. In other words: The percentage of the energy consumed within a certain period that has been supplied by local renewable energy (RE). This can be compared to historical RE-shares for the individual household. In addition, and likely more important, the mobile app will provide a comparison of the individual household's local RE-share with the average share of the neighbourhood and the average share of the 20% best performing. This will support user engagement by drawing on the dynamics of normative social influence and elements of competition.
- **Local competitions and use of social media:** Further utilizing the neighbourhood approach of RESPOND, a competition should be created among the RESPOND households on who's performing best. More specifically, it is suggested to make a competition about "who's able to achieve the highest share of locally-produced RE in their own energy consumption" (cf. the previous-mentioned DR-performance indicator). The further details need to be developed in close collaboration with pilot partners and taking into account the local context (e.g. with regard to what prize or award would make best sense to reward the winning household). Also, the RESPOND

mobile app should ideally include a feature that makes it possible for the individual household to share its “local RE-share performance indicator” via social media. This can fuel further competition among the local RESPOND households.

- **Hands-on demonstrations:** It is recommended to arrange hands-on demonstrations (e.g. a “home party”) at the beginning of the RESPOND validation phase at each pilot site. Here, the local RESPOND households can meet and get demonstrations of the mobile app and the related devices; how they work and how to perform DR actions etc. This support the dissemination of knowledge and competences related to practices of time-shifting energy consumption.

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