Smart domestic appliances in sustainable energy systems – consumer acceptance and restrictions

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Abstract

Demand-side load management, based on coordinated intelligent operation of large numbers of domestic appliances, is a cornerstone of sustainable energy systems with a higher share of intermittent generation, e.g. from wind or solar energy. Simulations undertaken in the "Smart-A" project (www.smart-a.org) (in the framework of the programme "Energy Intelligent Europe") show that many European countries can benefit significantly from smart appliances operation. The share of the technological potential that is realised, however depends on the user acceptance with regard to load-shifting, including e.g. delay the start of washing cycles, intermediate interruptions of the operation of appliances, or temporarily storing energy for freezers.

Quantitative and qualitative consumer research using questionnaires and focus groups was conducted in several European countries (Austria, Germany, Italy, Slovenia and UK). Detailed scenarios were introduced to identify to what extent and under which conditions consumers are ready to accept smart operations of appliances. Major changes to daily routines, significant additional costs or loss of comfort will not be accepted easily. The willingness of consumers to adopt intelligent appliances depends on the perception of a mature technology and on financial gains. Ecological benefits are viewed as a positive side effect, which makes them feel good and indicates their green conscience, but for most people they are not sufficient as the sole reason to buy smart appliances. Economic advantage, higher security and good usability will be the key factors to increase user acceptance when it comes to smart operation of appliances.

Introduction

The underlying concept of smart appliances in energy efficient demand side management is to consume electricity when it is available and not the other way round. This will save costs and resources and lead to fewer CO_2 emissions. A key benefit of smart appliances for RES integration is their ability to contribute to the compensation of imbalances which occur as a result of the variability of e.g. wind power generation. The project "Smart Domestic Appliances in Sustainable Energy Systems" (Smart-A) aims to develop strategies showing how smart domestic appliances can contribute to load management in future energy systems. The acceptance of consumers concerning the new options offered by smart appliances is a key success factor for the introduction of this new technology on the market. The aim of the consumer research within the Smart-A project was to reveal the extent to which consumers will agree to load-shifting, including e.g. delay the start of washing cycles or intermediate interruptions of the operation of appliances. Research questions focused on the readiness and flexibility of consumers to change their behaviour and the benefits they expect in order to accept the use of smart appliances.

The consumer research consisted of four sequential steps which were conducted in five European countries:

- Analysis of existing studies and interviews with experts in the area
- Survey with questionnaires
- Phone interviews with consumers
- Focus groups

This paper gives a summary of the results of the consumer research with its main findings. It gives an assessment of the acceptance level of consumers with regard to smart appliances and outlines how to increase the consumer acceptance.

Smart-A

AIMS OF THE SMART-A PROJECT

Demand-side load management is a cornerstone of sustainable energy systems, which feature a higher level of intermittent generation, depending on the availability of renewable energy or demand for heat from CHP processes. For instance, the UK government (DTI, 2005) concluded that a valuation of the approximate annual benefit from a Demand Side Management (DSM) programme in the UK (including Commercial Customers) could lead to savings of between 460 000 and 1.3 M tonnes of CO_2 over a ten year programme. Such systems require smart energy loads that can coordinate their operation with levels of energy supply (Boardman et al, 2005).

Domestic appliances can offer a range of options for load-shifting, including delaying the start of washing or dishwashing cycles, intermediate interruptions of operation of appliances, or the use of refrigerators and freezers for temporarily storing energy.

The main objective of the Smart-A project was to identify and evaluate the potential synergies that arise from coordinating the energy demand of domestic appliances both with local sustainable energy generation and with the requirements of regional load management in electricity networks. The potential benefits of using smart appliances are the reduction of losses in the energy system as a result of reduced peak load, thus increasing energy efficiency and reducing overall system cost.

SMART-A THEMATIC OVERVIEW

The Smart-A project focuses on the following thematic activities in addition to the research on consumer acceptance, which the main body of this paper describes in detail.

Synergy potential of smart appliances

We assessed the possibilities for domestic appliances to adapt their operation to the requirements set by the energy supply on the object and the regional level. The focus of the analysis was on technical possibilities for a more flexible operation, including the impact on the quality of service delivered by the appliance.

We also analysed the additional technical elements required to enable smart operation of domestic appliances, including communication interfaces with other appliances, local energy generation systems and electricity network operators. The additional cost and energy demand of these "smart" elements was assessed, for example taking into account additional energy that might be consumed by communication equipment or resulting from a less optimal mode of operation of the appliance. The assessment will be the basis for an overall comparison of cost and benefits of improved coordination between appliances and energy generation.

Local energy generation networks

There are many examples of significant energy savings initiated thanks to automation systems, e.g. in heating control or daylight control for lighting systems, for instance the Energy Saving Trust (Energy Saving Trust, 2008) indicates that installing heating controls to one household's heating system could lead to CO_2 savings of 530 kg/yr. The efficiency potential of an integrated approach with sustainable energy generation can be even greater (Hinnels, 2008). In order to envisage how smart domestic appliances can be designed to operate in relation with local energy generation systems, it is necessary to learn about the typical modes of operation of systems used for local energy generation. These systems can be renewable energy production systems, micro-cogeneration installations and/or hot water storage systems.

The possibility that a generation device will produce electricity and heat, while consumer loads will vary independently, increases the scope for "smart" energy consuming devices even further, since local energy generation systems are usually optimised for stand-alone use in a similar way to domestic appliances. A concept for communication and user-interaction was developed, opening the way for interactive optimisation. Both the communication in previous demand management projects and case studies and future trends and the opportunities of smart household appliances were considered (Shafiu et al., 2008). The conclusion for communication is that the crucial part of the communication path is the last few meters inside the household.

The work followed a four-step approach:

1. Identification of potential benefits from smart appliances for local energy generation systems
2. Evaluation of possible communication containers
3. Integration of user preferences and behaviour into the implementation strategy
4. Consumption and cost of intelligent systems.

Energy networks

The objectives of the energy networks theme were to understand how smart appliances may be used to provide reserve and frequency response specifically for intermittent renewable generation (in particular for wind power), how smart appliances may be used to provide reserve and frequency response for power systems supplied from conventional generation. The theme also aimed consider both the commercial and environmental benefits of this application of Demand Side Management, to propose techniques for effective Demand Side Management using smart appliances including load shifting and to estimate their effectiveness (based on the concrete example of the UK power system and with generalisation of the results for other Member States) under various future development scenarios. Additionally, we examined the communication and control requirements for load shifting of domestic appliances in response to the needs of the power system.

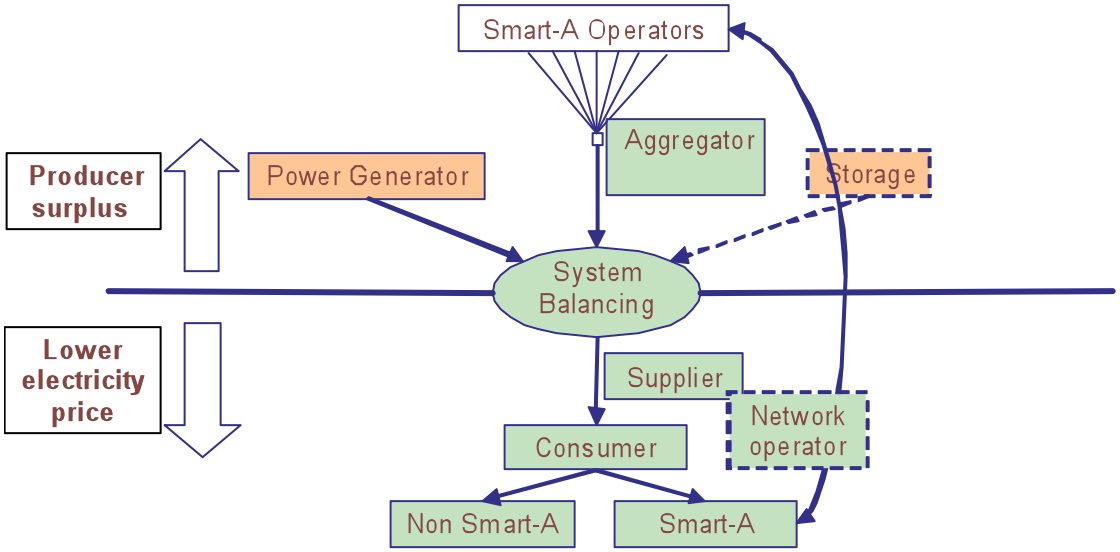

Figure 1. Allocation of value between Smart-A providers and electricity consumers.

Case studies

Whereas the previous themes had a generally analytical character, the case studies in this work package are intended to perform a "reality check" involving experts from industry and stakeholders at a regional level. The case studies were carried out in four partner countries, with an additional aim to reach same regions as the focus groups of the consumer acceptance studies.

Each case study featured a sequence of two full-day workshops, involving experts from appliance manufacturers, electric utilities, consumer organisations, renewable energy generators and other relevant stakeholders. In these workshops, the participants discussed the preliminary results from the other work packages. As a focal point for this discussion, the concrete framework conditions in a certain region, e.g. a service territory of a specific electric utility, was used. The main objective of the case studies was to discuss the proposed concept for smart appliances and their integration in the energy system with a number of stakeholders which have practical experience in a regional context. The relevant results from the main work packages were presented to the stakeholders and the work package leaders discussed with them how a practical implementation of the findings and recommendations could look.

Overall potential

Finally, a synthesis of the results from all previous steps is planned. It assesses the overall costs and benefits of the coordination of smart appliances with sustainable energy technologies at the domestic level as well as the level of electricity networks, and will develop a methodology for optimising the cost/benefit ratio.

Figure 1 shows diagrammatically the basis for the methodology developed to link together the separate coordination strategies from the two levels (the object level and the energy network level) into a single strategy, which aims to maximise the overall benefit of coordination between sustainable energy supply and demand. This is an important step, as it is possible that the optimisation strategy from the energy network level would require a different mode of operation from smart appliances than the strategy from the object level (for example, optimised usage of solar thermal heat on the object level could require operation of appliances at times where the electricity network has peak demand).

Based on this analysis, a high-level model will be developed which allows for a simulation and systematic evaluation of the potential environmental and economic benefits from improved coordination on both levels. This analysis will be based on quantitative and qualitative results from specific model analysis. In a scenario, the potential impacts and benefits of such coordination efforts will be analysed and assessed for the whole of Europe, taking into account all major factors which are determining cost and benefits.

Research methods

The acceptance of consumers is a key factor for the introduction of smart appliances. Therefore the Smart-A project features a detailed assessment of the user acceptance of smart appliance operation using a mix of quantitative and qualitative methods. As a first step, a survey with questionnaires was conducted in five European countries. The aim of the survey was to obtain information regarding the perception of smart appliances as well as to estimate whether people are willing to change their habitual behaviour or to accept higher initial costs of smart appliances. Subsequently phone interviews with respondents of the survey were carried out, which allowed a better understanding and assessment of the survey results. Finally, focus groups enabled a thorough discussion of consumer attitudes towards smart appliances. The aim of the focus groups was to question the results obtained and to gain additional information on existing consumer attitudes.

SAMPLE CHARACTERISTICS

For the survey the research team tried to ensure a representative sample in every country, including consumers of different age, education, income and household status. Originally it was planned to distribute the questionnaire to client databases of energy suppliers, but this was only possible for Austria and Germany. In Slovenia and Italy face-to-face-interviews with

Table 1 Sample size

	Austria	Germany	Italy	Slovenia	United Kingdom
Survey	943	1 332	200	200	232
Phone interviews	10	10	–	–	10
Focus groups	2	2	–	3	3

consumers in shopping malls were performed. In the United Kingdom the interviews were done with an online-questionnaire, which was distributed to a database of 11,000 persons on the university campus. The data-base included besides academic and research staff also administrative/management, clerical/secretarial, academic support and manual/craft staff, but mostly academics were answering. The same is the case for the other country samples. Despite the different modes of distribution, in all samples academics are over-represented. It was expected that people with higher education and income might be more in favour of smart appliances. The high percentage of academics in the sample and the fact that acceptance of smart appliances in all countries is very high, seems to point in this direction, even though no significant correlations could be found.

For the interpretation of the results one has to keep in mind that the sample for the quantitative research has some specifics: we have a high rate of academics (40%), the majority of respondents (62%) are male, middle-aged (between 36-50 years) and work or have worked (53%) in a technical field, with an income between 2000-3000 Euro (30%). The majority live in a house, without children (60%). These sample specifics are not really surprising as people who are interested in ecological topics and have a technical understanding are more likely motivated to participate in such a survey than others. But the high acceptance of smart appliances as found in the survey might not be directly transferable to other social strata.

Furthermore it also has to be considered that there is a gap between real behaviour and attitudes. The questionnaire did not ask how respondents really use their appliances, but how they can foresee using them. Consumers are estimating their future behaviour using appliances, which are unknown to them. Consequently the high acceptance level and readiness to change their user behaviour in order to be able to use smart appliances must be judged with a certain cautiousness.

The sample size for the survey differs between the respective countries, as a result of the different methods of distribution.

The phone interviews and focus groups give a more sophisticated picture about the underlying conditions for consumer acceptance and help to draft starting-points to optimise scenarios for the use of smart appliances. For the qualitative research the samples were chosen according to defined criteria, such as gender, age, education, profession, technical interest, environmental attitudes etc.

All in all, the findings of the quantitative and qualitative research correspond with each other. Whereas the study "Vernetztes Wohnen" (Meyer et al., 2001), in the year 2000 found a rather negative attitude towards smart homes (50% have a negative attitude, only 30% view it in a positive way) and the attitude towards single smart appliances was often labelled with objections like it is "too expensive", "too complicated" or that such technologies are error-prone, this has clearly changed in the meantime, probably due to the broad uptake of cell phones, touch panels, smart devices, etc. The current research shows that the consumer acceptance for smart appliances is rather high, with no substantial differences between the different countries.

Overall no significant correlations between age, gender, income, education and acceptance could be found. Only energy saving behaviour seems to have an influence: the more people engage in energy saving behaviour, the higher is their acceptance of smart appliances. For more details see Smart-A report D 5.2 Evaluation report – consumer survey on smart appliances (Suschek-Berger & Mert, 2008).

Consumer opinions about smart appliances

For the purposes of the research three simplified user scenarios were presented to the consumers and they had to estimate whether they would accept each and under which conditions.

- Mode A: the user presses a "smart mode" button and defines by which time the operation must be finished at the latest. Operation starts after the appliance receives a signal (e.g. power-line triggered) from the utility that renewable energy is available. This mode is applicable for smart washing machines, tumble dryers, dish washers and air conditioners.
- Mode B: the user is informed via a display on the appliance that for financial and ecological reasons it would be better to start operation at a specific time later that day. The user has to decide whether to delay the operation or not. This mode is applicable for washing machine, tumble dryer, dish washer, air conditioner.
- Mode C: the appliance is set in a "smart operation mode" by pressing a button on it. During operation short interruptions might occur or the operation might be prolonged. This mode is applicable for air conditioner, refrigerator, freezer, electric water heater, electric heated boiler, central heating pump.

Regarding the three different operation modes as described above we found that the consumers would accept all three presented options. No clear preferences for one of these operation modes could be distinguished. Consumers who preferred operation mode A claimed that this use option would be more convenient, as no further user interaction is required, after setting the appliance. However they want to be able to determine both the starting and finishing time of operation.

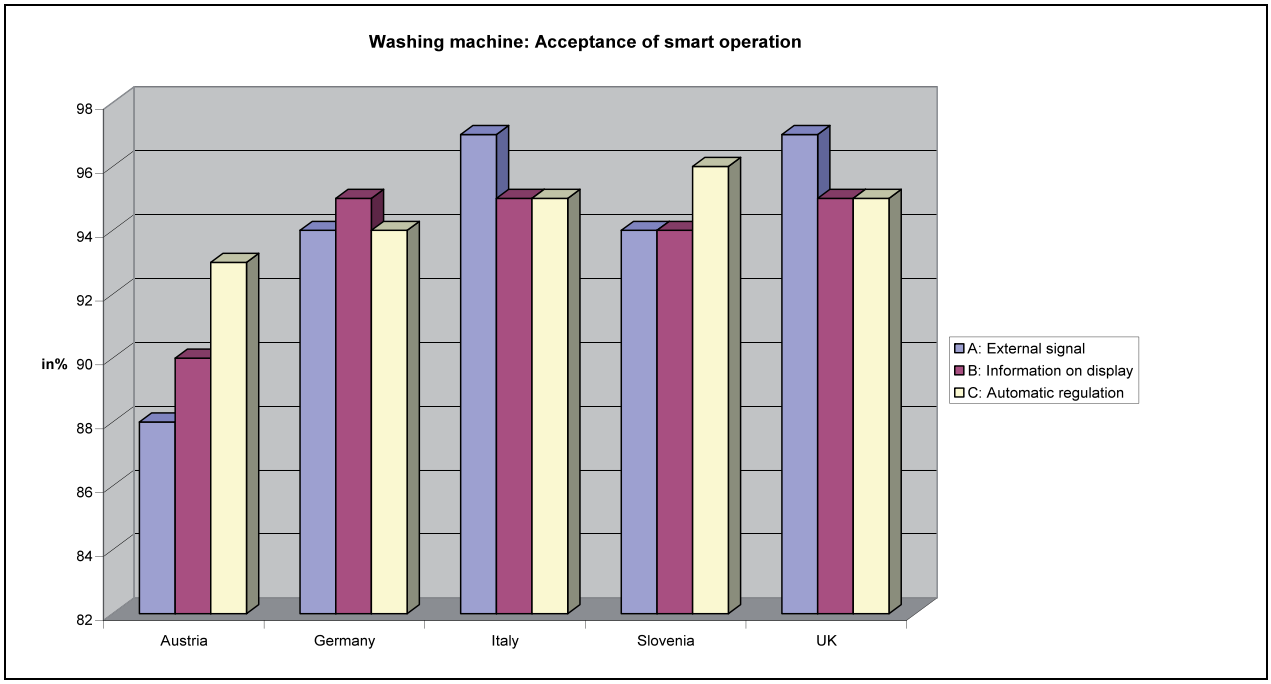

Figure 2. Washing machine: acceptance of smart operation.

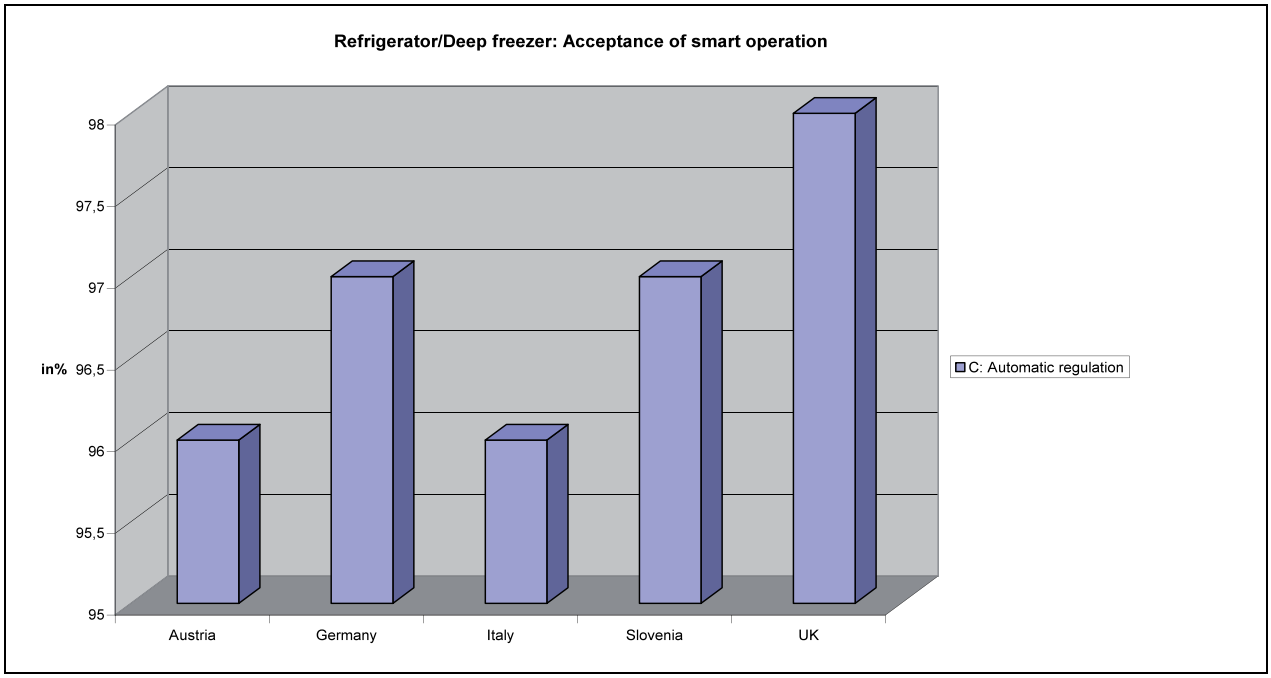

Figure 3. Refrigerator/Deep freezer: acceptance of smart operation.

The operation mode B gives consumers more control and they can be sure that renewable energy is used, whereas in the first case, it could also happen that conventional electricity has to be used to finish operation till a predefined time.

Regarding automatic regulation as described in operation mode C some consumers found it difficult to grasp the concept. They could not see the benefits of this solution as many of the respective devices use night tariffs anyway. On one hand this operation mode is viewed as the most convenient one as no user interaction is required. On the other hand consumers fear a loss of control and comfort. However, if they are able to override smart operation, if desired, and no loss of comfort occurs, this mode is also widely accepted.

Averaging over all countries up to 90% of the respondents would accept different options for smart operation of appliances. But the acceptance depends on the respective device and can not be generalised over all appliances. Smart operation for washing machine (see Figure 2) for example is highly accepted. Depending on the country, 88 to 97% of the respondents would accept smart operation. Similar results where obtained for smart dish washer and tumble dryer. However the potential for a smart tumble dryer is only agreed, when the tumble dryer is integrated in the washing machine, as users are usually not willing to wait for this service. As one respondent put it:

"[…] I have a four persons household, if the weather is bad and you need clothes, then I need the dryer immediately. A smart

operation is difficult, although I believe that the dryer in comparison to the other appliances, because it needs a lot of energy, would profit the most from a smart operation. But in real life, at least for me, I would not use it. If I have time to dry the laundry on the line, I wouldn't need a dryer."

Smart (automated) regulation of devices such as air conditioner, refrigerator, deep freezer, central heating pump is accepted, but only if comfort is not lost and users keep full control over the devices. According to the survey up to 98% of the respondents would accept for example the smart operation of a refrigerator and deep freezer (see Figure 3).

The survey showed that consumers are willing to postpone operation for long time intervals. In Italy more than half, in UK and Slovenia more than 40% of the respondents claimed that they would accept a postponement of the operation of washing machine, dish washer and tumble dryer up to 24 hours. In Germany and Austria about a third were willing to accept such long intervals. Asked again in the phone interviews, the respondents were more cautious. A shift of between half an hour and three or four hours is realistic, precondition is that comfort is not lost.

This corresponds to results of the study "Preis, Verbrauch und Umwelt versus Komfort – der mündige Energieverbraucher" (Thieman et al., 2007) which showed that in case of differentiated tariffs with cheaper energy (e.g. during night) a majority would be ready to do the housework during these times, as long as comfort is not reduced. This is especially the use of washing machines, dish washers and dryers as well as the recharging of rechargeable batteries. An adaptation of habits and time management is refused.

The main motivator for the majority of consumers to buy smart appliances is the prospect of a financial benefit. The ecological benefit is viewed as a positive side effect, which makes them feel good and indicates their green conscience, but for most people they are not sufficient as the sole reason for buying smart appliances. Only few consumers would buy them solely for ecological benefit.

"The point is... if you replace something, it's effort. You have to care for the disposal or sell it. And the installation etc., it all causes big efforts. The incentive has to be really big to bring oneself to buy a new one."

"I would buy it, no matter if price of smart appliance is higher. If price of energy stays same and there are ecological benefits, I would buy it."

All in all, consumers expect low additional costs for smart appliances. In general consumers would be ready to buy smart appliances, if they do not cost more or only slightly more (e.g. 5-25 Euro) than conventional ones. Higher prices might be acceptable, depending on the specific appliance and whether the investment is paid back. Additional costs have to be viewed in relation to the absolute price of a new appliance (e.g. for expensive appliances additional costs are accepted more easily). A reasonable pay-back time is expected as well as to be able to save money in the long-term. A pay-back time of five years seems too long, some even felt that a three year payback was too long for such a small amount of money.

"[…] the promise of payback within three years is a bit shady for me. Because washing practices are different. I assumed, washing twice per week, and calculated 15 Cent for reward. How should this reward look like, so it works? That is a shady promise, which can not be kept. This means someone who washes everyday – I don't know three, four small children – and someone in a single household who washes once per week will have different payback times. That's not working. So much can't be rewarded."

"50 Euros is not a lot, but if it's 50 Euros more than another product I would still want a measurable benefit."

"This is not a selling point – 50 Euros payback over three years is nothing – I would just buy it for environmental reasons."

A further key factor for consumer acceptance is the maintenance of control. One background reason for this feeling is a certain mistrust in high tech solutions. Paramount for the consumers is that they can override the smart operation mode any time they want. Service on demand is important to them and they are afraid that if operation is influenced by the energy provider comfort might decrease. So even in case of automatic regulation they want to keep control over the appliance, at least in principle.

"I want to keep control, the way I imagine it now there are several possibilities, either there is a huge regulation behind it, because many appliances have a certain cycle and when it is turned off in the middle of the cool down than it is bad for the appliance. I want to be able to control the cycle – I don't want the energy supplier to control it. In any case I want some kind of emergency button or something."

"To me it's an outside company dictating what you do in your own home... this is just one step too far."

Studies about smart homes (e.g. Haines et al., 2005) showed that the successful introduction of smart technologies into the home is related to a number of challenges: consumers may be resistant to the new concepts that the smart home presents, they may have limited technical experience to operate the system effectively which may reduce their motivation to use it, etc. Despite the overall high acceptance of smart appliances in the current study, consumers also expressed many objections, varying from safety fears, to potential technical problems to emotional scepticisms when it comes to smart operation of appliances.

One major concern of consumers is that they feel uneasy leaving their appliances switched on, if they are not at home or during night. In the words of a respondent: *"Well, it sounds highly interesting, but I personally do not like to leave an electrical appliance turned on, when I am not at home. For a washing machine, there is a risk. These appliances would need sufficient security mechanisms, so I can be sure, nothing might go wrong. I don't leave my home when an appliance is working."*

Consumers are afraid of break-downs which might lead to flooding or fire. The perception of risk depends to a very high degree on their current use practices and their knowledge about the technology. For example: users are not willing to run the washing machine when they are not at home or during the night, but are much less worried about the dish washer, although both appliances work very similarly. Obviously they are already used to running the dish washer unattended and they are more concerned about their clothes: *"I'm not bothered about dishes, but clothes are quite personal things – we express ourselves through them."*

Safety issues are also linked to smart freezers or refrigerators, people fear that smart operation might damage the food

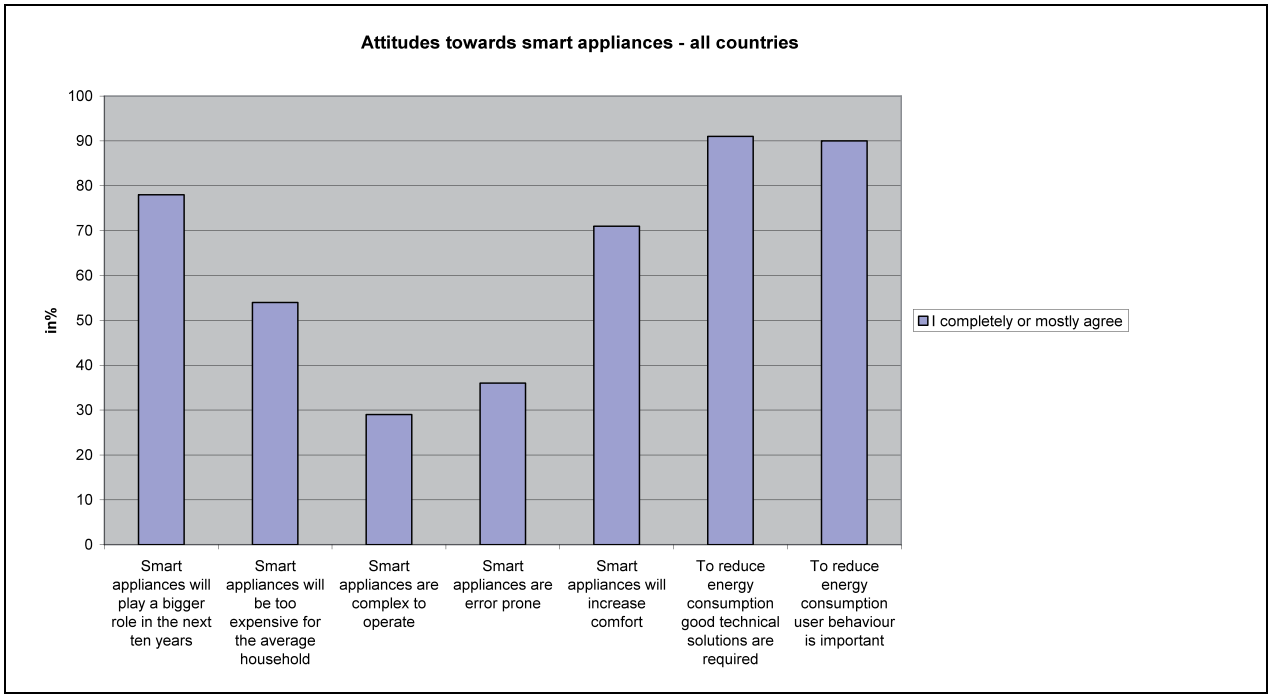

Figure 4. Attitudes towards smart appliances (all countries).

quality or frozen items might defrost. Even if they would get the guarantee that from technological point of view there is no risk they feel uncomfortable about it – mostly because they do not understand how the appliance works.

In a study in Switzerland (Devine-Wright, 2005) experts from demand side and suppliers were asked how their own customers would like "smart living", they said that 93% are too less informed. When asked what they themselves are experiencing or missing, 85% criticize that too many and confusing terms are used, 59% stated that information search is too time-consuming, 56% criticised that suppliers for information were missing and 49% stated that the existing information was incomplete. The Smart-A study confirms the need for good information, at least for the consumer side. Consumers have only a vague idea how smart appliances might work and have to some degree difficulties in understanding the underlying technology. They lack knowledge of how the electricity grid works and how a higher share of renewable energy will influence it. Consumers are concerned, how limited renewable energy is distributed and that artificial power consumption peaks are created. They want to know how a fair system can be established, so that everyone who uses smart appliances will benefit from cheaper tariffs. They are sceptical about the price of renewable energy in general, as they believe that renewable energy will remain more expensive than conventional energy. They also want to be sure that they are really using green energy.

"*What is for example at noon, the sun shines brightly, the signal comes that renewable energy is available, and the people start millions of washing machines. How is it controlled? First come, first serve? Or is it distributed evenly? Do I know if I am using renewable energy or is energy supplied from elsewhere, because millions of washing machines are running?*"

"*Maybe it is smart to have some important organization standing behind this project... I don't know…EU maybe or some other institution with good reputation. People would have more trust that smart appliances are ecological and consumer friendly and would buy them in a higher degree.*"

In the survey only 36% of the respondents were afraid that smart appliances are more error-prone (see Figure 4), but the interviews showed that some concerns exist that smart appliances might easily break-down because of the additional electronics or have shorter lifecycles because of interrupted operation. Consumers consider it important to know for example, whether spare parts can be bought or whether the device as a whole has to be replaced. They want be sure that a good support and repair service will be available.

Studies showed that on one hand consumers view consumption information as useful, as it helps them to save money. On the other hand they are afraid of a big brother effect and they fear that data recording might be misused. Younger generations were more open-minded towards the connection to external net-works than older generations (Meyer et al., 2001; Haines et al., 2005). Surprisingly, in the current study most consumers are not concerned about the monitoring of their energy consumption by their energy supplier. 93% of all respondents would accept this (definitely or probably), 54% say definitely yes. A comparison of the survey answers by country shows that older people (over 50 years) seem to be less sceptical, as well as respondents with apprenticeship or academic degree. Also the qualitative research showed that consumers would accept a permanent monitoring of their energy consumption and they do not expect any incentives for it. "*I would just be one tiny digit out of 10 million people.*" However there are also many who did not like the idea and are worried about misuse. Good data protection and deletion after some time as well as the possibility to have access to ones own data is expected. On the one hand the possibility to view the own energy use in real time is perceived as interesting and could be used to optimise one's energy consumption, on the other hand also some fears were

expressed that people with a high energy consumption might be reprimanded.

All in all consumers would be ready to buy smart appliances if

- the technology is perceived as mature and safe,
- they need a new appliance anyway,
- handling is easy,
- comfort is maintained or enhanced
- and consumers maintain control over the appliances.

Expert views and opinions on acceptance of smart appliances

Interviews with experts in the white goods industry as well as experts in consumer-related businesses were conducted to gather the perception of various experts from different fields of the business concerning the consumer and consumers surveys, and motivations and strategies to implement smart appliances.

16 experts from Austria, Belgium, Germany, Italy, Netherlands, Spain and UK were asked about existing studies, about the motivation and attitude of consumers versus behaviour of consumers, about country specifics, and about the main actors needed to foster implementation. Interviews were conducted by telephone and typically took between 30 min up to 60 min.

It was clear for all experts that smart appliances as for the Smart-A project (i.e. interconnected in a smart demand side energy management), must be beneficial for the household. People must at least be prepared to give up temporarily the service the appliance provides and they cannot start the operation at any time, etc. Two incentives to get the agreement of the household were mentioned as being most important: either people gain an economic benefit or people want to contribute to reduce the environmental burden.

Smart appliances attract in particular the attention of people that are fond of innovative products and "new generation" products and who appreciate electronic functions and interfaces. This was mentioned as a second motivation that is true for this certain consumer group. To extend the attractiveness to a broader public smart appliances and their utilisation should be associated with a modern and progressive life style.

It was found a prerequisite that smart appliances should not only operate in a demand side energy management system but also show its strengths to increase the user's comfort. One interviewee put it the following way:

"And there are more considerations such as the additional comfort that smart appliances can offer. E.g. if you come home you find that the home is at a certain temperature, the lights are on, etc. You have also the protection, the safety measures, etc".

It was judged differently by the experts whether smart appliances will ever save enough energy to make a considerably reduction in the energy costs of households. This would be a fact that would attract those people who are very efficiently and economically organized and want that everything is "worthwhile" or "pays back".

In the previous chapter the point was whether people could be motivated to use or to buy a smart appliance within a smart metering context. The focus of this chapter is to which extent people are willing to change their habits in case this is a precondition. The experts were asked: which restrictions or which discomfort will be acceptable or just tolerable for the consumer who is using such a smart appliance?

Some interviewees guessed that by no means the consumer will tolerate the loss or reduction in the appliances' services (except for attractive tariffs, maybe). The consumer is accustomed to getting these services whenever he wants and that electricity is always available. However, other interviewees saw no problems with inconveniences or said this will depend on the living situation:

"Acceptance depends on consumer groups and their situation of living. There is certainly a difference between people in their own house and people in residential buildings who have their washing machine in the basement and cannot realize the smart possibilities anyway."

Several barriers were mentioned: people might fear that health is affected, that the noise is disturbing, etc. and this could in the end result in a negative behaviour.

It was also stated twice that the behaviour of people could not easily be perceived:

"This is the situation concerning technical products: if there is an innovation, let's say the digital camera, you cannot estimate its impact. The innovation is introduced on the market and as a consequence the consumer's photography behaviour is revolutionised. Completely from one day to the other. It is difficult to estimate this in advance. Maybe you could put people in a laboratory environment or do some simulations."

"In our studies we rated the attractiveness of various solutions for tariffs and smart meters in categories from 1 to 6. All results were around 3, in the range 2.5 to 3.5. We also asked the willingness to buy one of these solutions including an information display in the home that is often favoured in UK and the US. It was disillusioning. But I am more and more convinced that these surveys are not worth while. Provide people with those appliances, let them experiment, and evaluate their real experiences".

There was also a strong vote by some experts that smart appliances were no contradiction at all to the familiar standard of convenience.

Another topic was the question how far the consumer wanted to be informed and how far he should be informed e.g. on the technical background, on the tariff structure, etc. All experts were in favour of coherent and comprehensible information of the customer. This has to be provided appropriately, allowing for different preferences in depth and in detail:

"Most people who have decided to act need only few, coherent information. Nevertheless there are always some, maybe 10% who want to control and verify everything. And maybe another 5% scrutinise everything."

This will be a challenge since the customer has to cope with a bundle of technical solutions. The complexity e.g. of the tariff structure might be high; particularly if there is an option to retrace single operations, whereas the corresponding savings would be only a few cents each.

On the other hand it was put forward by two of the interviewees that complete automation is also an option:

[In a presentation it was] "argued vehemently that demand response, everything that is related to tariffs, trying to influence consumer behaviour, you can forget about it. There has to be a

fully automatic solution. To his opinion the utilities were most successful that simply contacted the customer, offered him a certain tariff or bonus if he let control some appliances which were in the following equipped with power-line and subsequently controlled by the utility without the customer realising it."

"*We made an investigation „washing with the sun". 30 participants received a daily e-mail on the expected hours with sun [hence the pv-electricity]. The participants were totally eco-motivated, the financial incentive being almost nothing. But the conclusion of the participants was: all right with the e-mail but in the long run it should be automated.*"

When the discussion moved on to country specific variations in consumer attitude most of the experts seemed to feel not really comfortable with this topic. Differences in the energy supply systems were stated at first. The interviewees also thought of cultural distinctions in electricity use in general and in the attitude towards purchasing and handling the major domestic appliances as well as appraising their services. But those differences probably decrease in quantity and quality. On the other hand behaviour is quite diverse, e.g. the way to do the laundry etc.

The interviewees were at last asked what could be the most successful strategies to increase consumer's attitude towards smart appliances and who has to be the main actor then: the energy supplier, the appliance producer, government, or who else?

Most of the experts stated it clearly: the major benefit is for the utility that most often operates both a network and the transmission system and the main profit from smart appliances controlled by utility requirements results in an optimisation of the whole chain from generation, to transmission and distribution, to the consumer.

One of the interviewees from the white goods industry summarized most of the promises but also the challenges as well as the difficulties for the further development with his statement:

"*To improve the single performance [of an appliance] is really difficult. The step forward is to think instead of isolated appliances of "social appliances"; appliances able to play different roles according to the energy conditions of the house or the region.…I try to name the connectable appliances in this way, because "connectable" looks at the technology and "social appliances" means that they are able not to be alone, not isolated but actively part to create a new offer, a new solution. They have to talk with the other actors and if they are able to find a correct way to have a different attitude they are able to deliver results to the user and in the end to deliver results to the other actors involved in the energy system. Just naming the appliances this way makes you look at them in a different way, to try to imagine what this social attitude means for an appliance and try to invent in a way to become part of the life without creating drawbacks for the consumer but helping.*"

Also looking to the future another interviewee put forward the view that the consumer will gradually adjust his behaviour once this topic has been put on his agenda:

"*Take e.g. cars as an energy-consuming analogy: we have a sensitive perception of our petrol consumption and the price. We look for cheaper fuel stations – "Gosh, 1 liter is 5 cents cheaper!" – we drive petrol-saving. In contrary to the electric appliances. For years you have been trained to just flick the switch – it will be paid once a year.*"

Detailed information on the results is available in the Smart-A report D 5.1: Working paper on general consumer preferences and restrictions (Tritthart et al., 2008).

Strategies for increasing consumer acceptance

The results of the consumer research show that consumers have in general a fairly positive attitude towards smart appliances and would be willing to adopt them. Whether this positive attitude will lead to a market penetration depends very much on whether it will be possible to overcome the objections that exist. This will depend partly on the manufacturers and whether they are able to provide solutions which are comfortable, secure and easy to handle, and partly on the utilities – whether they will be able to offer attractive tariffs. The support of national and European institutions to promote smart appliances will also be important. An information and communication strategy to built trust in this new technology is necessary. Of the greatest significance is the need for the consumer benefits in using smart appliances have to become clear. Detailed information on possible strategies for increasing consumer acceptance is available in the Smart-A report D 5.5 Consumer acceptance of smart appliances (Mert et al., 2008).

Build trust in technology

Major objections of consumers are based on safety issues in a broad sense but also relate to any possibly greater strain on household items. Clearly use patterns play a big role here. Consumers are, for example, not accustomed to using the washing machine and tumble dryer when they are not at home. Instead of special guarantees for the appliances, users expect a high tech solution which prevents any damage. Some claim that even if insurance compensates for the smart appliances they would not operate them when they are not at home, because in case of breakdown the user still has the inconvenience. It won't be entirely possible to meet this consumer expectation, as no appliance will be 100% safe but additional safety mechanisms may convince those who have objections to leaving an appliance unattended. In fact the safety issue could be used as a sales argument, if manufacturer succeed in making smart appliances safer than conventional ones. For many consumers this would be a unique selling proposition which would be more convincing than money savings or ecological benefits.

Support of Smart-A concept by independent institutions

There is a lot of consumer scepticism that economic goals are hidden behind a "greenwashing" attitude. As consumers pointed out, information provided by the main beneficiaries (energy suppliers, manufacturers) will be met with reluctance. To overcome their doubts, the promotion of smart appliances should be supported by independent institutions, like governmental institutions at national and European level and by consumer organisations. Also the maturity of the technology and the assessment of ecological benefits should be verified by independent institutions. This can develop in parallel with energy efficiency labelling.

Provide coherent and comprehensible information

Most consumers have difficulties in understanding the underlying concept of smart operation, therefore good information about the functioning of the electricity grid and the feeding-in of renewable energy is required, which should be provided by the energy utilities. Consumers need to understand the bigger picture and the concrete implications of using smart appliances, to be motivated to adopt them. Also the tariff structure combined with smart appliances has to be easily understandable. The information should help the consumer to get an idea of his load curve, his saving potential and what are appropriate actions, such as peak load reduction.

Provide attractive financial benefits

There are two main reasons why consumers will adopt smart appliances: either to gain an economic benefit or to contribute to reducing the environmental burden. As the results of the research show, the majority of consumers clearly expect an economic benefit before they would use smart appliances. They are not prepared to change their behaviour without good incentives. Only a small percentage of environmentalists will be ready to buy smart appliances solely for environmental reasons.

Following this logic the main trigger to buy smart appliances will be attractive tariff offers of the utilities to their customers. The opinions and expectations about the savings differ: Possible savings for a single smart appliance will be rather low. For some consumers even such small savings would be a motivator, under the condition that the technology works safely and no loss of comfort occurs, others expect more substantial gains to accept smart operation. But consumers are aware of the fact, that in case several smart appliances are bought the sum of savings would have a bigger impact.

In case savings for smart operation are small it might be a feasible strategy if additional costs are sponsored by the energy utility, but in this case the motivation to use smart operation frequently would be lower.

In general, consumers think it is up to the energy supplier to provide an attractive cost model to convince them to use smart appliances and as already mentioned above, recommendations and evaluations of consumer organisations or independent institutions will be crucial for trust-building.

Provide options for consumers

One of the main questions of the consumer research was to assess whether consumers are willing to give an external party (energy supplier or network operator) insight in the use pattern of their appliances and the possibility for intervention. It depends on this acceptance whether the potentials of smart appliances can be fulfilled. Consumers generally agree to let the provider run the appliances and they would also be ready to accept a permanent monitoring of their consumption, a good data protection provided. But it became quite clear that users want to maintain control.

Many expressed the preference of solutions where they react to information of the network operator about price and availability of renewable energy. At least for appliances such as washing machine, dryer and dish washer which need a direct user interaction. They asked whether the availability of renewable energy would follow a regular pattern, so they could change their daily routines accordingly. This shows again, as already discussed, that consumers need relevant information about the background of the system to ensure their cooperation. It is very unlikely that users will spend time thinking about load management and shape their user behaviour accordingly. The more the systems work automatically, the higher the comfort for the users, but at the same time automation is rejected because users feel uncomfortable with it. To overcome their concerns about loss of control, consumers should have the option to decide actively whether to operate their appliances in a smart mode or not and overrule smart operation any time they want.

European standards for smart appliances will be a helpful way of increasing consumer acceptance, as consumers want to have the choice to change the energy supplier whenever they want. They do not want to be forced to stay with one supplier, to be able to use their smart appliances.

Provide additional consumer benefits

It is a prerequisite that smart appliances should not only operate in a demand side energy management system but also show its strengths to increase the user's comfort. Smart appliances have to be beneficial for the household, so that consumers will be ready to adopt them.

The use of smart appliances is not necessarily associated with higher comfort, on the contrary inconveniences are expected, but they would be accepted for financial savings. Financial benefits therefore seem to be the crucial point to accept smart operation, as already stated above. But consumers also stated that possible savings are rather small and might not be attractive enough to convince them, especially if they have doubts about the technology and might have to put up with less comfort. Thus, it is necessary to find additional benefits for smart appliances to make them attractive.

To sum up, the following conditions have to be met in order to convince consumers to buy smart appliances:

- Mature technology
- Maintenance of control
- Acceptable prices and/or subsidies
- Financial incentives for smart operation
- Feasible cost models
- Maintenance or enhancement of comfort
- Good information
- Good usability
- Attractive design

The current consumer study gives a first insight in consumer attitudes and opinions. Further research about desired tariff structures and handling and operation of smart appliances in real-life situations (e.g. pilot houses) as well as which degree of information consumers need and want are feasible.

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