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Smart services for connecting smart homes and grids: drivers and barriers of consumers

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Summary

Bringing sustainable and efficient energy management within reach of consumers

As part of the European project Interconnect (Interconnect Project - Homepage), in which 50 European entities are developing and demonstrating advanced solutions for connecting and converging digital homes and buildings within the electricity sector, six smart concept services are validated in an early design phase. The six smart concept services that have been designed are: Healthy Air, Smart Dishwasher, Green Charging of electric vehicles (EVs), Fresh Laundry, Smart Lock of the front door and the Smart Dryer. Each of them aims to (1) make the home environment (even) more pleasant, comfortable and/or safe for consumers and to (2) stimulate consumers to use energy when there is a large amount of sustainable energy (wind, solar) available, and less energy when there is a limited supply of energy. This enables the integration of sustainable energy into the grid. Based on the outcomes of this study the concept services will be improved in the design phase. After the completion of the design phase, the services will be implemented in apartments of the new building named Next, a large-scale test-site at Strijp S in Eindhoven, The Netherlands (Appartementen Eindhoven - Next Strijp).

The goal of the current study is to gather insights about the needs and wishes of consumers by conducting interviews with people who have a similar housing situation and demographic characteristics as the target group for the Next building. This research will not only give an indication of the interest in the market, but also provides insights into the process and the train of thought that residents have about the designed services.

Conclusions

Based on the results of the interviews the following conclusions can be drawn.

Participants perceive the Smart Dishwasher as the most attractive and the Smart Dryer as the least attractive smart service.
Although the results are based on a small number of participants, we do find a service that was valued most, and one that is valued least. The analysis of the interviews shows that the most attractive smart service is the Smart Dishwasher with nine out of ten participants intending to purchase it. The most prominent drivers for this choice are the cost advantage and the sustainability of the Smart Dishwasher (see Table 1 for an overview of the drivers per service). Additionally, convenience aspects and saving energy are mentioned as drivers.

For the least attractive smart device, the Smart Dryer, the perceived lack of safety (risk of fire) is the most often mentioned dealbreaker. Further, there is hardly any perceived need, the cost is perceived to be too high and there are doubts about the freshness of the laundry. As only half of the participants use a dryer and people do not experience noise pollution from the dryer, the additional benefits of the smart service do not target the demands of the participants.

Table 1. Overview of drivers per smart service, ranked from most attractive to least attractive smart service. In bold the driver that is mentioned most across services.

	Drivers
Smart Dishwasher	Cost advantage [8 participants] Sustainability [4 participants] **Convenience** [3 participants] Saving energy [3 participants] Control [2 participants]
Green Charging	Green energy [3 participants] Sustainability [3 participants] Independence [2 participants] **Convenience** [2 participants] Cost saving [2 participants]
Healthy Air	Positive impact on health [6 participants] Insight into air quality [4 participants] Close windows against mosquitoes or noise [3 participants] **Convenience** [3 participants] Saving energy [1 participant] Innovation [1 participant]
Smart Lock	**Convenience** [5 participants] Safety [1 participant]
Fresh Laundry	**Convenience** [6 participants] Freshness laundry [3 participants]. Cost saving [2 participants] Not hearing noise [1 participant] Renting the washing machine [1 participant] Renewable energy [1 participant]
Smart Dryer	**Convenience** [5 participants] Cost reduction [2 participants] Noise reduction [2 participants] Sustainability [1 participant]

Lack of need, high costs or low cost savings are the most dominant dealbreakers. In general, dealbreakers that are mentioned most often are lack of need and high costs or low cost savings (see Table 2). The lack of need mainly due to satisfaction with traditional appliances or preference for manual control is named as dealbreakers for each of the six services. High cost or low cost savings are dealbreakers for the smart services Healthy Air, Green Charging, Fresh Laundry, and Smart Dryer. A lack of safety or sense of insecurity are declared to be dealbreakers for Fresh Laundry, the Smart Lock and Smart Dryer. Finally, doubts about whether it works technically are dealbreakers for the adoption of the smart services Healthy Air and Green Charging.

Table 2. Overview of dealbreakers per smart service, ranked from most attractive to least attractive smart service.

	Lack of need	High cost/ low cost savings	Lack of safety/ sense of insecurity	Doubts whether it works technically
Smart Dishwasher	x			
Green Charging	x	x		x
Healthy Air	x	x		x
Smart Lock	x		x	
Fresh Laundry	x	x	x	
Smart Dryer	x	x	x	

There is a large variation in the amount people would be willing to spend on the iWonen package (i.e., all six smart services, including maintenance as well as an app for controlling the services).
The opinions differ quite heavily, ranging from 0€ to 150€ per month.

Mixed opinions about sharing data.
When it comes to data sharing, the opinions are quite mixed depending on the data. Some data, such as being present at home and the location, is more sensitive for people than other data, such as the time when the dishwasher is running. Important for participants is that the data is not used for commercial purposes.

The dependency on apps and the internet is often seen as barrier to purchase smart services.
When looking at the results for three out of six services, namely the Smart Dryer, Smart Dishwasher and Fresh Laundry, people are concerned about the dependency on apps as well as the internet. People are exhausted due to the sheer number of apps they have on their cell phone (Quote: "No, is just another app, I think. It's funny; I'm in favour of making things smart but not of an app everywhere, it's counterproductive."). Further, they think an app makes you dependent on the internet and good reception (Quote: "And the disadvantage is that you become more and more dependent on a good internet connection.").

Recommendations

Based on the most frequently mentioned drivers, barriers and dealbreakers for the purchase and adoption of each smart service, we make the following recommendations.

Develop propositions based on the needs of consumers and reduce perceived barriers of consumers

<u>Healthy Air</u>

- Communication should focus on the positive impact of the smart service on health. Specifically, people should be informed about the negative effects of bad air quality, such as the CO_2 levels which one does not notice oneself. Addressing this problem and showing how the smart ventilation improves this issue could also address doubts people have about whether the ventilation significantly improves the air quality.

- It also is perceived as convenient as the user does not have to turn off the ventilation manually anymore.
- Highlight the fact that it reduces energy usage whenever somebody is not present by means of the motion sensor.
- People find it important to be able to open their window. On a technical note, a sensor should be included which indicates the ventilation to stop whenever a window is opened in the house.
- In addition, highlight the downsides of opening a window: mosquitos, noise, and loss of heat (energy).
- Concerns about possible excessive cost (no costs were presented in the study) of the smart service can be reduced by being transparent and concrete about the costs and cost benefits of the service Healthy Air.

Smart Dishwasher

- The most mentioned driver of purchasing and adopting the Smart Dishwasher is the cost advantage, which means that communication should focus on being transparent and concrete about the cost benefits.
- Also, the benefits in terms of being more sustainable should be highlighted. This in turn should also reduce the perceived lack of need of the Smart Dishwasher. People do not perceive the need to delay washing their dishes.
- Further, the service is seen as inefficient, since people worry the dishwasher will start automatically while not being properly filled. Therefore, the functioning of the appliance should be explained properly.

Green Charging

- Communication about the smart service Green Charging should mainly focus on the usage of green energy and its positive impact on sustainability in contrast to the usage of conventional fossil fuel cars.
- Other aspects to highlight are the convenient app that shows how full the battery is and how far one can drive with it, as well as the use of self-generated energy in case of using one's solar panels.
- People have doubts about whether the service will work in unexpected scenarios, such as having an empty car battery, but no sun and no wind or everybody starts charging in the afternoon or at night. This is why concrete scenarios and examples of usage should be shown to the consumers. This may also eliminate the fear of being less flexible and restricted in one's freedom.
- Due to the fact that low cost savings are perceived as a dealbreaker, giving estimations of cost savings of "a few euros per month" is not concrete enough to be an argument that would convince consumers to adopt and invest in the smart service Green Charging. Again, being transparent and concrete about the costs and cost benefits may reduce the perceived barrier if the benefits are high enough.

Fresh Laundry

- Communication should focus on the convenience, meaning the regulation of the washing machine from outside the house, the service offers through the usage of the app.
- In line with that, it should be highlighted that it creates freedom to leave the house.
- Further, the freshness of the laundry due to the controllability of when the laundry is ready to be dried should be mentioned.

- Doubts about the functionality can be eliminated by precisely showing how the use of sustainable energy and the laundry being ready at a certain time, are two goals that can be attained at the same time.

Smart Lock

- Communication about the service Smart Lock should focus on the convenience of not having to carry around a key, not having to search for it or use it while for example carrying shopping bags though the door and focus on not having to pay for a new one when losing it, and changing the locks. Especially since consumers perceive the service as being redundant, communicating its convenience is key in this case.
- Further, in order to eliminate the experienced sense of insecurity (worries about being hacked) and lack in trust in the technology (in case of fire and internet outages), the functionality and safety the Smart Lock must be addressed properly.

Smart Dryer

- The convenience of the Smart Dryer, meaning the regulation of the dryer from outside the house, must be highlighted. Specifically, the usage of one app to keep track of all appliances in one's appartement is perceived as convenient.
- Based on the most important dealbreakers for the purchase and adoption of the Smart Dryer, namely the perceived risk of fire, we recommend offering a sensor which ensures fire safety.
- Further, the cost reduction should be highlighted.
- The costs and cost benefits should be communicated transparently.
- Finally, concrete scenarios should be used to increase the trust in the functionality of the service, especially when it comes to the freshness of the laundry. People are worried their wet laundry will be in the dryer quite some time before the dryer will be started.

Be transparent about the (usage of) data consumers are asked to share.
Due to the fact that people are suspicious about the data that they are asked to share via de apps that are part of the smart services, we advise to be transparent about (1) which data is asked of consumers, (2) who has access to this data, and (3) for what purposes the data is used. For the latter it is important to make sure as well as communicate that the data is not used for commercial purposes.

Consider providing an addition to the app, such as an in-home display.
In addition to using apps, a monitor in the house could be used in order to decrease the exhaustion people tend to feel when it comes to the number of apps, they have on their cell phone. The advantages of an in-home display are that people do not receive additional pop-up messages on their cell phones and feel less dependent on their cell phone when it comes to daily activities, such as washing the dishes. Survey research by Motivaction (2020) shows that some people prefer an app and others a display or webpage to manage the energy in their homes.

Contents

1 Introduction

1.1 Bringing sustainable and efficient energy management within reach of consumers

In the European project Interconnect (Interconnect Project - Homepage), 50 European entities are developing and demonstrating advanced solutions for connecting and converging digital homes and buildings with the electricity sector.

Within this project, six smart concept services have been designed to be executed in the Dutch large-scale pilot; Healthy Air, Smart Dishwasher, Green Charging, Fresh Laundry, Smart Lock and the Smart Dryer. These concept services are designed to make the home environment (even) more pleasant, comfortable and safe for consumers. The concept services also have to stimulate consumers to use energy when there is a large amount of sustainable energy (wind, solar), and less energy when there is a limited supply of energy. This enables the integration of sustainable energy into the grid.

The services will be implemented in apartments of the new building Next, a large-scale test-site at Strijp S in Eindhoven (Appartementen Eindhoven - Next Strijp). The exact implementation is depending on the available hardware and software as made available by different consortium partners.

The service concepts were created by the project team. First, two personas were determined based on the personas that were expected to rent apartments in the new building Next. These existing personas were adapted to reflect their views on smart appliances. In a second step, appliances that would be made available by project partners were selected. Based on these appliances, service concepts were developed that the two personas would appreciate. The personas can be found on the project website: Resources - Interconnect Project.

In order to make sure that these concept services match the needs and wishes of consumers they have been discussed with consumers in an early design phase.

1.2 Scope of the study

In the current study, the drivers and barriers of consumers, including their needs, are identified regarding six different smart services (see Appendix A for a detailed description) to be offered in the new building at Strijp S called "Next". Also, the purchase intention of those smart services and barriers that would prevent purchasing them (i.e., “dealbreakers”) are determined. Additional information on for example the concern with sustainability, the usage of the currently owned equipment and the willingness to share data, are gathered to get insights into the context of the drivers, barriers and dealbreakers of each smart service.

The participants in the current study are selected by Bouwinvest and are specifically chosen to resemble the residents that are expected to live in the new building “Next” at Strijp S. Therefore, selection criteria include housing situation (i.e., preferably living in an appartement) and demographic characteristics (i.e., different age groups).

1.3 Method

To identify the drivers, barriers, and dealbreakers of consumers, three researchers conducted ten interviews with three women and seven men. Not many women applied to participate in the study. The focus of the current qualitative study is to provide insights into the process and the train of thought that residents have about the designed services, rather than indicating the percentage of people who are, for example, interested in these services, which is qualitative research.

Out of the selected participants, half was 20-30 years old, one participant was 30-40 years old, one participant was 40-50 years old, one participant was 50-60 years old, and two participants were older than 60 years (see Table 3 for the gender distribution within each age group). These interviews took place between April and July 2021 and lasted about 1.5 hours each. Due to Covid-19 restrictions, the interviews were held online via Microsoft Teams.

Table 3. Gender distribution within age groups.

Age	Gender	
	Man	Woman
20-30 years	5 participants	
30-40 years		1 participant
40-50 years		1 participant
50-60 years	1 participant	
> 60 years	1 participant	1 participant

After introducing the goal and duration of the interview and gathering background data from the participants, a PowerPoint presentation developed by Bouwinvest, VolkerWessels and TNO, was used. This presentation included a short explanation of the incorporation of renewable energy into the energy system. For each smart service we used (1) one slide giving a short description of the service, (2) one slide about how it works and (3) one slide about the benefits and disadvantages of the service. Since the smart services “Green Charging”, “Fresh Laundry” and “Smart Dryer” will be optional in the apartments of the new building Next, additional costs are expected. That is why for these services, one slide about their cost and cost benefits was included as well.

To eliminate order effects, the services were randomized per participant. Finally, the last slide was about the content of the iWonen Package.

Per service, the participants were first asked about their associations, awareness and/ or usage of current (non-smart) services. Then the services were presented slide by slide. After each slide, participants were asked to give their first reaction and reasons for their reaction. Additionally, questions about their interest in the smart services were asked. For a detailed interview protocol, see Appendix B.

1.4 Reading guide

Chapter 2 contains the analysis and gives an overview of the results that emerged from the interviews, including a summary of the needs, barriers as well as dealbreakers per smart service. Chapter 3 contains the conclusions and recommendations.

2 Results

2.1 Introduction

In the following, we will present results regarding the background of the participants and each service separately. Specifically, the current behaviour of the participants will be explained, tables of drivers and barriers including dealbreakers will be summarised and a table of the intention to purchase the service will be shown. To illustrate each point made by one or more participants, several quotes have been selected from the answers of the ten participants.

2.2 Background

Housing
Six participants indicate that they live in an appartement, two participants live at home with their parents (unknown housing), one participant lives in a private house (unknown housing) and one participant lives in a terraced house.

Current usage of smart services
Four of the participants indicate that they do not use any smart services. Six participants use smart services. They mention the following smart services:

- Smart lights (Hue lights from Philips, google home) [mentioned by four participants];
- Google (Home, Nest, Chromecast) [mentioned by two participants]; and
- Smart meter [mentioned by four participants].

Sustainability
In the current research, more than half of the participants (six participants) say that they are engaged in sustainability (see Table 4). They mention owning solar panels, opting for the eco mode when using appliances, using a bicycle or public transport instead of the car, and washing dishes instead of using a dishwasher. The rest indicate that they are not concerned with sustainability. One reason named for this are doubts about the sustainability concerning the alternatives that are currently available, such as electric cars. The participant argues that the production of the batteries used for electric cars requires a lot of energy and there is no solution found for properly recycling them.

This attitude is line with findings of a recent study (Motivaction, 2021), which shows that less than 40% of the Dutch population indicates that sustainability plays an important role in their choices. This has not changed since 2019. However, despite a similar level of climate awareness and motivation for sustainable behaviour, the results show that Dutch citizens perform a number of climate-friendly behaviours more often than in 2019. In particular, they install LED lights, insulation glass, cavity wall insulation, solar panels and radiator foil and drive an electric car more often than in 2019.

Table 4 Engagement in sustainability

Engaged in sustainability?	Quote
Yes [6 participants]	I will certainly take it into account when choosing a new home. I find natural gas-free very important. Well, insulated and glazed, I quickly look at the energy label. Always been concerned about that. I have solar panels on the roof. The energy they generate is divided between the different apartments. I have been doing this for two years. I also have a heat pump. So, my energy consumption for cooking and such is relatively low. I do not drive anymore. I have an electric bike and am very happy with it. A bit. I don't drive that much by car, only when I have something inconveniently big to pick up or something like that. Other than that, I mostly take the bike or the train. Yes. In the sense that we find it more sustainable to do the dishes ourselves than to get a dishwasher for two people. Yes, as much as possible the cheaper options and the eco mode.
No [4 participants]	I am critical. All electric driving should be greener. It is not. I think a conventional car is more sustainable. The battery requires a lot of energy, and recycling is not possible either. Where do we have to go with this waste? *["This waste" refers to batteries.]*

2.3 Healthy Air

2.3.1 Current behaviour and needs with respect to ventilation

Most participants (eight out of ten) are concerned about fresh air in their homes and solve this mainly by opening windows or grilles (see Table 5).

There is a demand for ventilation against allergens, against heat and dryness, filtering fine dust, quiet ventilation, humidification of the air, responding to changes in air quality (e.g., when cooking or showering), having more than three settings in the ventilation system and good installation of the ventilation (see Table 6). In general, however, few problems are experienced with ventilation systems.

Table 5. Current behaviour with respect to ventilation

How do they do it now?	Quotes
Opening windows [7 participants]	Yes, I always have the window open.
Having ventilation but not doing anything with it [4 participants]	No not very concerned.
Having plants for oxygen [2 participants]	I also have plants for oxygen.
Humidifying the air [2 participants]	Diffuser for humidity.
Ventilating, opening windows, vacuum cleaning [1 participant]	Yes, by airing through, windows open, and vacuuming.
Not using CO_2 meter [1 participant]	We do not have a ventilation system in the house. We did have one. I did not

How do they do it now?	Quotes
	notice it very much. I heard it but did not really notice a difference. Still opened the windows. Keeping the house clean. We also had a CO2 meter, but I never looked into it, only when the light would be red.
Vacuuming or exchanging air filters [1 participant]	Vacuum the air filter every month. This is recommended by the manufacturer of the ventilation system. As soon as you have something to complain about, you must change the filters.
Changing settings when food is burned [1 participant]	Is always on. Is always on the same setting. In very rare occasions cases, food burnt or someone smoking inside.
Changing settings when cooking or showering [1 participant]	For a large part this is automatic (~80%), but if I am going to cook or shower, I would turn up the ventilation.

Table 6. Needs with respect to ventilation

There is a demand for...	Quotes
A possibility to open the windows [6 participants]	Lots of windows open, plants in the house. I just like fresh air.
Fresh air in the house [4 participants]	It must be fresh air and unpleasant odours must be removed.
Responding to changes in air quality (specific moments, such as cooking, showering, etc.) [2 participants]	Something that just works, that you do not really have to deal with. If you have burnt food, you can turn it up. Not overwhelming.
Ventilation against dryness [2 participants]	It is sometimes dry air.
Ventilation against allergens [1 participant]	I am allergic to house dust mites and cat hair. It is important for me to have as little of this in the house as possible.
Humidification of the air [1 participant]	That is where the opportunities for smart services lie. That the air is humidified in real time. Especially at night when I am sleeping.
Oxygen [1 participant]	That I can open a window and ventilate, but I also have plants for oxygen.
Ventilation against heat [1 participant]	I get warm quickly, especially at night when the window is closed. I would find climate control to be an added value compared to traditional heating.
Filtering fine dust [1 participant]	Fortunately, I do not (yet) experience any physical burden from the fine dust at the airport. It is sometimes just dirty outside.
Quiet ventilation [1 participant]	It is good to ventilate but ventilation systems also make noise.

There is a demand for...	Quotes
Functional ventilation [1 participant]	The ventilation grille is surrounded by cracks and crevices. They do not really close.
Having more than three settings of the mechanical ventilation system [1 participant]	We do have a mechanical ventilation for the shower and extractor, but you cannot have much influence on that. This mechanical ventilation has only 3 settings and I think that is too little. I would like more variation.
Good installation: the sensors must be in the places where ventilation takes place [1 participant]	Here in the house, there is only one in the kitchen and one in the bathroom, but the sensors are also in the bedroom and here (living room). This is no use – a smart system is stupid. So, the meter/ sensors are in different places than the ventilation outputs.

2.3.2 Drivers, barriers and dealbreakers

Drivers for the purchase and adoption of the smart service Healthy Air are the positive impact on health (most frequently mentioned by the participants), gaining more insight into air quality, saving energy, the innovativeness, convenience and less mosquitos or noise due to the closed windows (see Table 7).

Dealbreakers for a purchase are, not being able to open the windows, lack of need, doubts about how well it works technically and the cost of the service (see Table 8Table 9).

Table 7. Drivers for the smart service Healthy Air

Drivers	Quotes
Positive impact on health [6 participants]	Nice and useful. It is about health. So, I like it when there is equipment that measures this. You do not notice anything about CO_2 yourself.
Insight into air quality [4 participants]	I particularly like the fact that other substances in the air besides CO_2 are measured.
Close windows against mosquitoes or noise [3 participants]	Otherwise, you get tired and achy, so it only increases the quality of life. In my previous house I liked to keep the windows closed (no mosquitoes or noise).
Convenience [3 participants]	I like the fact that it has a sensor and switches on automatically based on air quality. In my current house, I don't turn on the ventilation manually anymore either.
Saving energy [1 participant]	If I can save energy with relatively little effort, I am open to it.
Innovation [1 participant]	I do not think a ventilation system is very new, but the new thing is a smart sensor, which senses when the air is polluted and then sets things in motion, and you can monitor that through an app.

Table 8. Barriers against the smart service Healthy Air, including the dealbreakers in bold. Those dealbreakers are based on (1) the reasoning why people would not want to buy

the service and (2) the conditions the opponents have given under which they would buy the service.

Barriers	Quotes
Lack of need [4 participants]	My air ventilation does not have to be smart too. Soon the dishwasher will have an App, my washing machine, my ventilation, ... Feels a bit like “overkill”. Without the motion sensor seems sufficient to me. It seems like a lot of hassle to me to have such a motion sensor at every door so without it I’m fine.
Doubts about whether it will work technically [3 participants]	Interesting system, I am simply curious how it looks in practice. How do you quantify if the air quality is good?
Too many control boxes on the wall [2 participants]	Now you have an extra control box, and it gets cluttered when you have a lot of these things. I would argue for integration instead of separate things.
Not being able to open windows [2 participants]	For me it is important to be able to open windows and doors. Also, if you have a cat, that it can go outside. I feel locked in if I do not open windows and doors.
Noise pollution [1 participant]	No noise pollution: then that thing can make a lot of noise unexpectedly. Probably confirms that I don’t want it.
High cost [1 participant]	Houses are already really expensive. I started living in a 4-storey house (after the break-up). An apartment costs easily 1200 to 1300 per month. There are very few things that I would like to add extra. Certainly not something as small as ventilation. Living is already very expensive, and it is strange that it’s so expensive. Then do not voluntarily spend even more.

2.3.3 Purchase intention

Half of the participants indicate that they intend to buy the Healthy Air service (see Table 9).

Table 9. Purchase intention of the smart service Healthy Air

Purchase intention	Quote
Yes [5 participants]	Yes, because it adds to how we think about air quality and ventilation. I find the measurement of substances in the air particularly important.
No [5 participants]	No I already have it, and purely for the motion sensor not.

2.4 Smart Dishwasher

2.4.1 Usage of dishwasher

Half of the participants own and use a dishwasher. This ratio is similar to the ownership and usage of dryers (see section 2.8).

2.4.2 Drivers, barriers and dealbreakers

Drivers for the purchase and adoption of the Smart Dishwasher are cost advantage (most frequently mentioned), convenience, saving energy, control and sustainability (see Table 10). The only deal-breaker is lack of need (see Table 11). These drawbacks mentioned earlier (e.g., cost, space in the kitchen and noise) are not identified as dealbreakers.

Table 10. Drivers for the Smart Dishwasher

Drivers	Quotes
Cost advantage [8 participants]	With energy saving it would be efficient and add value. If that energy makes it cheaper, it is very valuable. It appeals to me if you wash when there is enough energy available and that it is cheaper then.
Sustainability [4 participants]	Good that it considers when it is convenient in terms of energy and that you are sustainable.
Convenience [3 participants]	Very nice. Then I do not have to think about it myself.
Saving energy [3 participants]	Insight into usage, that you are less worried, that it turns on automatically.
Control [2 participants]	Good that the manual side does not disappear.

Table 11. Barriers against the Smart Dishwasher, including the dealbreakers in bold. Those dealbreakers are based on (1) the reasoning why people would not want to buy the service and (2) the conditions the opponents have given under which they would buy the service

Barriers	Quotes
Inefficiency [5 participants]	But of course, it should not wash automatically if it is only half-empty. Then you have to make sure it is always properly filled, and it seems to me that it comes on when it is not full yet. In terms of logistics, you have to take that into account.
Lack of need [2 participants]	Just like the washing machine and dryer that you just turn on by yourself. I prefer to do this manually. I also do a lot of washing by hand because there are only two of us, so the amount of dishes is too small to run a whole program.
Dependence on app [1 participant]	I do not know if you want that “dependency”. If your phone is empty or you have no internet, then functionality is gone. Also make sure you have something fixed, a unit/ screen or whatever in the kitchen where you can set everything by timeframes, or I do not know what.
Lack of security [1 participant]	I also look at security here, so it can only run when I am also at home.
Data security/ hacking [1 participant]	The only danger with such smart devices, you could get hacked again. So, I think it’s important that they get even smarter otherwise the devices run whenever they want.

2.4.3 Purchase intention

Nine participants report to be interested in purchasing the Smart Dishwasher service (see Table 12). However, several conditions have been mentioned, such as cost, space in the kitchen and noise.

Table 12. Purchase intention of the Smart Dishwasher

Purchase Intention	Quote
Yes [9 participants]	Yes, I think so. You have more advantages, insight, setting, when you want to turn it on. You do not have to worry about it as much. I would give it a chance depending on whether there are extra **costs** involved. Otherwise, it might be an expensive experiment. Yes, generally speaking, but now I **do not have room in my kitchen**. If it comes as standard, I would definitely use it. I sleep light so it should not make much **noise**.
No [1 participant]	I use it very little. With a large family, it might be a bit different.

2.5 Green Charging

2.5.1 Energy preferences and needs with respect to electric cars

None of the participants owns an electric car, but two do own a hybrid car. The majority (six participants) indicate a preference for green energy when it comes to charging an electric car (see Table 13). In addition, the majority (seven participants) would use solar panels for Green Charging if they had solar panels of their own (see Table 14).

In general, people demand a full battery, good availability of charging stations, low costs, and short charging times (see Table 15Table 16). In addition, one participant expresses doubts about the actual realization of supplying solely green energy at a certain part of the day. According to the participant, this promise is not feasible as momentarily there is not enough green energy available.

Table 13. Energy preferences when charging electric car

Energy preference when charging electric car	Quote
Green energy [6 participants]	Preferably natural or green energy.
No opinion [3 participants]	I will be driving electric then, that is already sustainable. I will not make demands on green or grey energy then.
Cheapest [2 participants]	The cheapest.

Table 14. Usage of solar panels for Green Charging

Usage of solar panels for Green Charging	Quote
Yes [7 participants]	Would be nice. You would have to have a lot of solar panels I think, but it would be very handy.
No [2 participants]	I have access to only a few solar panels of the apartment complex. So, this might be at the expense of the energy I use for cooking. So, I would rather use energy for the house instead of an electric car. I have solar panels myself. […] a car should be charged mainly in the evening hours, and then solar panels are not much use. As soon as you charge during the day, it is a no-brainer.
Other [1 participant]	I have no solar panels myself. Considered them though. Price, very expensive to buy.

Table 15. Needs with regards to the smart service Green Charging

There are demands for…	Quote
Good availability of charging stations [4 participants]	What I do see is that there are still too few electric charging stations. If you had a charging station in front of your door at home, that would be ideal.
Short charging time [4 participants]	For me, how long it takes to charge would be the most important thing. As far as I know now, electric cars are not so good for long distances. If you have driven a long way, it would not be nice if you had to wait a long time before you could continue.
A battery that is full enough [3 participants]	If I drive back in the evening and the battery is not full enough, I do not feel safe enough, I see that as a disadvantage.
Low cost [1 participant]	It has to be cheap.
Reality check: Is it at all realistic? [1 participant]	The system is not set up to provide green power for a certain part of the day.

2.5.2 Drivers, barriers and dealbreakers

The most mentioned drivers for the purchase or adoption of the smart service Green Charging are the usage of green energy and sustainability. Other drivers are independence, convenience and cost savings (see Table 17).

Dealbreakers for a purchase are doubts about the extent to which it works technically (mentioned by six of the participants), lack of flexibility/restriction of freedom, lack of need and the low cost savings (see Table 17)

Table 16. Drivers for the smart service Green Charging

Drivers	Quotes
Green energy [3 participants]	That something like a car which takes a lot of energy can be charged optimally by renewable energy.
Sustainability [3 participants]	It is environmentally friendly, of course. I mean you have no CO_2 emissions. This is a fact. Good. Especially from your own panels. This is very much more sustainable. Except no driving, that would be even more sustainable.
Independence [2 participants]	The fact that you actually control your own energy supply, so you are not dependent on others.
Convenience [2 participants]	Hypothetically, I would do it, and with an app it seems very convenient because you can see how full the battery is and how much you can drive.
Cost saving [2 participants]	Sounds like cheap driving to me. Would make it more affordable, more attractive.

Table 17. Barriers against the smart service Green Charging, including the dealbreakers in bold. Those dealbreakers are based on (1) the reasoning why people would not want to buy the service and (2) the conditions the opponents have given under which they would buy the service

Barriers	Quotes
Doubts about whether it will work technologically [6 participants].	What does that look like in practice? Suppose your car is empty, you are working all day. And it is windless and there is no sun, and you have to leave. Then you have a problem. And from an IT background, the ideal scenario is that the service learns your behaviour. But I also have unexpected scenarios – suddenly 2 hours in the car. If there is enough power, it's a very good plan. But if everyone starts doing this (i.e., charging in the afternoon or at night) then we have another problem.
Lack of flexibility/ restriction of freedom [4 participants]	Feels like freedom is being curtailed. Reminds me of shared cars. Feels like your own car is a shared car and you have to think beforehand whether you should use it. At my age – 23 – almost everything is "on demand", many impulsive things. Flexibility. Suppose you are away all day, you have no solar energy. You are bound to your own house. Whether there is a lot of energy available from wind and sun. We work the night shift so we cannot make full use of energy when it is most available. That is what I would like to steer towards.
Lack of convenience [4 participants]	Set or do lots of things before you can get into your car. No, you have to plan this out indeed [...].
Lack of control [1 participant]	The only thing – personal choice – is to make choices based on my behavior. I find that very irritating. You also see it with social media. I associate it with those algorithms. I assume you can turn off options.

Barriers	Quotes
Doubts about data security [1 participant]	Share your agenda: I would not do that quickly. Feels very personal.
Lack of need [1 participant]	Because I do not drive a car anymore.
Low cost savings [1 participant]	A few euros a month is not very much, but if you generate renewable energy yourself it is probably even cheaper.

2.5.3 Purchase intention

More than half of the participants (six participants) indicate that they intend to buy the Green Charging service (see Table 18Table 19).

Table 18. Purchase intention of the smart service Green Charging

Purchase intention	Quote
Yes [6 participants]	Yes, because it contributes immensely to our own goal of driving as green and electric as possible. Appeals to us.
No [4 participants]	No, I would wait for cars with hydrogen. No, because I do not drive a car anymore.

2.6 Fresh Laundry

2.6.1 Current behaviour with regards to Fresh Laundry

People usually do their laundry in the evening, at weekends and some during off-peak hours (see Table 19). Seven out of nine participants[1] do not leave their washing too long in the drum (see Table 20). Six out of nine participants[1], however, do leave the house when the washing is in progress (see Table 21).

Table 19. Time and/ or day when laundry is usually done

When do they do the laundry?	Quotes
Evening [5 participants]	It is on now – usually in the evening. So basically, when it is convenient, but also probably the most convenient time.
Weekend [5 participants]	Like the dryer at the weekend.
Off-peak hours [2 participants]	Or in the off-peak hours.
Monday [1 participant]	On Mondays, but this is very flexible. I happened to wash yesterday so actually I wash when it suits me.

Table 20. Leaving laundry in the drum for too long

Does it happen that the washing is left in the drum too long?	Quote
No [7 participants]	No, usually I try to hang it up straight away. And I have a timer on my washing machine

[1] There is one missing answer for this question.

Does it happen that the washing is left in the drum too long?	Quote
	so I can plan it so that my laundry is done when I get home.
Yes [2 participants]	Yes. Then I wash again.

Table 21. Leaving the house when washing machine is running

Leaving when the washing machine is running	Quote
Yes [6 participants]	Yes, but not for very long, try to go back in time.
No [3 participants]	I sometimes go shopping when the washing machine is on. No, not for safety reasons.

2.6.2 *Drivers, barriers and dealbreakers*

Drivers for the purchase or adoption of the smart service Fresh Laundry are the convenience (most frequently mentioned by the participants), freshness of the laundry, not hearing noise, renting the washing machine, the usage of renewable energy and cost savings (see Table 22). Dealbreakers are high costs, the lack of need and safety (see Table 23).

Table 22. Drivers for the smart service Fresh Laundry

Drivers	Quotes
Convenience [6 participants]	That you can turn it on through an app, when you are away for the whole day, choose when to finish it. So, it is more controllable, instead of having certain timeframes (3 hours, 6 hours, 9 hours). Creates more freedom.
Freshness laundry [3 participants]	Stay fresh, do not stay in the machine too long. You do not forget it. You can put it on right away. I now have it done when it suits me.
Cost saving [2 participants]	I immediately think “with low energy tariffs”; I find it interesting. If the washing machine comes on when it is cheapest, I do find it interesting.
Not hearing noise [1 participant]	Also, very nice that you do not hear the machine.
Renting the washing machine [1 participant]	No need to buy a machine. Also, easy if you are going to rent it and something breaks then you do not have to deal with investment.
Renewable energy [1 participant]	I think it is especially for me the difference of sustainable energy.

Table 23. Barriers against the smart service Fresh Laundry, including the dealbreakers in bold. Those dealbreakers are based on (1) the reasoning why people would not want to buy the service and (2) the conditions the opponents have given under which they would buy the service

Barriers	Quotes
High costs [6 participants]	I think the cost is 600 Euro, and then prefer to buy it at once. Rental costs are high. I think that is high. You are looking at 240 to 300 euros a year. A regular washing machine costs 500 euros. You cannot write that off in one year. Quite an investment.
Lack of need [4 participants]	Not necessary because I can set my washing machine to finish the laundry at a certain time, but I never use that. Maybe a bit redundant, you can do it without an app. The timer is quite handy, but I do not use it very often.
Dependency on app [3 participants]	Washing with my smartphone in my hand. It is another app with the washing machine. I find the buttons on the washing machine easy enough. With all those apps you become very dependent on the Wi-Fi and the internet. So, if anything happens to them, all your devices will not work anymore.
Doubts about whether it will work technologically [2 participants]	The washing machine itself chooses the starting time, but then it chooses the low energy tariffs. If you have to be ready in 8 hours, then you have a low tariff in 5 hours, so then the laundry stays in the washing machine for a very long time, and this is not good for the laundry.
Lack of safety [1 participant]	You do not know if there is a leak, you cannot monitor it.
Not willing to change habits [1 participant]	We often have the washing machine on in the evening, its off-peak hours, I am at home then anyway. I think I will keep it that way.
Data security/ hacking [1 participant]	You read a lot about hacking. I wonder how much control you still have.

2.6.3 Purchase intention

Seven participants indicate that they do not want to buy the service (see Table 24).

Table 24. Purchase intention of smart service Fresh Laundry

Purchase intention	Quote
No [7 participants]	No, I find it useless and would like to be home when the machine is running. Not for the amount it would be now.
Yes [3 participants]	Yes, I think so, definitely. If these options are in, make up your own mind: am I going to be home in two hours, I'll turn it on now. Not driving home.

2.7 Smart Lock

2.7.1 *Current behaviour with regards to access to home*

The majority (six participants) lets others into their home when they are not at home (see Table 25Table 26). Most people (nine participants) have people close to them who have a house key (see Table 26Table 27).

Table 25. Giving access to home when not present

Giving access to home when not present	Quote
Yes [6 participants]	Yes, my parents, for example. My sister or my friend. Yes. For example, watering the plants while I am on holiday.
No [4 participants]	No, never. Few people come to the door.

Table 26. Other people having a house key

Other people having a house key	Quote
Yes [9 participants]	Some friends who do have the key. The people I trust so much have the key. If a friend needs to pick something up, I put it in the garden and leave the garden gate open. Yes. Neighbours – the other people live too far away now.
No [1 participant]	No that is still on our list to do. I think when we go on holiday, we will give the key to the neighbour.

2.7.2 *Drivers, barriers and dealbreakers*

Drivers for the purchase or adoption of the Smart Lock are convenience (most mentioned) and safety (see Table 27). Dealbreakers are mainly the feeling of insecurity and lack of need (see Table 28). In addition, cost is also mentioned as a barrier to purchase interest but is not identified as a dealbreaker.

Table 27. Drivers for the Smart Lock

Drivers[2]	Quotes
Convenience [5 participants]	Admitting people from a distance is convenient. The idea sounds handy that you do not have to deal with the key anymore. Then you do not have to make another key, for example. Also, nice when you are standing in front of the door with your shopping bag – so the automatic unlocking is nice. I could also run without a key – that is handy. For the elderly/people who need informal care it would be handy.
Safety [1 participant]	I have just got a similar lock. I have a pin code and a device. It is from a security company against burglary.

[2] There are three answers missing for this question.

Table 28. Barriers against the Smart Lock, including the dealbreakers in bold. Those dealbreakers are based on (1) the reasoning why people would not want to buy the service and (2) the conditions the opponents have given under which they would buy the service

Barriers	Quotes
Sense of insecurity [7 participants]	I would not use wireless via the internet. Then you can open the door anywhere in the world. If you can do it, others can too. Sensitivity of hacking. I am indeed concerned with security and feeling comfortable in the home.
Lack of need [4 participants]	Very redundant. I find it useless and even inconvenient.
Lack of trust in technology [3 participants]	Perhaps the biggest disadvantage is that you are once again dependent on electronics. What if a fire breaks out, can you still open the door? [...] sensitivity to internet outages.
Use of Bluetooth [2 participants]	I think that phone would be empty quite often if you also have to use Bluetooth. Less functional in that respect.
Doubts about whether it will work technologically [1 participant].	When I look at the picture, I wonder at what point I should open the door. If I have hands full is open, it is not convenient. Automatic unlocking based on location, what is the distance. Tricky, but easy. Should not be when I am driving by that my door jumps open.

2.7.3 Purchase intention

Less than half (four participants) say they intend to buy the Smart Lock service (see Table 29).

Table 29. Purchase intention of the Smart Lock

Purchase Intention	Quote
No [6 participants]	No, useless for me. Annoying to do everything with the phone or apps, things you could just do yourself. In my experience it does not save much energy either. No, not because I still find it too exciting. And I do not mind the keys either.
Yes [4 participants]	Yes, it depends on the situation. Just like giving someone a key. Only a bit easier. *Note*: Depends on how **expensive** it is and how secure. Yes, I already have something similar.

2.8 Smart Dryer

2.8.1 Current behaviour, attitude and noisiness with regards to dryers

Half of the participants use a dryer (see Table 30). Two of the participants using a dryer live in an appartement, one in a terraced house, and for two it is unknown. Two out of six participants living in an apartment own a dryer. Those who do not have a dryer also have no intention of using one in the future, as they find it superfluous or an extra expense. People who do have a dryer say that it makes the

laundry nice and soft and that it comes in handy when you do not have enough space to hang the laundry up. Disadvantages that users mention are safety, extra energy consumption and the limited suitability of a dryer. Finally, users indicate that they have no noise pollution from the dryer or only a little (see Table 31).

Table 30. Usage, advantages and disadvantages of a dryer

Use of a dryer	Quote
Yes [5 participants]	*Advantages:* Yes, it is nice that laundry becomes soft. That is a practical reason that I do not have to hang it up. We do that more because we have a very small balcony and not enough space, so a dryer is the perfect way to dry the standard things.
	Disadvantages: I do not dare turn on dryer very well when I am away from home. We had a fire once due to dryer. I would not need a smarter dryer. Motor in dryer burned out. Always stays on. I was not at home at the time. In the scullery, neighbour had discovered it. But not all laundry is suitable for the dryer, or it depends on your preference, so if you want soft or stiff towels. When the weather is nice, I hang the laundry outside – then you can save energy again. If you dry it outside, it is always a bit cooler and the dryer is a risk device: If you do not maintain it properly your house can burn down so it requires maintenance.
No [5 participants]	No. I did consider it when I was buying/collecting everything. I'm only alone. I can put my washing on a rack. Just extra costs. No, I use the laundry line. No, I think dryers are unnecessary. They use power that you do not need.

Table 31. Experienced noisiness of dryer

Noisiness	Quote
A little [2 participants]	My best friend has one, you can hear it rattling. I would not call it a burden.
No [3 participants]	Not at the moment because my current dryer is not that old. When they get older, they will make some more noise. And my dryer is far away from my bedroom, so it does not bother me either.

2.8.2 Drivers, barriers and dealbreakers

Drivers for purchasing or adopting the Smart Dryer are convenience, sustainability, cost reduction as well as noise reduction (see Table 32). However, the dealbreakers are more pronounced. When looking at both the reasoning why people would not want to buy the service and the conditions the opponents have given under which they would buy the service, the most mentioned dealbreaker is risk of fire (see Table 33). People do not want to leave the house when the dryer is running because of the risk of fire. Other dealbreakers are doubts about the freshness of the laundry, high cost, lack of durability and lack of need/ utility.

Table 32. Drivers for the Smart Dryer

Drivers	Quotes
Convenience [5 participants]	It would be nice if you could keep track of all the appliances in one app. Both sound, lighting, kettle, can control. Dryer when you are not at home: nice. I think it is very handy for people with a big family and little space also that you cannot hang up your laundry. Then a dryer is ideal. Now we depend on the weekend. Here you could decide the time when you take out the laundry, so the flexibility is nice.
Cost reduction [2 participants]	Very cool if the dryer will run during off-peak hours though.
Noise reduction [2 participants]	The noise can be very annoying and if that is limited that is nice. It is nice for the neighbors if it happens during the day.
Sustainability [1 participant]	I worked for the company of that dryer, Siemens. But I know they are very into sustainability; I would definitely use this.

Table 33. Barriers against the Smart Dryer, including the dealbreakers in bold. Those dealbreakers are based on (1) the reasoning why people would not want to buy the service and (2) the conditions the opponents have given under which they would buy the service

Barriers	Quotes
High costs [7 participants]	You are not going to pay it back anyway. Then you rent it for ease of use. That should be doable too. 20-30 euros a month, if it costs 600 euros, you keep it for five years then you pay the rent for] five years. Then I think the rent is too high. I would rather buy a dryer. After two years I have already earned it back.
Doubts about the freshness of the laundry [5 participants]	I do not like that. If you put your washing in the dryer it will be wet and if you wait for the favourable energy rates your washing will start to go mouldy. When the washing has been in there for a number of hours it will have a certain smell so it's not nice.
Lack of need/ utility [4 participants]	It does not help that the dryer is running when I'm not at home. I can also press the button and then leave. Only then it does it automatically. No, I think I would really not buy it and just use the washing machine and laundry line.
Doubts about whether it will work technologically [4 participants]	For me, linking the app with calendar would not be very useful because I would not put almost half of it in there. With an app like that, it's more convenient to just press the button when you leave.
Risk of fire [3 participants]	I would not switch it on if I am not at home. Dryers all work with dry air. Are not very safe with fire hazards. I have been a firefighter by profession, so I have some experience with dryers causing fires when people are not

Barriers	Quotes
	at home. So, when I think of a Smart Dryer, I think I would not like to have one – for safety reasons.
Dependency on app/ internet [2 participants]	No, is just another app, I think. It is funny; I am in favour of making things smart but not of an app everywhere, it is counterproductive. And the disadvantage is that you become more and more dependent on a good internet connection. If it breaks down, the washing will not be any fresher.
Inefficiency [2 participants]	I think the fact that you still need to have that connection with the washing machine and time it.
Lack of sustainability [1 participant]	If you want to live sustainably you should buy as few appliances as possible. I just wait one day for the washing to dry.

2.8.3 Purchase intention

There is no intention at all to buy the Smart Dryer service (see Table 35).

Table 34. Purchase intention of the Smart Dryer

Purchase intention	Quote
No [10 participants]	No. Wet laundry in dryer and start later. Does not make it any fresher. Would not want this service due to fire hazard. No, because of durability and not necessary.

2.9 iWonen package

The iWonen package consists of all six smart services, including maintenance of the services as well as an app for controlling them.

The amount people would be willing to pay varies between 0€ and 150€ per month for the whole iWonen package. In Table 35Table 36, explanations of the choices that have been made are given.

Table 35. Amount and explanation for the amount people would be willing to pay for the iWonen package

Amount for iWonen package	Explanation
0€	
I would not pay for it.	
1 - 50€	
10 to 20€ for just the extended functionality, because that is what it is in my opinion	With current rents, it is already so expensive, ridiculously so. Then I want to buy Healthy Air. Ten cents' worth of work. Max? Actually, I think that climate control should be a standard part of housing.
I would say around 15€ per month.	Tricky. I would take my washing machine with me and have no need for Green Charging, and I do not want a dryer. I think Healthy Air should be part of the flat, like being able to open a window.

Amount for iWonen package	Explanation
Collectively 30-40€ per month.	I would only look at the Fresh Laundry and Smart Dryer (because monthly costs are indicated here). Healthy Air should be part of the flat. It does not add any extra value to that motion sensor. App you should have anyway when you get the washer and dryer. Charging point and lock is just in there.
For all services 30-50€ per month.	
50 Euros per month.	Feels reasonable because there are a lot of things in there that I do not need. If the choice is between flat with <*those smart services*> and no flat, then with. The Smart Lock I would replace.
50 - 100€	
If it is only 70€ then maybe you can do it.	Because of the maintenance. But still, I do not need to have too many devices because of durability.
80 to 100€ I would consider profitable.	If it is more than that it is quickly too expensive.
More than 100€	
120€ extra on the rent, I would consider it. I would not be shocked.	
For a total of 150€ per month.	You save energy. I assume you do not use gas. I assume HR gas; you save on that. I assume solar panels are used. You save with that. I assume you can also regulate indoor air yourself. You save with that.

2.10 Sharing data

Opinions differ when it comes to sharing data (see Table 36). It appears that some data, such as Smart Lock data (e.g., data about presence at home and location), is more sensitive for people than other data, such as the time when the dishwasher is running. Some participants also indicate that the data should not be used for commercial purposes.

Table 36. Willingness to share data. In this case opinions instead of participants were counted because the opinions of some participants differed for some services

Willingness to share data	Quote
Yes [7 opinions]	I find it interesting to know for myself, but I do not mind that it is stored in an app. I want to see it for myself. I rely on safe storage. When my dishwasher is running is not so important for me if people know.
No [7 opinions]	If a company has an agreement that it is not for commercial purposes, I have less of a problem with it. Then it misses the target (you say you are doing something sustainable but in fact you are selling data). Data when you are at home and when you are not at home, I find sensitive information. Yes, I have problems with it. Everything that is going on outside, that I do not have a say in, I find annoying. The only thing I do not feel comfortable with is the lock. People can abuse it. I do not like sharing data about my presence and location. But if they know where you are, it feels less nice.

3 Conclusions and recommendations

3.1 Conclusions

Participants perceive the Smart Dishwasher as the most attractive and the Smart Dryer as the least attractive smart service.
Although the results are based on a small number of participants, we do find a service that was valued most, and one that is valued least. The analysis of the interviews shows that the most attractive smart service is the Smart Dishwasher with nine out of ten participants intending to purchase it. The most prominent drivers for this choice are the cost advantage and the sustainability of the Smart Dishwasher (see Table 37 for an overview of the drivers per service). Additionally, convenience aspects and saving energy are mentioned as drivers.

For the least attractive smart device, the Smart Dryer, the perceived lack of safety (risk of fire) is the most often mentioned dealbreaker. Further, there is hardly any perceived need, the cost is perceived to be too high and there are doubts about the freshness of the laundry. As only half of the participants use a dryer and people do not experience noise pollution from the dryer, the additional benefits of the smart service do not target the demands of the participants.

Table 37. Overview of drivers per smart service, ranked from most attractive to least attractive smart service. In bold the driver that is mentioned most across smart services.

	Drivers
Smart Dishwasher	Cost advantage [8 participants] Sustainability [4 participants] **Convenience** [3 participants] Saving energy [3 participants] Control [2 participants]
Green Charging	Green energy [3 participants] Sustainability [3 participants] Independence [2 participants] **Convenience** [2 participants] Cost saving [2 participants]
Healthy Air	Positive impact on health [6 participants] Insight into air quality [4 participants] Close windows against mosquitoes or noise [3 participants] **Convenience** [3 participants] Saving energy [1 participant] Innovation [1 participant]
Smart Lock	**Convenience** [5 participants] Safety [1 participant]
Fresh Laundry	**Convenience** [6 participants] Freshness laundry [3 participants]. Cost saving [2 participants] Not hearing noise [1 participant] Renting the washing machine [1 participant] Renewable energy [1 participant]
Smart Dryer	**Convenience** [5 participants]

	Drivers
	Cost reduction [2 participants] Noise reduction [2 participants] Sustainability [1 participant]

Lack of need, high costs or low cost savings are the most dominant dealbreakers

In general, dealbreakers that are mentioned most often are lack of need and high costs or low cost savings (see Table 38). The lack of need mainly due to satisfaction with traditional appliances or preference for manual control is named as dealbreakers for each of the six services. High cost or low cost savings are dealbreakers for the smart services Healthy Air, Green Charging, Fresh Laundry, and Smart Dryer. A lack of safety or sense of insecurity are declared to be dealbreakers for Fresh Laundry, the Smart Lock and Smart Dryer. Finally, doubts about whether it works technically are dealbreakers for the adoption of the smart services Healthy Air and Green Charging.

Table 38. Overview of dealbreakers per smart service, ranked from most attractive to least attractive smart service

	Lack of need	High cost/ low cost savings	Lack of safety/ sense of insecurity	Doubts whether it works technically
Smart Dishwasher	x			
Green Charging	x	x		x
Healthy Air	x	x		x
Smart Lock	x		x	
Fresh Laundry	x	x	x	
Smart Dryer	x	x	x	

There is a large variation in the amount people would be willing to spend on the iWonen package

The opinions differ quite heavily, ranging from 0€ and 150€ per month.

Mixed opinions about sharing data

When it comes to data sharing, the opinions are quite mixed. Some data, such being present at home and the location, is more sensitive for people than other data, such as the time when the dishwasher is running. Important for participants is that the data is not used for commercial purposes.

The dependency on apps and the internet is often seen as barrier to purchase smart services

When looking at the results for three out of six services, namely the Smart Dryer, Smart Dishwasher and Fresh Laundry, people are concerned about the dependency on apps as well as the internet. People are exhausted due to the sheer number of apps they have on their cell phone (Quote: "No, is just another app, I think."). Further, they think an app makes you dependent on the internet and good reception (Quote: "And the disadvantage is that you become more and more dependent on a good internet connection.").

3.2 Recommendations

Develop propositions based on the needs of consumers and reduce perceived barriers of consumers

Healthy Air

- Communication should focus on the positive impact of the smart service on health. Specifically, people should be informed about the negative effects of bad air quality, such as the CO2 levels which one does not notice oneself. Addressing this problem and showing how the smart ventilation improves this issue could also address doubts people have about whether the ventilation significantly improves the air quality.
- It also is perceived as convenient as the user does not have to turn off the ventilation manually anymore.
- Highlight the fact that it reduces energy usage whenever somebody is not present by means of the motion sensor.
- People find it important to be able to open their window. On a technical note, a sensor should be included which indicates the ventilation to stop whenever a window is opened in the house.
- In addition, highlight the downsides of opening a window: mosquitos, noise, and loss of heat (energy).
- Concerns about possible excessive cost (no costs were presented in the study) of the smart service can be reduced by being transparent and concrete about the costs and cost benefits of the service Healthy Air.

Smart Dishwasher

- The most mentioned driver of purchasing and adopting the Smart Dishwasher is the cost advantage, which means that communication should focus on being transparent and concrete about the cost benefits.
- Also, the benefits in terms of being more sustainable should be highlighted. This in turn should also reduce the perceived lack of need of the Smart Dishwasher. People do not perceive the need to delay washing their dishes.
- Further, the service is seen as inefficient, since they worry the dishwasher will start automatically while not being properly filled. Therefore, the functioning of the appliance should be explained properly.

Green Charging

- Communication about the smart service Green Charging should mainly focus on the usage of green energy and its positive impact on sustainability in contrast to the usage of conventional fossil fuel cars.
- Other aspects to highlight are the convenient app that shows how full the battery is and how far one can drive with it, as well as the use of self-generated energy in case of using one's solar panels.
- People have doubts about whether the service will work in unexpected scenarios, such as having an empty car battery, but no sun and no wind or everybody starts charging in the afternoon or at night. This is why concrete scenarios and examples of usage should be shown to the consumers. This may also eliminate the fear of being less flexible and restricted in one's freedom.

- Due to the fact that low cost savings are perceived as a dealbreaker, giving estimations of cost savings of "a few euros per month" is not concrete enough to be an argument that would convince consumers to adopt and invest in the smart service Green Charging. Again, being transparent and concrete about the costs and cost benefits may reduce the perceived barrier if the benefits are high enough.

Fresh Laundry
- Communication should focus on the convenience, meaning the regulation of the washing machine from outside the house, the service offers through the usage of the app.
- In line with that, it should be highlighted that it creates freedom to leave the house.
- Further, the freshness of the laundry due to the controllability of when the laundry is ready to be dried should be mentioned.
- Doubts about the functionality can be eliminated by precisely showing how the use of sustainable energy and the laundry being ready at a certain time, are two goals that can be attained at the same time.

Smart Lock
- Communication about the service Smart Lock should focus on the convenience of not having to carry around a key, not having to search for it or use it while for example carrying shopping bags though the door and focus on not having to pay for a new one when losing it, and changing the locks. Especially since consumers perceive the service as being redundant, communicating its convenience is key in this case.
- Further, in order to eliminate the experienced sense of insecurity (worries about being hacked) and lack in trust in the technology (in case of fire and internet outages), the functionality and safety the Smart Lock must be addressed properly.

Smart Dryer
- The convenience of the Smart Dryer, meaning the regulation of the dryer from outside the house, must be highlighted. Specifically, the usage of one app to keep track of all appliances in one's appartement is perceived as convenient.
- Based on the most important dealbreakers for the purchase and adoption of the Smart Dryer, namely the perceived risk of fire, we recommend offering a sensor which ensures fire safety.
- Further, the cost reduction should be highlighted.
- The costs and cost benefits should be communicated transparently.
- Finally, concrete scenarios should be used to increase the trust in the functionality of the service, especially when it comes to the freshness of the laundry. People are worried their wet laundry will be in the dryer quite some time before the dryer will be started.

Be transparent about the (usage of) data consumers are asked to share.
Due to the fact that people are suspicious about the data that they are asked to share via de apps that are part of the smart services, we advise to be transparent about (1) which data is asked of consumers, (2) who has access to this data, and (3) for what purposes the data is used. For the latter it is important to make sure as well as communicate that the data is not used for commercial purposes.

Consider providing an addition to the app, such as an in-home display.
In addition to using apps, a monitor in the house could be used in order to decrease the exhaustion people tend to feel when it comes to the number of apps, they have on their cell phone. The advantages of an in-home display are that people do not receive additional pop-up messages on their cell phones and feel less dependent on their cell phone when it comes to daily activities, such as washing the dishes. Survey research by Motivaction (2020) shows that some people prefer an app and others a display or webpage to manage the energy in their homes.

References

Motivaction (2020). Gedragsonderzoek Energieverbruiksmanagers. Retrieved from: https://www.rijksoverheid.nl/documenten/rapporten/2020/02/10/rapportage-gedragsonderzoek-energieverbruiksmanagers

Motivaction (2021). Publieksmonitor Klimaat en Energie 2021: Rapportage. Retrieved from https://www.rijksoverheid.nl/documenten/rapporten/2021/10/11/publieksmonitor-klimaat-en-energie-2021-motivaction

A Description of six smart services

A.1 Healthy Air

The smart service "Healthy Air" is a ventilation system that automatically ensures a supply of fresh air in the house, thanks to a smart sensor. It includes a sensor that measures temperature, humidity and substances in the air (such as fine dust, carbon dioxide, gases and paint fumes, new floor covering, cleaning products, smog), and motion sensors that measure whether someone is present in a room. In case the air quality is not good, the system starts to ventilate (more). If nobody is present, the system will ventilate less to save energy. Either the sensor gives a signal when the air quality is good again or you decide for yourself when the air quality is good. You can also increase or decrease ventilation yourself anytime. It is also possible to open the window or door while the ventilation is on. However, heat will be lost so opening windows and doors should be reduced to a minimum.

The benefits of this smart service are:

- No more worries about air quality.
- Better insight into air quality, including insight in activities that have an impact on air quality.
- Saving energy by recovering heat in the ventilation system.

The disadvantages of this smart service are:

- It causes noise pollution when running at higher speed for fresh air supply.
- Ventilation through windows and doors must be limited.

A.2 Smart Dishwasher

This service is a dishwasher that turns on automatically when there is a lot of energy available, meaning when energy is cheaper. The dishwasher comes with an app. In the app, you set the dishwasher to wait until the moment when the use of electricity is cheapest. First, you fill the dishwasher, select the programme and press "start". The dishwasher will then usually start at night or in the afternoon, but you can also indicate the latest time at which the dished should be ready. Additionally, turning the dishwasher on manually is also possible at any time.

The benefits of this smart service are:

- Contribution to sustainability by incorporating sustainable energy (sun- and wind-energy).
- Cost saving in combination with flexible tariffs.

The disadvantages of this smart service are:

- Selection of preferences in the app necessary once.

A.3 Green Charging

With the smart service "Green Charging", your electric car is charged when there is plenty of energy available from the wind and/or sun, including from your own solar panels. The car is charged when there is a lot of sun (mostly in the afternoon) or wind (mostly at night). In this way you contribute to the integration of sustainable energy. Depending on how much the car is charging and how much flexibility it can provide, a few euros per month can be saved. Green Charging comes with an app with which you can set one or two standard scenarios (e.g., "to work", "at home"). You also decide about the minimum battery fullness and when this should be reached (e.g., because you want to leave). These default settings can be adjusted (e.g., if you do not go to work one day or want to go to work an hour earlier). There is also the option of putting a weekly schedule in the app or linking the app to your digital calendar. Another option is that the service learns from your behaviour and based on that, automatically makes choices or suggests a handy recharging schedule. You can also choose to change the settings every day.

The benefits of this smart service are:

- Contribution to sustainability by incorporating sustainable energy (sun- and wind-energy).
- Saving money by using cheaper energy.

The disadvantages of this smart service are:

- Selection of settings: when you want to go out by car, and how much the battery needs to be charged.
- Or sharing your schedule with the service.
- Or the Green Charging service remembers when you use the car and the charging station.

A.4 Fresh Laundry

The smart service "Fresh Laundry" is a smart washing machine that makes sure your laundry is ready exactly when you get home so you can hang it up or put it in the dryer. The service comes with an app in which you can set the earliest possible time for your laundry to be ready. After you have put the laundry in the washing machine and set it to start automatically, it chooses its starting moment, while taking into account low energy tariffs. The rental costs of the smart service Fresh Laundry costs about 20-30 Euros per month. The estimated cost savings are a few euros per year, which may become more in the future when energy prices change.

The benefits of this smart service are:

- Fresh Laundry: your laundry never stays in the drum for too long. The wash is always ready when you want it.
- The larger the time frame, the more you can benefit from lower energy tariffs.
- The washing machine can be operated remotely once the programme has been set.
- Contribution to sustainability by incorporating sustainable energy (sun- and wind-energy) within your chosen time frame.

The disadvantages of this smart service are:
- Selection of preferences in the app necessary once.
- If the internet connection goes down, the settings remain stored in the system, but the washing machine can no longer be operated remotely.

A.5 Smart Lock

With the smart service "Smart Lock", you can use an app to give others, such as he cleaner, friends, family, the babysitter or a delivery person, remote access to your home. This access you can grant for a certain period of time and remove at any time. If the other person does not own a smartphone (with the possibility to use an app), you can also give them a PIN code. In case you have forgotten your phone yourself or your battery died, this PIN code comes in handy as well. Additionally, the lock can also be opened with a "turnkey" like an old safe. Another feature of the app is that you can press the unlock button in the app when you are nearby or let it automatically unlock based on location.

The benefits of this smart service are:
- A key is no longer needed, meaning that you only need to have your smart phone with you to open the door and there is no risk of forgetting your key.
- If you lose your key, it is no longer necessary to change the locks.
- External persons can get access without a key, meaning there is no key transfer or key hiding necessary.
- Good overview via the app over who can enter the house and when people have entered.
- The access to the house can be withdrawn at any time.
- The front door can also be opened with a pin code which can be chosen and changed by the user.

The disadvantages of this smart service are:
- If your smartphone is empty or you forgot it, you have to remember the PIN code and use it.
- If you have a new phone, you have to re-authorise it.
- Bluetooth needs to be on for automatic unlocking.

A.6 Smart Dryer

The smart service "Smart Dryer" is a dryer that turns on when you are away from home in order to reduce noise pollution. It comes with an app in which you can indicate when you are not home, or you can link the app to your calendar. After you have put the laundry in, the dryer the dryer starts when you are not home, while also taking into account favourable energy rate. The rental costs of the smart service Fresh Laundry costs about 20-30 Euros per month. The estimated cost savings are a few euros per year, which may become more in the future when energy prices change.

The benefits of this smart service are:
- No noise from the dryer.

- The larger the time frame, the more opportunity there is to take advantage of lower energy tariffs.
- Remote control of the dryer when programme is set.
- Contribution to sustainability by incorporating sustainable energy (sun- and wind-energy) within your chosen time frame.

The disadvantages of this smart service are:

- If the internet connection goes down, the settings remain stored in the system, but the dryer can no longer be operated remotely.

B Interview protocol

B.1 Introduction

In this interview, we want to discuss a number of services that are part of a so-called "smart house". These services will be offered in the new building at Strijp S called "Next".

These products and services should encourage residents to use a lot of energy if there is a large supply of sustainable energy, and less energy if there is less supply. The products and services must also ensure that living at home becomes (even) more pleasant, more comfortable or safer.

There are no wrong answers, it is about your own opinion.
This conversation lasts a maximum of 1.5 hours.

B.2 Background

- Gender
- Age
- What kind of house do you live in now?
- Do you already use smart devices or services? Which?

We have several products and services that we would like to present to you.

B.3 Healthy Air

Air quality
When you think about the air quality in your home, what are your first thoughts?
Are you aware of the air quality in your home? How?
Do you ever experience air quality problems in your home?

Ventilation
When you think about ventilation in your home, what are your first thoughts?
Are you aware of the ventilation in your home? How?
Do you ever experience ventilation problems in your home?

[Show the Healthy Air Service slide]
What is your first reaction?
What appeals to you?
What appeals to you less?
What questions does it raise?

I will now give some more details of this service. [Let slide How does it work? see]
What is your first reaction?

Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

These are the pros and cons of the service. [Show slide Pros and cons]
Does this change your opinion about the service?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

B.4 Smart Dishwasher

Do you have your own dishwasher?
Are you concerned about/ engaged in sustainability?
In which ways?

[Show slide dishwasher]
What is your first reaction?
What appeals to you?
What appeals to you less?
What questions does it raise?

I will now give some more details of this service. [Let slide How does it work? see]
What is your first reaction?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

These are the pros and cons of the service. [Show slide Pros and cons]
Does this change your opinion about the service?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

B.5 Green Charging

Electric driving
Do you have an electric car?
What energy would you prefer to charge your car on?
Imagine driving an electric car in the future. What thoughts do you have about charging the electric car?
What energy would you prefer to charge your car on?

Sustainability
Are you concerned about/ engaged in sustainability?
In which ways?
Imagine you have solar panels. To what extent does it appeal to you that you can then use the energy you have generated yourself for Green Charging?

[Show slide Green Charging]
What is your first reaction?
What appeals to you?

What appeals to you less?
What questions does it raise?

I will now give some more details of this service. [Let slide How does it work? see]
What is your first reaction?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

These are the cost/savings. [Show slide costs/savings]
What is your first reaction?

These are the pros and cons of the service. [Show slide Pros and cons]
Does this change your opinion about the service?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

B.6 Fresh Laundry

When do you usually do the laundry?
Does it happen that the laundry is left in the drum for too long?
Do you ever leave when the washing machine is running?

[Show slide Fresh Laundry Service]
What is your first reaction?
What appeals to you?
What appeals to you less?
What questions does it raise?

I will now give some more details of this service. [Let slide How does it work? see]
What is your first reaction?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

These are the cost/ savings. [Show slide costs/ savings]
What is your first reaction?

These are the pros and cons of the service. [Show slide Pros and cons]
Does this change your opinion about the service?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

B.7 Smart Lock

Does it happen that you want to let someone into your house while you are not at home yourself?
Can you give examples?
Are there people in your area who have a house key from you?
Can you give examples?

[Show slide Smart Lock]
What is your first reaction?
What appeals to you?
What appeals to you less?
What questions does it raise?

I will now give some more details of this service. [Let slide How does it work? see]
What is your first reaction?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

These are the pros and cons of the service. [Show slide Pros and cons]
Does this change your opinion about the service?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

B.8 Smart Dryer

Do you use a dryer?
If so, what do you like about a dryer? And less nice?
If not, would you like to use a dryer?
Do you ever experience noise nuisance from the dryer?

[Show slide Smart Dryer]
What is your first reaction?
What appeals to you?
What appeals to you less?
What questions does it raise?

I will now give some more details of this service. [Let slide How does it work? see]
What is your first reaction?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

These are the cost/ savings. [Show slide costs/ savings]
What is your first reaction?

These are the pros and cons of the service. [Show slide Pros and cons]
Does this change your opinion about the service?
Would you buy this service? Why or why not?
Are there conditions under which you would buy this service?

B.9 Closing after all individual services

Finally, we would like to ask you about all the products and services we discussed.
What services would you like to have? Why this one?
Are there any products or services that you never buy like this? Which? Why?

B.10 iWonen package

The entire package of services that will soon be offered in the "Next" building looks like this: [show slide iWonen package]
How much would you be willing to pay for the whole package of services?
First open question, only then range as.
0-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, euros per month.

B.11 Sharing data

Is there any data that you find it difficult to share or that you are hesitating about at the moment?
For example: data about when the Smart Lock is open, when you go to work with the EV, your agenda, the air quality, when the dishwasher is running, when the washing machine or dryer is running, or when you are or are not present in, for example, your bedroom or living room.

Thank you for your participation. Do you have any questions yourself?