DESIGNING AMPUL

EXPLORING FUTURE PROSUMER INTERACTIONS

A MASTER GRADUATION WORK BY JAAP RUTTEN

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EXPLORING FUTURE PROSUMER INTERACTIONS

GRADUATION THESIS OF JAAP RUTTEN

FOR THE MASTER DEGREE OF DESIGN FOR INTERACTION AT THE FACULTY OF INDUSTRIAL DESIGN ENGINEERING AT THE DELFT UNIVERSITY OF TECHNOLOGY.

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18 APRIL 2013

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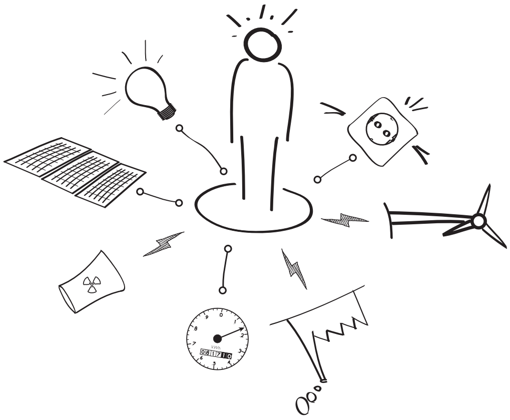

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IN THIS PROJECT AN EXPLORATION IS DONE OF THE CURRENT PLACE OF THE USER IN THE ENERGY MARKET AND LEADS TO THE CONCEPTUALISATION OF A NEW PRODUCT WHICH I NAME AMPUL. IT AIMS TO CONNECT PERSONAL OR SMALL-SCALE ENERGY PRODUCTION SUCH AS SOLAR CELL TECHNOLOGY WITH PEOPLE'S DOMESTIC ENVIRONMENT AND THEIR DAILY LIFE ACTIVITIES IN A MEANINGFUL AND NATURAL MANNER.

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7 INTRODUCTION

11 **PART 1**

13 (A) Dutch Energy market

25 (B) The User, its role in the current system and relation to the other players

37 **Intermezzo**

39 **PART 2**

41 (C) Eco visualisation

49 (D) User motivation, which tools can be used to stimulate household electricity prosumption

63 **Intermezzo**

65 **PART 3**

67 (E) Bottom up, designing for User involvement in Electricity Prosumption

87 (F) Validation, user testing of ampul

105 IMPLEMENTATIONS

110 ACKNOWLEDGEMENTS

111 APPENDICES

ABOUT AMPUL

Ampul is a product-system which is designed to give people more control over their household electricity consumption through positive stimulation. Unlike other products, Ampul encourages the user to generate his/her own electricity by e.g. solar cells. When the user has installed solar cell modules, it recommends when and how the generated electricity can be put to use best. In order to develop Ampul, several in depth user studies have been conducted to define particularly the user interaction with the product-system. As a result Ampul has the ability to become a sixth sense for the user, in terms of electricity production and consumption.

INTRODUCTION

ENERGY HAS BECOME ONE OF OUR PRIMARY NEEDS, NOT ONLY TO KEEP OUR HOUSES WARM BUT ALSO TO SUPPORT OR TO MAKE POSSIBLE MANY OF OUR DAILY ACTIVITIES. VAST INFRASTRUCTURAL SYSTEMS SUPPLY EVERYONE WITH ENERGY FOR A REASONABLE PRICE. THEY ARE HOWEVER LARGELY DEPENDENT ON FUEL SOURCES WHICH ARE NOT SUSTAINABLE. IN ORDER TO ESTABLISH A SECURE AND ENVIRONMENTALLY SOUND ALTERNATIVE, THE NETHERLANDS HAS LIBERALISED ITS ENERGY MARKET. ALTHOUGH IT WAS INTENDED TO ESTABLISH A MARKET PLACE WHERE COMPETITION COULD TAKE PLACE, IT IS CURRENTLY DOMINATED BY FEW LARGE PLAYERS WHO CONTROL THE SYSTEM TIGHTLY. DEMOCRATISATION OF THE SYSTEM IS NEEDED TO OPEN THE ENERGY MARKET AND STIMULATE INNOVATION WHILE ENSURING A BALANCE BETWEEN SUPPLY AND DEMAND.

Thanks to advances in technology a time has arrived where it is possible to generate energy by virtually everyone for a competitive price. To produce energy on a small scale, fossil fuels are unattractive because energy can be extracted from them more efficiently on a larger scale. For technologies such as solar photovoltaic panels, there is no scale limitation. For that reason alone, solar panels are an attractive means to generate energy for households. Nevertheless, experts or people with good background knowledge are needed to install and run such an energy production facility at home. So for laymen users without 'special' knowledge, the idea of personal energy production might not be very appealing. I believe that in order to establish a democracy in the energy market every user in the system should be able to become an active player and use technologies to generate energy.

To describe the technology transfer of photovoltaics as mass energy production system as I envision it, I would like to use an analogy: the Internet. We met the Internet in its very early form when the first computers were developed in the 1950's, but it was only in 1995 that the Internet became widely available to consumers. In this analogy, the Internet and the hardware are comparable to what photovoltaic panels are now in the energy world. The Internet was available to consumers in 1995 through computers, which were not optimised to be integrated in households and were not easily accessible for most consumers. With the introduction of the iPhone and other smartphones in 2007 and later, the Internet became an easy to use technology for virtually everyone, it became a democratised commodity. The Internet is a particularly successful example of a democratised system which is constantly improving, because new players are constantly entering the system and make it better. Solar energy might not be able to follow literally the same route as the Internet did to become a commodity technology accessible to every user that can afford it. But, as solar energy by photovoltaics has evolved over the years into an affordable technology, it should also evolve into a more accessible technology by implementing it in a more attractive and natural way in the domestic environment. Then we can assure that every user will play an active role towards a more democratised energy system.

Is such a change in 'users' role' easy to achieve? In the current energy market, 'not'! Energy as medium is very abstract and does not carry any tangible form and is therefore very hard to relate to a tangible action. In order to motivate people to take an active role in producing and using it, I think the way and the form we use it, should have more relation with human nature. In order to do that, first the current understanding regarding 'energy production and consumption' of users should be explored. The so called 'prosumer' is introduced, which combines producer and consumer in one user.

In this project, after a thorough exploration of the current place of the user in the energy market, I create a concept- which I name Ampul- that aims to connect personal or small-scale energy production with people's domestic environment in a meaningful and natural manner. The Concept House1, which was built in Heijplaat, Rotterdam under a European founded project to explore the user perception, involvement, understanding and acceptance of newly introduced sustainable technologies, is used as a context to test the created concept with actual users.

This report presents my journey through designing of 'Ampul'. I present this journey in three parts.
PART 1: understanding the current energy market
PART 2: exploring user involvement
PART 3: designing user involvement

The questions tackled in these three parts are as follows:

PART 1

Q1 How is the energy market shaped in The Netherlands? And why is it shaped this way? (answered by Literature)

Q2 What are the current solutions for renewable energy production? (answered by Literature)

Q3 Which form of renewable energy is most convenient for democratisation? (answered by Literature)

Q4 What is the current awareness of users on the use of electricity? (answered by Literature and user-Study 1: Online Survey)

PART 2

Q5 What are the existing tools and methods used in involving users in electricity production/ consumption (prosumption)? (answered by Literature)

Q6 How is information regarding prosumption visualized in these existing tools? (answered by Literature and an Expert Interview)

Q7 How can the user be motivated for household electricity prosumption? (answered by Literature and user-Study 2: Field Study)

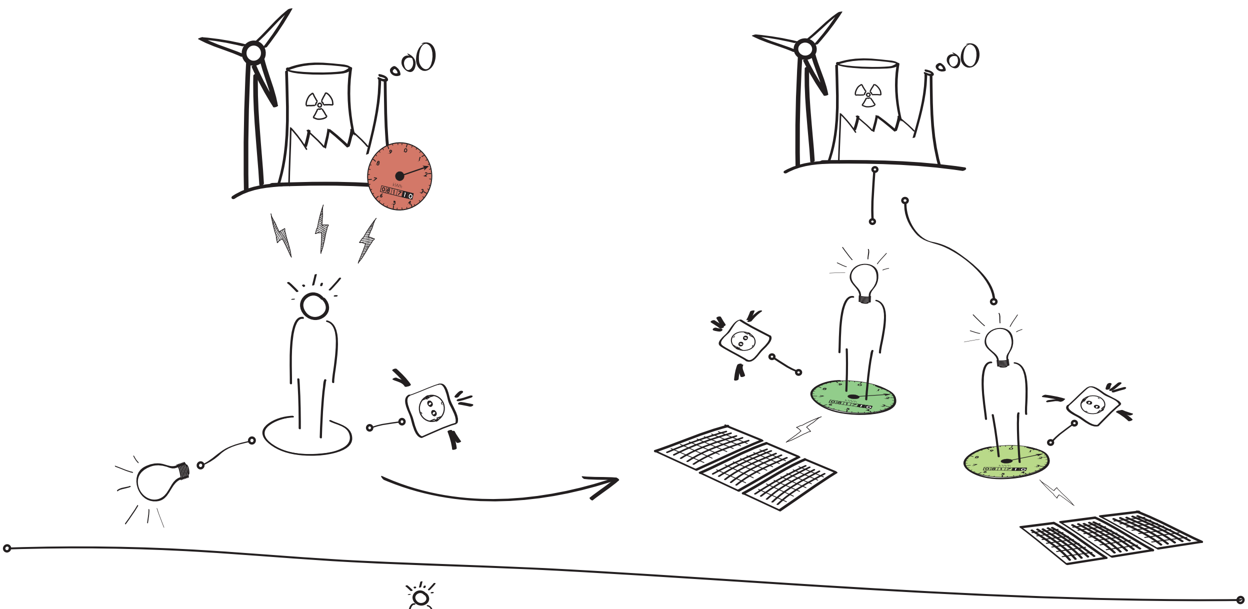
PART 3

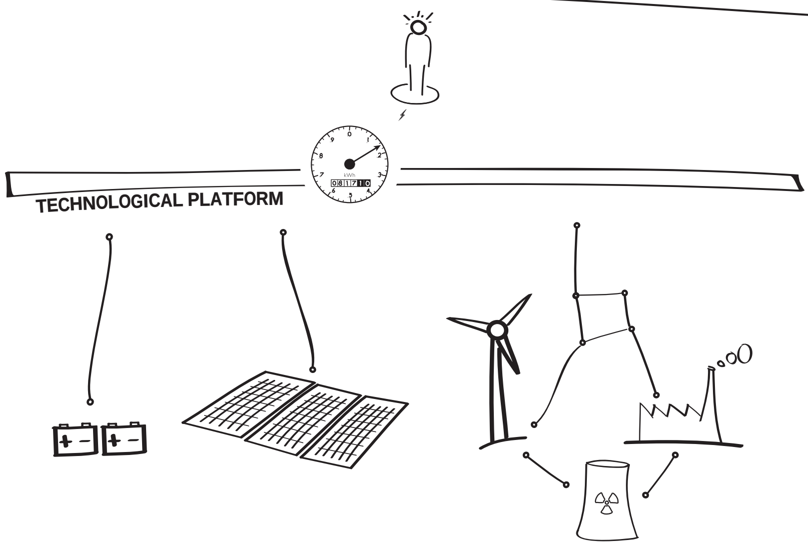
Q8 What are the final 'design and experience' requirements for a system that involves user actively? (answered by literature, findings of study 1&2, the ViP Method and Conceptualisation)

Q9 Does the final design achieve the main aim? (answered by user-Study 3: participatory User Testing)

EXPLORING FUTURE PROSUMER INTERACTIONS

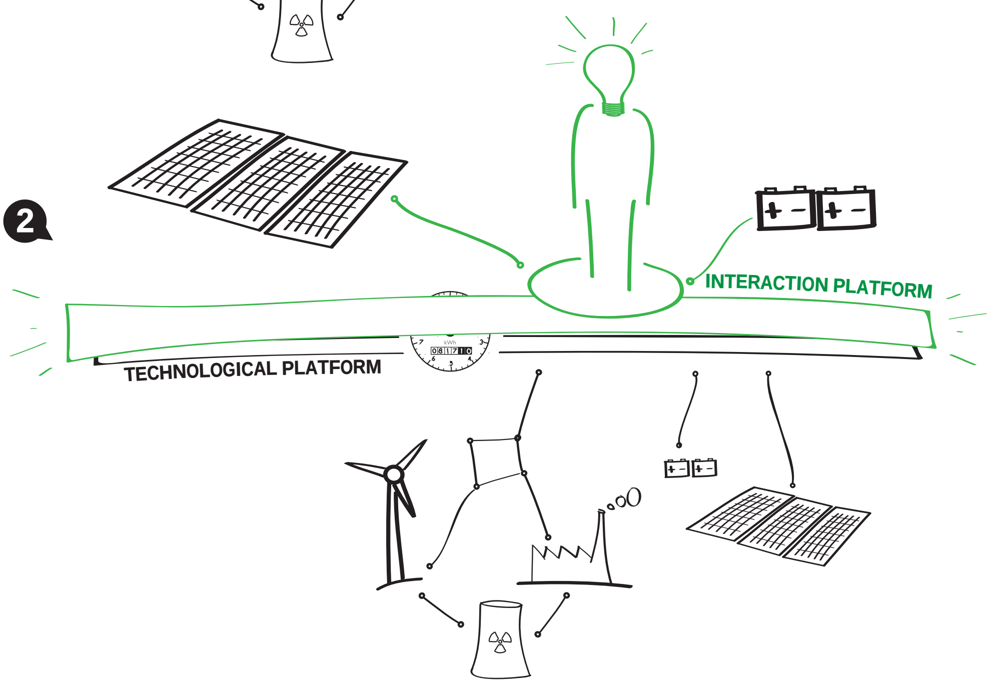
FROM **PASSIVE** CONSUMER → TO **ACTIVE PROSUMER**





1 current system

The system has a distinctive top-down character. Although the consumer pays for the electricity, he or she has a rather passive role in the system. This prohibits the possibility for the user to have influence on the consump-tion and production of the electricity he or she uses.



2 envisioned system

To give the user a more active role while consuming electricity and in the energy market, he or she should become also a producer of electricity or at least have a say in the production system. The so called ‘prosumer’ is introduced, which combines producer and consumer in one user. To give the prosumer movement momentum, the entry-level should be lower as it is currently. An interaction platform is introduced in the technical world of the energy market.

By installing solar cells on the roof of any suited household, consumers also become producers of electricity.

PART 1
UNDERSTANDING THE CURRENT ENERGY MARKET

IN THE INTRODUCTION I ARGUE FOR A DEMOCRATISATION OF THE ENERGY MARKET. IN THIS FIRST PART OF THE PROJECT WILL BE EXPLORED HOW THE CURRENT ENERGY MARKET IS SHAPED AND WHICH PLACE THE USER HAS IN IT. THE FOLLOWING QUESTIONS WILL BE DISCUSSED:

Q1 HOW IS THE ENERGY MARKET SHAPED IN THE NETHERLANDS? AND WHY IS IT SHAPED THIS WAY?

Q2 WHAT ARE THE CURRENT SOLUTIONS FOR RENEWABLE ENERGY PRODUCTION?

Q3 WHICH FORM OF RENEWABLE ENERGY IS MOST CONVENIENT FOR DEMOCRATISATION?

Q4 WHAT IS THE CURRENT AWARENESS OF USERS ON THE USE OF ELECTRICITY?

photo:
Photovoltaic PV
Northern Ireland

source:
http://www.ambergreenenergy.co.uk/tag/solar-panels/page/2

(A) DUTCH ENERGY-MARKET

ENERGY IS ONE OF OUR PRIMARY NEEDS AND HAS BECOME INCREASINGLY IMPORTANT FOR MANY OF OUR ACTIVITIES IN THIS INCREASINGLY HIGHLY DEVELOPED WORLD. TO BE ABLE TO UNDERSTAND WHY A DEMOCRATISATION OF THE ENERGY MARKET IS NEEDED, THE FOLLOWING CHAPTER WILL EXPLORE THE CURRENT SITUATION OF THE DUTCH ENERGY MARKET AND IT'S EFFECTS ON THE CURRENT AND FUTURE SCENARIO OF ENERGY SUPPLY AND CONSUMPTION.

1. THE GRID: A FACILITATOR FOR EFFICIENT USE OF FOSSIL FUELS

The network of electricity systems that connects the facilities where electricity is produced to the places where it is consumed, is also known as the grid. In the last century it has evolved from a system of small local systems, to a large interconnected complex system.

1.1 History

After electricity became a competitor for gas in 1880, the first small scale and private installations for generation of electricity were established. Those were followed by the establishment of a grid which would serve to distribute the generated electricity to consumers to sell it. After the Second World War (1945) energy companies formed two partnerships, the SEP (Samenwerkende Electriciteits-Productiebedrijven) and VEEN (Vereniging van Exploitanten van Elektriciteitsbedrijven in Nederland), which respectively were a partnership between energy producers and an association of energy distributors. This initiative created a self regulatory system with very little influence of the regional and national government (Rödel, 2008). After the first oil crisis in 1973, the Dutch government became increasingly aware of the importance of energy for the country and felt their involvement in its infrastructure and generation should be more influential. They reacted with their first Energy White Paper (1974), with as major outcomes, the increase of diversification of energy sources and the efficiency of energy to reduce environmental impacts. The energy companies were unhappy with this involvement and saw a decrease of their influence on the energy market, which was dominated by them (Verbong and Geels, 2006). The government requested to change the fuel mix for the electricity generation, to meet their targets issued in the Energy White Paper.

The SEP, who became owner of the national electricity grid in 1970 established amongst others the E-plan, which was accepted by the government and used to determine the expansion of the grid based on the growing demand. In 1980 a second White Paper was published by the government, with energy saving as one of the top priorities in future legislation. One of the incentives was to stimulate connection to the grid of decentralised CHP (Combined Heat and Power) installations in companies. Private companies were already producing 3200 GWh or 10,6% of the total Dutch energy production, but this energy was mainly for private use and not connected to the national energy grid (Verbong and Geels, 2006). One of the obstacles which prevented the decentralised units to become part of the grid were the low compensation tariffs that the producers would receive for the electricity they would provide. The traditional larger energy companies were not cooperating in setting up an attractive system in which private energy companies would be stimulated to become producers. Finally the government stepped in and forced the energy corporations to include the private producers to the grid. After 1983 decentralised energy started to gather speed, but mainly because new CHP plants were build (Verbong and Geels, 2006).

An important change in the Dutch electricity market was initiated by the introduction of a national planning system which eventually resulted in a new law (Van Damme 2005). The electricity grid became a national system, where it was first consisting out of small regional grids. The most efficient power plants where connected to the national grid first and the regional energy plants where used to balance the supply and demand. This system was supposed to become more efficient, with supply and demand more balanced and made it possible to import and export electricity from other European countries. With the new system the transport and distribution infrastructure for electricity was separated from the production infrastructure, the Energy Distribution Company (EDC) was established as well as a standard base tariff for supply to the grid. Four large EDC's dominated the market, Nuon, Essent, Eneco and Delta, which were buying energy from competing producers. The EDC's also started to invest in their own production companies and eventually, the supply and demand was not tuned anymore which resulted in cut backs on fundings for the decentralised electricity suppliers. The result is a liberalisation of the energy market with competing energy companies and large EDC's which operate between supply and demand (Verbong and Geels, 2006), see also figure 1.1.

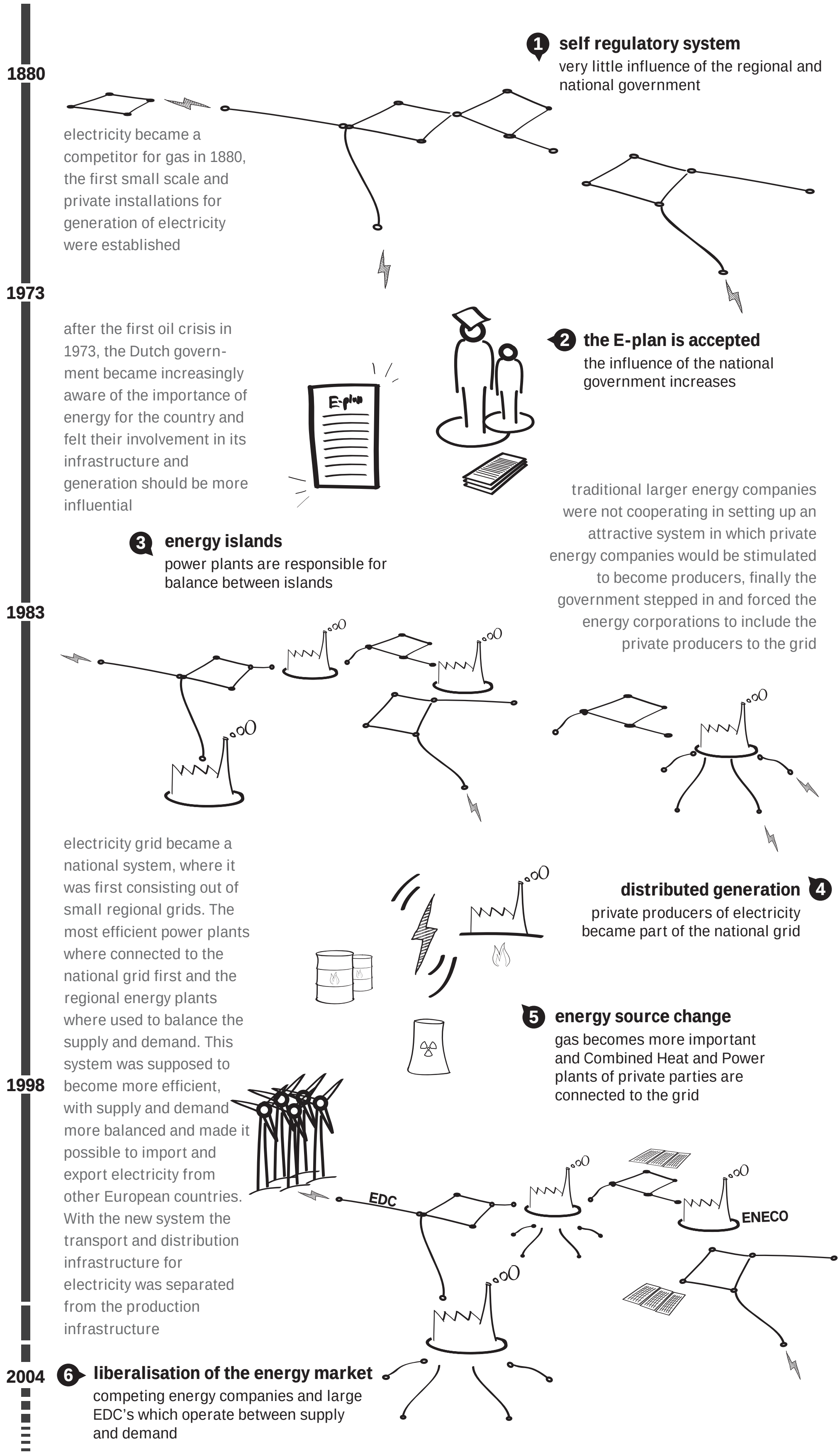


figure 1.1
the evolution of the energy market in The Netherlands, with focus on important changes which shaped the current system

1.2 STATUS QUO, CURRENT DUTCH ENERGY MARKET

The current system is characterised by the developments of the past and particularly by the liberalisation of the energy market, which took place from 1998 till 2004 (Van Damme 2005). The different actors in the current market can be categorised in the following layers: an institutional, an economical and a physical layer (Kobus, 2010). The institutional layer provides and prescribes the rules and shape of the current energy market, in which the Dutch government is owner of the grid and other parties supervise and regulate it. The economical layer operates together with the physical layer, where producers, suppliers and consumers in the physical layer, determine how traders and brokers in the economical layer shape the energy market. On the APX (the Dutch power exchange) electricity is traded for the next day, to either buy or sell electricity to foresee changes in demand. The APX exists due to the inability to store electricity in the current system, with as result higher electricity prices in peak hours and a complex system to secure the stability of the grid. All electricity producers in the grid are made ‘program responsible’, which means every supplier of electricity submits a schedule with a plan for generation and/or consumption to TenneT, which operates the electricity transportation grid in the Netherlands since 1998, according to Wikipedia (2012). In theory the schedules should make a tight match in supply and demand, but in practise sudden peaks in demand will have to be supplied by special power reserve plants (Kobus 2010).

The physical layer of the electricity system in the Netherlands can be divided in generation, transport, distribution, supply and consumption, see also figure 1.2.

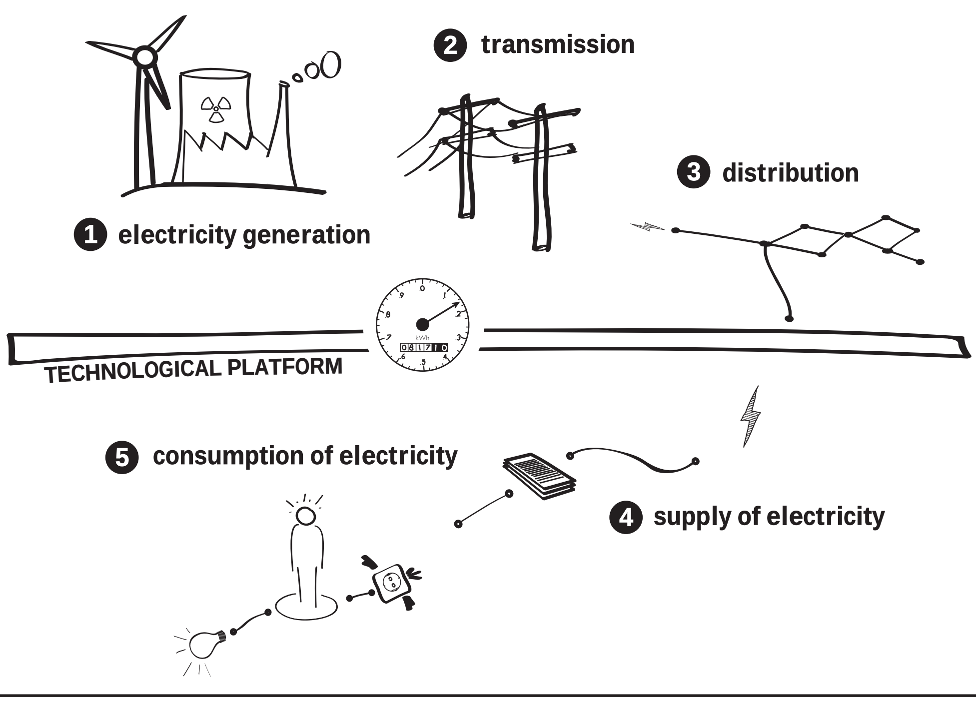
The generation is executed by four large producers, Electrabel, E.ON Benelux, Nuon and Essent and many small producers, also called distributed generation (DG).

Transmission and, balancing supply and demand of electricity is the responsibility of the operator of the electricity grid, which is TenneT in the Netherlands.

The distribution is the responsibility of the Distribution System Operators (DSO), of which there are thirteen in the Netherlands. They provide everyone access to the grid and also

figure 1.2

CURRENT PLAYERS IN THE DUTCH ENERGY MARKET



The current players in the energy market. These five main entities take part in the complex system which forms the electricity grid. The government is the owner of the grid, but the suppliers can be seen as very powerful because they control the relation between the consumer and the rest of the players. A technological platform provides the fundament for the system.

maintain and construct the distribution grid.
The supply of electricity is done by suppliers which buy the electricity from producers and traders or do their own production and sell it to the consumers.
The consumers are ranging from large scale, mid scale, small scale consumers, where domestic users are counted as small scale consumers (Kobus 2010).

2. THE PRICE WE PAY FOR OUR ENERGY SUPPLY

The price of electricity in The Netherlands is accumulated of three parts, a part is for the producer of the electricity, a part is charged as VAT and a part is comprised of a special energy tax. As of 2012/2013 the electricity price on average is 22 cents, comprised of 7 cents production cost, 3,5 cents VAT and 11 cents energy tax, according to the website of Milieucentraal (2012). Because electricity is seen as primary need, a part of the tax is refunded to every private user in The Netherlands regardless the amount of energy that is consumed (Verbong and Geels 2007).

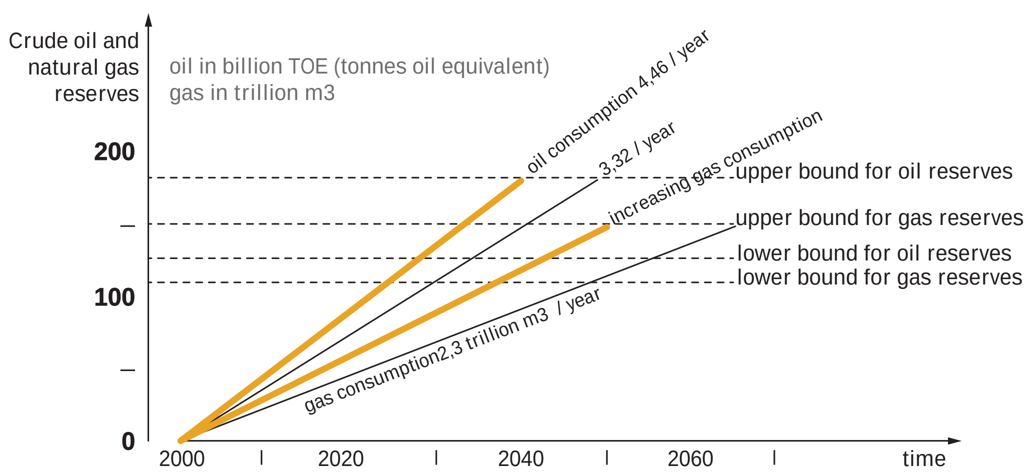
The fact that energy is a primary need makes it very important that we secure the energy supply in the future. Since the invention of electrical energy we have started to use energy increasingly for secondary needs, next to the primary need of heating our houses and cooking our food. In an increasingly highly developed world, the secondary energy needs have become highly important for both the functioning of societies and economies. With the world population increasing and becoming more developed, the consumption of energy is increasing rapidly. To foresee in the needs of the energy hungry world we are paying a high price, not only in terms of hard cash but also environmentally and geopolitically.

2.1 FOSSIL FUELS AND PEAK OIL

The crude oil, coal and natural gas reserves are the finite sources of energy which are currently used to provide the global economy with its ever more important supply of reliable energy. A point in time will likely be reached this century where the demand for crude oil and gas fuels becomes higher than what their sources can provide. One can argue when this point in time will be reached, but it is questionable wether it is worth to delay the shift of the balance in demand and production (also often referred to as: peak oil). Even if one argues that the environmental damage done by continuing to burn fossil fuels could be neglected, the economic chaos which will almost inevitably occur when peak oil is reached is likely to rise beyond repair. The estimated duration of fossil fuel reserves, shows that reaching peak oil and peak gas in the near future is not unrealistic, see figure 1.3. (Scheer 2012, p 105). Coal sources will last longer than this century but have large disadvantages from a carbon emission perspective.

figure 1.3

CRUDE OIL AND NATURAL GAS RESERVES



Estimated duration of crude oil and natural gas reserves.

2.2 THE ECONOMIC MODEL AND SUPPLY CHAIN OF FOSSIL FUELS

To supply our rapidly urbanising world with energy, currently an electricity and natural gas grid is used to transport energy generated by large production plants. The rise of mega-cities is made possible by this organisation of the energy system which is required to provide the high energy density in large cities. This requires large quantities of energy to be transported from the place where it is generated to the place where it is consumed. Even more so if the energy is produced by fossil fuels, the fuel also has to be transported to the location of transformation into energy. The money spent on the import of fossil fuels in the Netherlands was 21% of the revenue made by exports in 1985. This stands in glaring contrast with developing countries which trade in energy constitutes a much larger part of their economies. The centralised character of the necessary supply chain to generate energy from fossil fuels, makes the global economy very dependent on the fuel sources for producing this energy. This encompasses the danger of crises, when the unmissable link in the supply chain, the fuel source, will become increasingly unreliable by scarcity or ownership by a single power e.g. authoritarian regimes (Scheer 2012, p 115).

2.3 GEOPOLITICAL DOWNSIDES OF FOSSIL FUELS

Shortages of land and sustenance will catalyse, conflicts and violence in those places where the fossil fuel is extracted. Which then require intervention of the party who was initially interested in the extraction of the fossil fuel at that location. Many examples of bloody conflict and affected livelihoods have occurred during the history of fossil fuel extraction from the earth.

The following developments are highly likely to occur when fossil fuels remain the main energy sources for the world economy:
Highly unequal distribution of global fossil fuel reserves will become more severe as stocks are depleted
Increasing environmental damage created by fossil fuel extraction or potential nuclear accidents, causes the devastation of livelihoods of ever more people (Scheer 2012, p 135).

THE CURRENT ORGANISATION OF THE SYSTEM IS LARGELY INFLUENCED BY THE DEPENDENCE ON FOSSIL FUELS AS ENERGY SOURCE. TO EFFICIENTLY EXTRACT ENERGY FROM FOSSIL FUELS IN THE FORM OF ELECTRICITY, IT'S BEST DONE ON A LARGE SCALE. THIS RESULTS IN A SYSTEM WHERE LARGE CENTRALISED POWER STATIONS DISTRIBUTE THEIR ELECTRICITY TO SMALLER PLAYERS ON THE DEMAND SIDE. THE CURRENT ENERGY MARKET IN THE NETHERLANDS IS CHARACTERISED BY THIS ORGANISATION. THE LIBERALISATION OF THE MARKET HAS ESTABLISHED THAT THE DIFFERENT PARTS OF THE SYSTEM WITH THEIR RESPONSIBILITIES ARE DISTRIBUTED TO SEPARATE PARTIES WITH THEIR OWN RESPONSIBILITIES. ONE OF THESE PARTIES IS THE CONSUMER, THE USER OF THE ELECTRICITY, WHICH HAS PARTICULARLY LITTLE RESPONSIBILITIES AND INFLUENCE ON THIS COMPLEX SYSTEM.

3. TOP DOWN, THE NEGLECTED USER BECOMES PROSUMER

In the current system which provides electricity to everyone who wants to use it, several layers can be identified. An institutional, economical and physical layer describe the rules of the playground. The market is shaped by the rules which are described here and the physical systems which are used (Kobus 2010).

What is striking about the current system is the way it is designed, the system has a distinctive top-down character. The role of the consumer is to open the switch and let the electricity flow in. Although the consumer pays for the electricity, he or she has a rather passive role in the system. This prohibits the possibility for the user to have influence on the consumption and production of the electricity he or she uses.

There are many players involved to keep the system operational and provide electricity for a fair price to the consumer. Although the system is designed to provide the consumer with the best price and reliability, the transparency for the consumer is relatively low. The system has taken this shape to be able to maintain these values while using mainly fossil fuels to generate the electricity as efficient as possible. Fossil fuels are not only polluting our environment and causing political tension, but are also expected to become increasingly expensive.

To give the user a more active role in the consumption of electricity and in the energy market, he should become a producer of electricity or at least have a say in the production system. To ensure that energy stays affordable, the Dutch energy system needs a revolution in order to stay in tune with the needs of today and the future. The so called 'prosumer' is introduced, which combines producer and consumer in one user (figure 1.4).

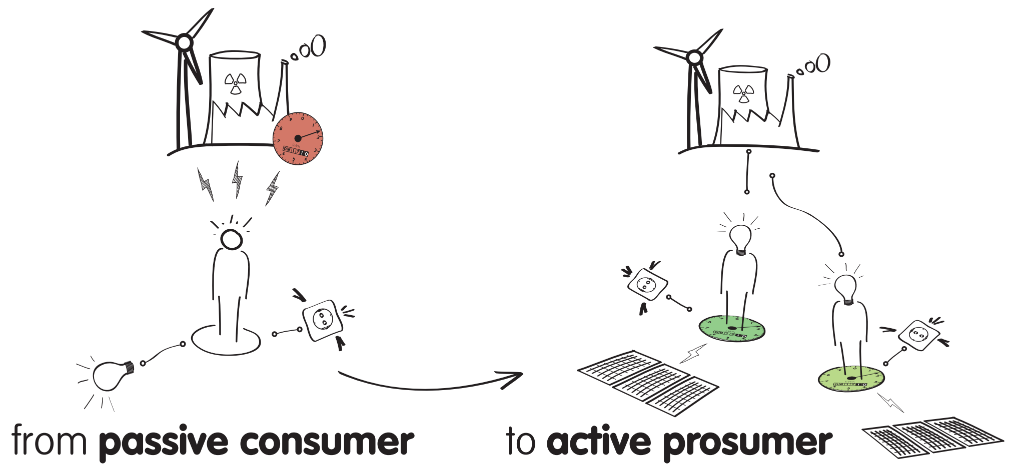
The prosumer is defined as underneath according to the 'Improsume' joint research project:

"Prosumer is an emerging concept in the power market that applies to consumers of energy that can also be producers. In a SmartGrid a prosumer can be a new and active participant in balancing the electricity system. A prosumer can be characterised by distributed generation technologies, energy storing equipment, smart meters and equipment to monitor, control and operate. The SmartGrid creates the basis for intelligent integration of user- actions in securing a continuing high supply security while integrating more fluctuating renewable energy into the electricity supply system. An important requirement is acceptance and active adoption of the new possibility by the prosumer." (Loock 2012)

Becoming a small scale producer of electricity has become more attractive in recent years, with the technological development of new generation systems such as, solar photovoltaic cells and wind turbines. In the following section will be explored which form of renewable energy will be considered as most suitable to be taken as case study in this project.

figure 1.4

DEMOCRATISE THE ENERGY MARKET, BOTTOM-UP



By giving the user more responsibility as 'prosumer', the relation to the other players in the market can change.

4. RENEWABLE ENERGY AND HOW IT IS APPLIED

The energy we use can be produced by different sources, two main types are distinguished: non-renewable and renewable energy. As the word comprises, energy produced by renewable sources can be renewed in a considerable amount of time and does not deplete the source. Opposed to renewable energy sources, the non-renewable sources like fossil fuels can and will be depleted after using them extensively to power the cities on our globe.

In 2011 the total amount of renewable energy used in The Netherlands is 4,3% of the total consumed energy, according to the Dutch Central Statistical Office (CBS). Since 1990 this number has grown from 1,1% and according to the EU guidelines this should reach an amount of 14% in The Netherlands by 2020 (CBS 2011).

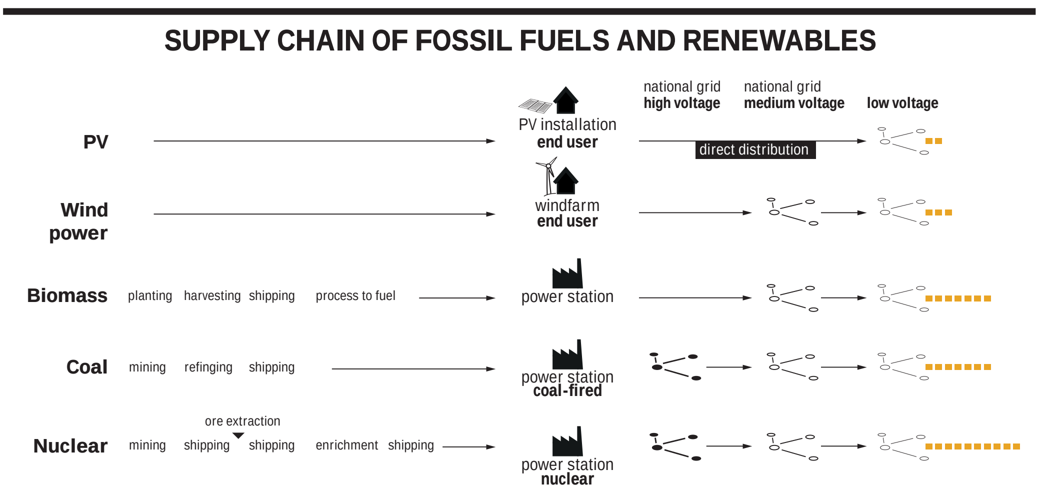
Of the currently produced renewable energy roughly half is consumed as electricity and 0,3% is generated by Solar-Energy, this amounts to 130 MegaWatts (MW) of energy power. 40 MW was placed in 2011 which was roughly two times more than was placed in 2010 (CBS 2011). The installed 130 MW solar energy systems yielded approximately 90 million kWh in 2011, see also Appendix Ia. As a reference, an average household uses 3300 kWh of electricity on average per year in The Netherlands, which would translate in a theoretical 27.272 households powered by sunlight in 2011. The majority of the installed Photo Voltaic (PV) systems are installed as grid connected systems, see Appendix Ib. Meaning the house or building on which the system is installed uses the electricity from the PV system when it is available, but also uses electricity from the traditional electricity grid, e.g. at night.

4.1 A FUEL TRANSFORMATION

Previously, several downsides of using non-renewable energy sources were described. Therefore alone one would argue the transformation to renewable energy sources is desirable. It is however not only the alternative to the downsides, which requires a transformation to renewable energy sources. The renewable energy source, solar photovoltaics (solar panels) offers considerable advantages while also eliminating the downsides of non-renewable energy.

Different renewable energy sources are available, which all take away the downside of producing carbon dioxide (CO2). This single argument does however not take into account the following differences between several renewable energy sources. Biomass, water power, tidal power and solar thermal plants all meet the requirement of producing electricity without the side effect of producing carbon dioxide emissions, but they are all dependent on concentrated supplies of energy sources. Therefore these energy sources and their respective technologies, are more cost efficient when they are transformed into electricity by using large turbines and power plants. Albeit the emission free production, the electricity still has to be transported through the high, medium and low voltage electricity grid just like electricity produced by fossil fuel or nuclear power (Scheer 2012, pg 73-74).

figure 1.5



The supply chain of the energy source is non-existent for solar photovoltaics or wind power (Scheer 2012)

The advantage of wind and solar photovoltaic electricity generation is the absence of a required 'complex' supply chain. In figure 1.5 is shown how the supply chains of different energy sources compare to each other. As can be seen in figure 1.5 the supply chain of the energy source to produce electricity is non-existent for solar photovoltaics or wind power, since the location of energy source is not geographically bound. What really leverages these technologies, is to use their ability to be placed close to the demand for electricity. When a solar panel (and the required inverter) is installed on the roof of a building its generated electricity can be put directly to use, without the need for an extra infrastructure besides the available electrical wiring in the building. Thereby the need for a complex electricity grid (high, medium and low voltage), could be partly avoided. To realise this in practise, photovoltaic cells currently seem a very suitable solution in urbanised environments since they do not need to occupy extra space, they can be integrated on existing roofs or other surfaces of buildings. Therefore electricity generation by solar photovoltaic cells will be used as future proof case in this project (thereby not excluding other renewables or technologies from future scenarios) (Scheer 2012).

4.2 SOLAR PHOTOVOLTAIC ENERGY

After the first energy crisis in 1970 initiatives started, to develop PV technology for applications in remote locations without grid connections, e.g. street lamps and harbour beacons. PV was however not considered for larger scale energy production, it was seen as unfeasible by policymakers especially when operated in the Dutch climate, with relatively low solar radiation values. Nevertheless universities started research projects on PV and researchers started to form a lobby to promote PV projects. By the late 1980s, the possibilities for grid connected systems started to appear, but the relatively high costs were seen as an obstacle for the integration of PV energy in the existing grid. At the end of the 1990s the government considered to choose PV energy to use in their renewable energy program, but eventually decided the kWh price was too high compared to conventional energy sources. Instead wind power and biomass were emphasised to be implemented in future plans for renewable energy production (Verbong and Geels 2007). As a result the major actors in the energy market hardly feature any PV solutions, except for a few small initiatives for promotion purposes.

The tide is however changing. As of 2011 the photovoltaic industry reached a world wide production volume of about 35 GWp (Giga Watt peak) of photovoltaic modules. The yearly growth rates over the last decade were on average between 40% and 90%, which makes it one of the fastest growing industries at present (Jäger-Waldau 2012).

Thanks to its feed-in tariff regulations, Germany is still leading with the highest number of installed kiloWatts in 2010 (Solarplaza 2012). The number two in 2010 was Italy which also profits from the feed-in tariff. The feed-in regulation provides a financial incentive for both consumers and businesses that install solar power systems. Thanks to the growth in demand the international solar power industry is rapidly growing. In 2010 the biggest markets were still driven by financial support programs. According to Solarplaza this is however likely to change in the coming years, forcing industry to lower their production costs and consumer prices. Since 2009 the price for solar PV modules has decreased with 60%, which will soon lead to a very competitive price point per kWh if compared to other energy sources, Solarplaza (2012).

The world total consumption of energy in 2010 was estimated by the International Energy Agency (2012) as 8677 Mtoe (Million tonnes of oil equivalent) or 100.913.520 GWh. To put this number into perspective: Germany had an energy consumption of 2.674.900 GWh in 2010 taking a share of 2,65%. In Germany the so-called green power was representing 19,9% in the power mix of which 3,2% of the total was generated by solar photovoltaics in 2011 according to an article in the US edition of Reuters (Eckert 2011).

4.3 THE PRODUCTION OF SOLAR PHOTO VOLTAIC CELLS

The price of solar panels has been rapidly declining in the last decade, making it possible to become a competitive alternative to the ever increasing price of energy made with fossil fuels, see figure 1.6.

The rapid decline in price is mainly caused by the increased amount of production companies and their overcapacity, which resulted in a reduction of prices for poly-silicon material, solar wafers and cells and consecutively solar modules. Currently 85% of the produced solar modules uses wafer-based crystalline silicon technology. Mainly because the required production facility up and running in a relatively short time-frame (Jäger-Waldau 2012). The modules produced with the wafer-based crystalline silicon technology has been commonly applied since the invention of photovoltaic cells and are regarded as the first generation of solar cells.

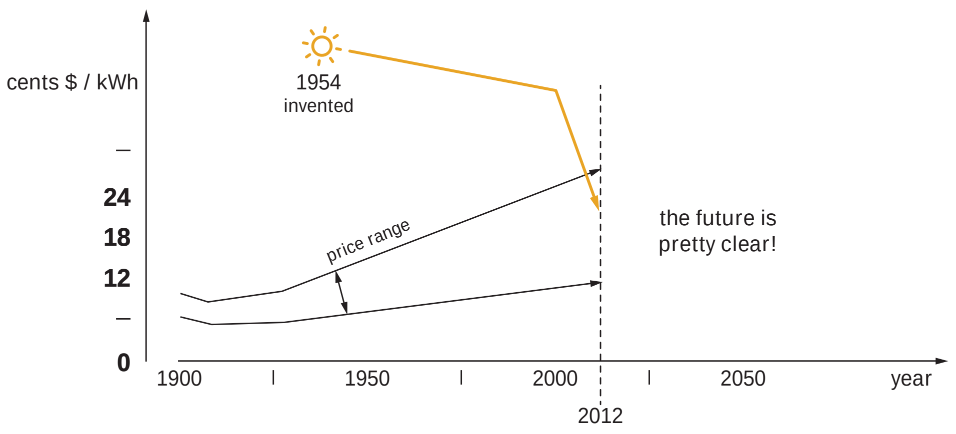
However between 2005-2009 a temporary shortage of silicon and the introduction of turnkey production lines for thin-film solar cells resulted in the involvement of currently 200 companies in the production of thin-film solar cell production process. Thin-film solar cells are regarded as the second generation of solar cells after the previously described first generation of wafer-based crystalline silicon technology (Green 2001). The thin-film solar cell technology (see figure 1.7a) mainly distinguishes it self because of its wider spectrum of applications, made possible by their physical flexibility, their good performance under indirect light and lower sensitivity to temperature related efficiency reduction (Jorna 2012).

A third generation of solar-cells is likely to introduce an even wider spectrum of applications and where possible to avoid the use of rare earth minerals currently used in the first and second generation solar cells. Cadmium sulphide, amorphous silicon, copper indium diselenide, cadmium telluride and thin-film polycrystalline silicon are currently used raw materials to manufacture solar cells. In widely applied production technologies for solar cells in the future, the costs are likely to be dominated by the constituent materials. It is therefore argued that photovoltaics is likely to evolve to a third generation high-efficiency thin-film technology (Green 2001).

A possible alternative for the current thin film technologies is a solar cell technology based on a CZTS semiconductor. Its components are: copper, zinc, tin and sulfur, which have as advantages that they are abundant in the earth's crust and non-toxic. Next to that the CZTS semiconductor has near ideal technical properties to constitute a solar photovoltaic cell. An IBM-led research team has developed a CZTS based solar cell (see figure 1.7b) which can currently operate at an efficiency of 11,1%, meaning it converts that percentage of the sunlight that falls on to it into electricity (Wang 2012).

figure 1.6

THE PRICE OF ELECTRICITY FROM SOLAR OR FOSSIL FUELS



The price of electricity in the United States, made from solar or fossil fuels. (Kennedy 2012)

THE FUTURE WILL POINT OUT WHICH MATERIAL WILL BE MOST SUITABLE FOR THE DIFFERENT APPLICATIONS OF SOLAR CELLS. IT IS HOWEVER EASING THE MIND THAT THERE ARE FUTURE POSSIBILITIES WHICH CAN PROVIDE US WITH CLEAN AND ABUNDANT ENERGY.

figure 1.7a
The Agua Caliente solar project in Yuma County, Arizona, which is one of the world's largest solar panel farms (thin film technology), is now generating 200 MW of solar power, and will provide 290 MW when completed (enough for an estimated 100.000 U.S. households). Published July 16, 2012 on Gigaom.com in Huge Arizona solar panel farm now 2/3 completed.

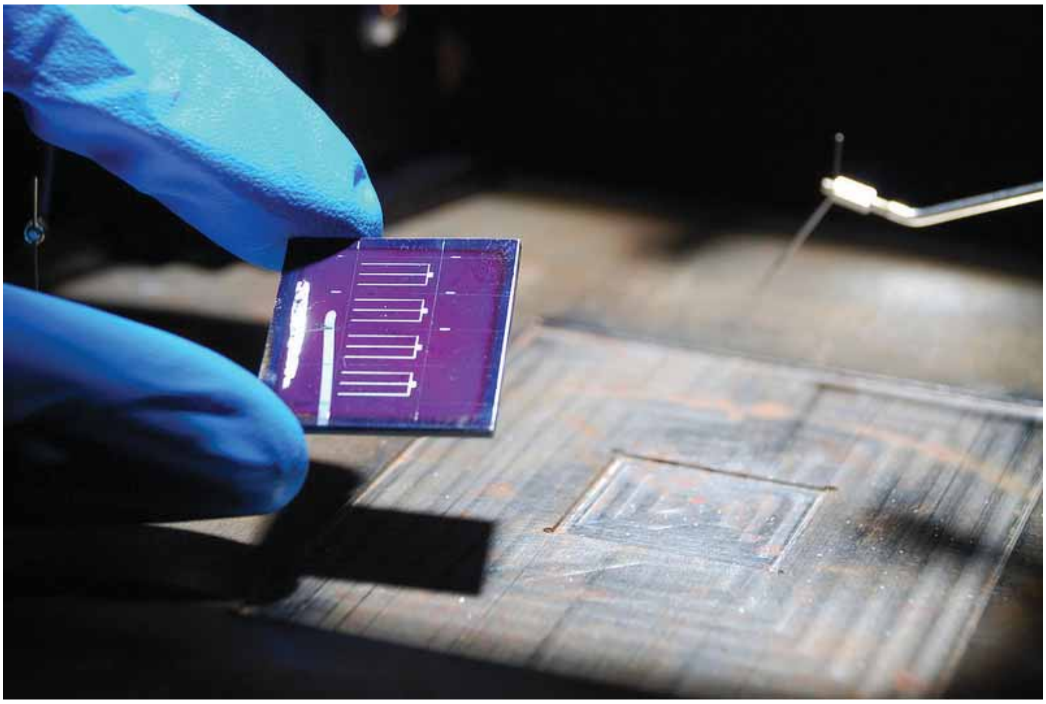


figure 1.7b
New Solar Panels Will Be Built With Common Metals, in the figure is shown a solar cell based on CZTS semi conductor technology developed by an IBM-led research team. Courtesy of: Renewable power news, www.renewablepowernews.com.

5. DISCUSSION: DETERMINE THE PLAYGROUND

The current approach and system which determines the energy market is not yet adapted to the new sustainable forms of electricity production. This transformation should however take place to take away the negative aspects of the current fuel resources and change the way consumers use electricity. Fossil fuels will continue to become increasingly expensive, they are causing environmental damage and geopolitical imbalances and in the current system the user has very limited possibilities to take a pro-active role and take part in a bottom-up transformation of the energy system.

The Dutch energy market has been going through a so called liberalisation process since 1998. While this transformation might have shown improvements on other levels, it is most likely also one of the causes of the further decrease of user influence. Therefore the goal of this project is to democratise the energy market, rather than stimulate market liberalisation. With democratising, meaning to create true user participation and bottom-up initiatives from any electricity consumer.

Electricity production with energy from the sun by photo voltaic cells is a very suitable technology in an energy revolution, because it is a technology which can be easily scalable. It is therefore suited for decentralised domestic electricity production. This allows users to install their electricity production facility on even the smallest scale and contribute to the possible solution of an energy market which is shaped bottom-up. By taking responsibility and suffice in their own energy needs, users can become more aware of their own influence on the energy problem. In this project this will be used as hypothesis to successfully design a product which leverages the physiological and sociological effects of the change in responsibility for energy sufficiency.

The above is slowly gaining acceptance in more countries and governments and is technologically feasible. However to gain acceptance for the larger majority of users a lower entry level is required. The user needs to be provided with tools that make him or her more powerful and influential in the way electricity is consumed and eventually also how it is produced. The form in which these tools have to be provided has to be determined carefully. Therefore this project will focus on creating tools which can facilitate an energy revolution, or more specifically a user driven solar photovoltaics revolution. In the next chapter will be explored how users are currently approaching the subject of electricity generation and what their current possibilities are.

(B) THE USER

ITS ROLE IN THE CURRENT SYSTEM AND RELATION TO THE OTHER PLAYERS

IN THE PREVIOUS CHAPTER IS EXPLORED HOW THE ENERGY MARKET HAS REACHED ITS CURRENT FORM AND WHAT WOULD BE A DESIRED FORM IN THE FUTURE. THIS PROJECT IS SEEKING FOR TOOLS WHICH CAN REALISE THAT ENVISIONED FUTURE BY MEANS OF A BOTTOM-UP MOVEMENT FROM USERS. IN THIS CHAPTER WILL BE EXPLORED HOW USERS ARE CURRENTLY APPROACHING THE SUBJECT OF INDEPENDENT ENERGY GENERATION AND SPECIFICALLY THE GENERATION OF ELECTRICITY BY MEANS OF SOLAR CELLS. WHAT ARE THE CURRENT POSSIBILITIES FOR USERS AND WHAT DO USERS UNDERSTAND FROM ELECTRICITY AS CONCEPT? THE EXPLORATION IN THIS CHAPTER WILL LATER BE USED AS INSIGHT FOR THE DEVELOPMENT OF TOOLS WHICH CAN ENABLE USERS TO TAKE PART IN AN ENERGY REVOLUTION WHICH REFORMS THE ENERGY MARKET IN THE DESIRED DEMOCRATIC WAY.

1. ACQUIRING SOLAR PHOTOVOLTAIC CELLS, MAIN PLAYERS

The energy revolution, as it is named by many now, seems to start unrolling slowly with different small initiatives. Different types of initiatives can be categorised as:

1. Local Dutch communities who aim to become energy sufficient together

   The first initiative, is the start of a truly democratic way of distributing and generating energy. It is mainly driven by the ideals of the community to become more self sufficient and progress to a truly sustainable way of foreseeing in their energy needs. The initiative is usually driven by a few front runners in the community which have the ideals and the knowledge to start this new way of foreseeing the communities energy needs. They stimulate the other members in the community to do an investment in solar cells or a windmill, which will be connected to the local, low voltage electricity grid (figure 1.8).

2. Leasing companies who aim to sell solar PV panels, at a lower entry level

   These companies often sell solar PV panels, but also have the option of providing a loan and lease the panels. This could drastically lower the entry level of becoming an electricity producer, because the necessary investment is spread over several years. These companies do not leverage the community initiative, but do provide extra services like installing and maintaining the solar PV panels. Many households in The Netherlands have installed solar cells independently. In the past this was stimulated by government fundings, but nowadays the financial threshold is low enough to have a very reasonable time-frame on return on investment.

3. Energy utility companies which try to reform the energy market system from inside out

   The utility company Greenchoice in the Netherlands is stimulating households to install solar PV panels and deliver

figure 1.8
Flyer which promotes to invest in solar cells with a community. The initiative is usually driven by a few front runners in the community which have the ideals and the knowledge to start this new way of foreseeing the communities energy needs. This particular flyer explains: Amsterdam on Sun creates a city on clean energy by residents and neighborhood-businesses that joined the cause. You have teamed solar energy generation in a way that brings financial benefits to both. By combining tax advantages for companies with unused roofs of individuals stimulates the growth of clean energy.

the surplus of produced electricity to the grid. In that way the company ensures its customers who do not have any electricity generation possibility installed, that the energy they buy is 100% sustainably generated. The electricity is transported using the national Dutch grid, meaning it is untraceable once it is delivered to the grid.

What all these initiatives have in common, is that they are convinced that the energy revolution has to take place rather sooner than later. Where the Dutch government or the existing energy market seems to be rather reticent in progressing towards a more sustainable solution to foresee in our future energy needs. After all, as the previous chapter describes, the current system is specifically designed to facilitate the efficient generation of energy from fossil fuels. Which might explain the difficulty of transforming the current system, which inevitably means the adaptation to a more decentralised system with more freedom for entry of new players. Thereby also redistributing the influential power, which is now largely in the hands of central powers, like utility companies, the government and the distribution companies, see also chapter (A) 1.2.

In order for households to start producing electricity and use it, consumers will need to be informed. The form of this information should be relatively approachable in order to reach a large group of people. In this chapter, the basics of electricity generation at home will be explored, to provide insights for the user research in a later stage.

1.1 PRICE OF PHOTOVOLTAIC CELLS

Solutions are available, ranging from roughly €3200 to €5400 for systems which claim to deliver 1400 kWh - 2000 kWh yearly. Price mainly varies based on the efficiency of the PV panels which are used in the system and the installation costs which are made by the respective company. The price indication is done based on the Dutch comparison website, CompareMySolar (2013). According to statistics obtained from their own website, CompareMySolar shows that the price of the same installation in 2011 has decreased 50% in price in 2013 (Appendix II). This price includes all necessary components and installation of the system and thanks to the decrease it is now possible to reach return of investment in less then 8 years. Since the solar cells will be able to generate electricity for at least 25 years, the savings on electricity costs will at least amount to two times the original investment.

The power which solar modules generate is measured in Wattpeaks (Wp). It specifies the nominal power of a module of solar photovoltaic cells under prescribed conditions in a laboratory. These prescribed conditions simulate the sunlight hitting the earth's surface at latitude 35 degrees North in the summer under an environment temperature of 25 degrees Celsius. These conditions are not representative for the typical Dutch weather or any North European country, but they provide a good means of comparison when comparing different solar modules. In The Netherlands a rule of thumb is applied to calculate the yearly electricity production, the Wp value of a solar module is multiplied with 0,85 to obtain the kWh value of the module, Wikipedia (2013). Currently available modules typically range from 170-280 Wp, meaning they produce from 145-238 kWh in an average year in The Netherlands, Kijk & Vergelijk zonnepanelen (Compare solar-panels) (2013). Modules with a higher Wattpeak per square meter value are more efficient and will generate more electricity compared to modules with lower Wp values. They are however, generally more expensive, it is therefore recommended to compare the prices of modules with similar Wattpeak values. Panels with a higher efficiency are very suitable when the available surface area is limited, when there is plenty of room the efficiency of the solar modules is less important.

1.2 INSTALLATION OF PV SYSTEMS

The company, 'Goedkoopste zonne-energie' (cheapest solar-energy) (2012) in the Netherlands offers different packages to consumers, which include all necessary equipment and a pricing plan with a loan. By offering the complete equipment and installation of the system in combination with a loan, the consumer pays roughly the same or less for a kWh, as would be paid to a conventional energy supplier (CBS 2011, p. 24). However the payment for the loan will be finished after 10 to 15 years and from then on the owner of the PV panels will have an expected 10 years more of free use, with the total life expectancy used for PV panels by most sellers of 25 years. The energy will be renewable as opposed to the energy which most conventional suppliers sell to consumers and the price of the energy will be fixed, while the price of conventional energy is expected to grow every year (Kennedy 2012).

Sungevity, a company which was co-founded by Danny Kennedy (2012) in the United States, sells a similar package with an installation and maintenance service and the necessary equipment to run a solar powered electricity system. They advertise their package as an investment which will immediately save the consumer money, because the accumulated costs of the reduced conventional energy and the lease costs of the solar system are less than just using the conventional energy companies, see figure 1.9.

Sungevity is now also operating in The Netherlands, next to other companies which sell and install solar modules for homes. Other than contracting a company to install the PV modules, home-owners can also opt to install the modules by themselves. This will often require to do the investment at once, but will in the end result in lower total costs than any other solution.

1.3 QUALITY GUARANTEE AND REGULATION

With the higher demand of photovoltaic panels, the rapidly growing market is attracting new producers which have to produce the panels more efficiently and for a lower price. Where Germany was responsible for a large part of the production of photovoltaic panels for the European market, it is now the production companies in Asia which supply the panels.

Suppliers generally guarantee a 90% of the original efficiency of the solar cells in the first 10 years and an 80% efficiency after 20 years of total use. Many renowned solar module producers give a 10 year guarantee on every module they sell, which generally covers the time-span in which the modules reach their point of return on investment.

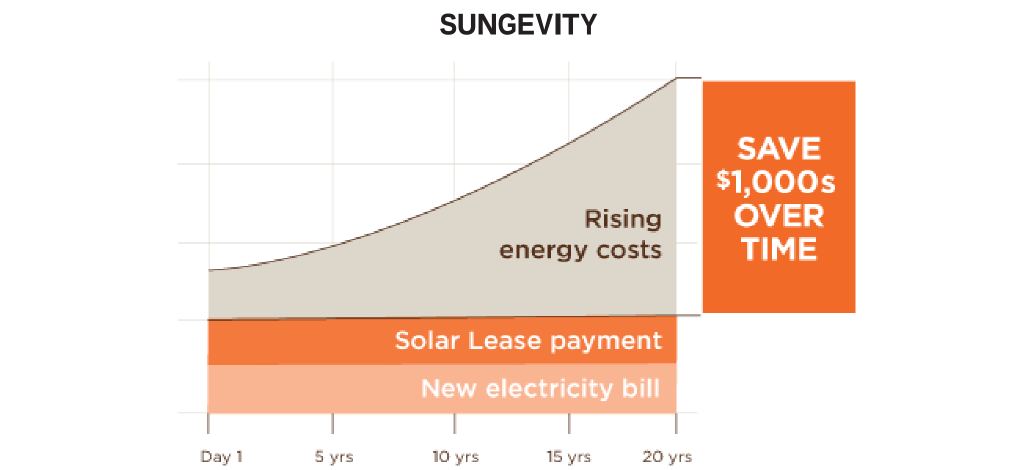
Certification

The modules are expected to be manufactured as inexpensively as possible because they constitute a significant part of the cost of the electricity which will be generated by the solar cells in the module. However the module must be capable of operating in many different climates under the extremest conditions (Osterwald and McMahon 2008).

"A PV module can be defined as a collection of individual solar cells integrated into a package that protects them from the environment in which the module is installed for a long period of time." (Osterwald and McMahon 2008)

Early 2013, bad publicity has appeared in The Netherlands regarding cheap solar panels which could reportedly not live up to the standards

figure 1.9



Graph from Sungevity website (2013) "While electricity costs go up every year, you can lock in low Solar Lease payments. This means that over the life of your Solar Lease, you can save thousands."

they promise. When investing in solar modules it is important to not only trust the efficiency and durability claim of the supplier but also make sure the modules are certified by an independent certification body.

A commonly acclaimed reliable regulation-standard for certification is established by the International Electrotechnical Commission (IEC). Other certification standards are made by the International Standardisation Organisation (ISO), American Society for Testing and Materials (ASTM), Institute of Electrical and Electronics Engineers (IEEE) and Semiconductor Equipment and Materials International (SEMI). Among those the IEC is the most important body regarding certification of specifically photovoltaic modules which convert solar energy into electricity (Lenardic 2012). Since the widespread availability to the consumer-market the IEC test standards have become the only accepted standard by both module-manufacturers and buyers (Osterwald and McMahon 2008).

It is however important that the certificate is given by an acclaimed testing and certification body such as TÜV, see figure 1.10. The following quotation indicates why a label stating the IEC alone is not sufficient to guarantee the quality of the module.

"Module labels attached by manufacturers use phrases such as ''IEC 61215 Certified.'' This usage is misleading and incorrect for two reasons: (1) the IEC itself does not certify any products; rather, it is a standards organisation responsible for publishing and maintaining test procedures and (2) there was no license issued by a certification body." (Osterwald and McMahon 2008)

It can be advised to make sure the internationally renowned standards of the IEC are tested and certified by an external certification body like the TÜV, before proceeding to buy any photovoltaic module. In the future the modules are likely to become more reliable and will have to pass stricter tests, due to maturing of the technology and upscaling of manufacturing facilities.

Regulation

By acquiring and installing PV modules to generate electricity, one becomes a producer of electricity. The majority of users in the Netherlands installs the modules and connects

Figure 1.10
A special climate chamber with UV light for the artificial aging of photovoltaic modules in TÜV Rheinland's solar laboratory.

Photo: TÜV Rheinland, source: http://www.tuv.com them to the national Dutch electricity grid as opposed to a grid-independent installation, see Appendix Ib. The Dutch law allows users of the national grid to deliver electricity from their own production facility and prescribes that their utility company should compensate them for the electricity that is delivered back to the grid. Up to a limit of 5000 kWh per year the utility company should deduct the full kWh price including taxes to compensate the producer for every delivered kWh to the grid. Unless the electricity production of that single user is more than his or her consumption, then the utility company can decide on the price that will be paid for the overproduced electricity.

The Dutch utility company Greenchoice (2013), advertises that it is on a mission to connect as much 'prosumers' to the Dutch grid as they can by providing a fair price for the generated electricity of their users. Their particular price is constituted of the standard price for energy generation and the VAT, respectively 7 and 3,5 euro-cents in 2013. The Dutch energy tax which is normally paid by users, when they buy electricity from a utility company, is not charged, neither is it refunded to users which overproduce electricity and feed it to the national grid. This means the individual user that is overproducing electricity is awarded with €0,105 per kWh of electricity which delivered to the grid.

Feed in Tariff

The Netherlands does not feature a feed in tariff system (FIT), which has proved to be a very successful stimulator in other countries to accelerate the implementation of 'green' energy generation systems.

Anyone who generates renewable electricity is payed a price based on investment costs for the used generation technology (wind, solar, biogas, etc.), in order to provide investors a reasonable return-on-investment. The principle was first successfully implemented in Germany when the Renewable Energy Act was implemented in the year 2000. At first the tariff for electricity generated by photovoltaic cells was determined at €0,5065 per kWh delivered to the grid (Agnolucci 2006). To stimulate technological innovation the tariff for solar PV was reduced with 5% yearly. The tariff is determined at €0,1592 for April 2013, which suggest that the policy has resulted in a significant price drop of the solar cell technology.

After the successful implementation of the feed-in tariff in Germany in 2000, in 2010, 50 other countries had implemented the policy according to Wikipedia (2013). Depending on the location and situation PV modules can now almost deliver electricity for the same price as the electricity grid.

THE ENVIRONMENT FOR INVESTING IN THE TECHNOLOGY OF SOLAR CELLS AND INSTALLING THEM AS HOME-OWNER HAS BECOME LESS HOSTILE VERY RAPIDLY AND MIGHT BE VERY WELCOMING SOON. THANKS TO THE STIMULATION OF THE FEED-IN TARIFF POLICY AND OTHER INFLUENCES IN GERMANY INITIALLY AND CONSECUTIVELY IN MANY OTHER COUNTRIES, THE PRICE OF PHOTOVOLTAIC CELL TECHNOLOGY HAS DROPPED ENORMOUSLY. THIS HAS RESULTED IN A GROWING MARKET FOR PV MODULES WITH MORE AFFORDABLE SOLUTIONS THAN EVER BEFORE. THE SOLAR CELL TECHNOLOGY IS HOWEVER STILL RAPIDLY GROWING AND IT SHOULD BE ADVISED TO BUY MODULES WHICH HAVE BEEN PROPERLY TESTED BY A RENOWNED CERTIFICATION BODY. IT IS THEREFORE ALSO RECOMMENDED TO CONTACT A RENOWNED INSTALLATION COMPANY TO DISCUSS THE BEST CHOICE OF SOLAR PV MODULES AND LET THEM TAKE CARE OF THE INSTALLATION. WHEN A PRODUCT WILL BE DESIGNED IN THIS CONTEXT THESE FACTORS SHOULD BE TAKEN INTO ACCOUNT. THE INFLUENCE OF THIS CONTEXT ON THE USER WILL BE DISCUSSED IN PART 2 OF THIS REPORT, IN PART 3 THESE CONTEXT FACTORS WILL BE TAKEN INTO CONSIDERATION WHEN DESIGNING A PRODUCT.

2. USER UNDERSTANDING OF THE CONCEPT: ELECTRICITY

The purpose of this section is to explore the current place which electricity commonly takes in our daily lives. We all know what electricity does and how we can put it to use, it has become a commodity and it has integrated in our lives and daily activities. Several generations have passed since the widespread integration of electricity outlets in our houses and it has therefore become engrained in our culture.

2.1 THE COMMON USER UNDERSTANDING OF ELECTRICITY USE

What is it that makes electricity generally something so difficult to comprehend? The production of electrical power is measured in (kilo) Watts (W) and the usage of electricity in (kilo) Watt hours (kWh) and is consecutively also often displayed in those units. When comparing the consumption of electricity to the consumption of water, one could argue that water consumption is a lot easier to understand since we all know what a Litre of water looks like. Unlike electricity where the units, W and Wh are often used to display the electricity use as accurately as possible, but are perceived as meaningless by users (Heller and Borchers 2011).

Feedback for the user of the electricity is typically infrequent and not transparent, the common way of feedback is the monthly or yearly energy bill. The bill only shows a total of the used kWh of the month or year and does not indicate any reference. Furthermore it is addressed to only one person in the household resulting in little involvement of the other members of the household (Petersen, Steele et al. 2009).

According to Chetty, M., D. Tran, et al. (2008), householders are mostly unaware of their in-moment energy consumption or power usage (kW) for different appliances as well as their total household energy consumption or energy usage (kWh), because it is very invisible to them.

“Because these utility systems have faded into the background of householders’ lives, we suggest that systems are developed that encourage householders to reflect on and re-engage with these aspects of the home’s infrastructure.” (Chetty, Tran et al. 2008)

To explore how the current engagement of users and their approach to consumption and production of electricity will affect this project, a user study with sample group of Dutch householders has been done.

2.2 INTERNET SURVEY ON ELECTRICITY CONSUMPTION AND GENERATION

The study focusses on the way people in The Netherlands, currently perceive and justify their electricity consumption and how that correlates to their attitude towards renewable or self produced electricity. The aim of the study is thereby not to obtain or test to make a statistic overview of the exact consumption quantities but rather to investigate how the knowledge of people on the subject relates to the decisions they make and how they view themselves. The following research questions are phrased to be explored in this user study:

[1] How far does the current knowledge of people reach?

1. Are people aware of their own yearly electricity consumption?
2. What do people understand of the current representation of electricity consumption?
3. Are people able to estimate how different appliances in their households affect their electricity consumption?

[2] How do people appraise their current own electricity consumption, how do they position themselves among others?

1. Do people think that they are average electricity consumers or not? And how do they support their argument? (i.e. with knowledge, estimation, etc.)
2. Do people consider themselves as an initiator in their household when it comes to consuming less electricity?

[3] What do people think about producing their own electricity?

1. What are their motivations to produce their own electricity by solar panels?
2. What hinders them that can prevent them from investing in solar panels?

Method

To be able to make a scientifically sound argumentation for above questions, a relatively large sample group is needed. Therefore an online survey was chosen as a method for this particular study; 91 participants reacted to the online invitation. The survey was at first send to family, friends and acquaintances, which were consecutively asked to forward the survey to their circles (snow ball sampling). The 'Qualtrics' (2013) tool, a web based questionnaire design tool, was used to create the survey.

Setup

The survey started with some 'warming-up' questions to make the participants familiar with the subject. It was emphasised that the survey aimed to obtain the sincere opinion of people and not to measure people's knowledge (no wrong or right answer). This was explicitly emphasised since the survey was also distributed to friends and family who could try to fill out the survey too thoroughly not to lose face.

They were first asked to fill in their age, educational level and their current household situation. Then they were asked wether they could estimate their yearly total electricity consumption and how they positioned themselves compared to average consumption values in The Netherlands. They were then confronted with the average values for different households according to research of the Dutch Central Statistical Office (CBS) and asked wether they were surprised based on their answer for the previous question.

The next set of questions were related to the electrical appliances that participants use in their household. They were asked to choose from a set of given appliances the ones they personally used most frequently. The selected device was used as reference in the next questions, where participants were asked to estimate the amount of electricity the chosen device could consume. Consecutively they were asked to rank the devices in order of electricity usage, large consumers first and small

table 1.1

ARE YOU AVERAGE?

The average amount of kWh per house in 2010 according to the Central Statistics Bureau (CBS) is: 2250 kWh per year for apartments, 3350 kWh per year for terraced houses, 4550 kWh per year for detached houses. You answered before.. (values of the participant would be displayed) e.g. the yearly electricity consumption of your 'apartment' is 2600 kWh.

Are you surprised to see the values from the CBS? Could you explain why?

Typical answers for: "yes, I am surprised"	nr.	Typical answers for: "no, I am not surprised"	nr.
The average is lower than I expected, my consumption is higher than average! Maybe because the number of people in my house is quite high?	3	My house is much bigger than average, thats why it is higher, or: In my house live a lot of people (studenthouse), so we use more.	7
The average is higher than I expected, I did not know I would score below average!	2	I already knew my own use and the average numbers!	5
But I am not interested in this at all!	1	Because, I am not familiar. I don't have a feeling of reference yet.	2
How come the differences between the different housing types are so big? I would say the only difference is the amount of lamps, which only make up a small part of the electricity consumption.		We bought very efficient appliances on purpose, or: I have a few solar panels for electricity production.	2
		I am not surprised, but I think many people do not have the awareness of their electricity consumption!	1

Participants were asked to compare their estimation with an average value. More than 70% of the group indicated that they did not know how much electricity their household consumed on yearly basis. When participants were asked wether they thought the electricity consumption of their household was average, most of them indicated that this was the case. Only 21% indicated that the electricity consumption of their household could be above average.

consumers last.

The first two blocks of questions regarding the estimation of total household use and the consumption of different electrical appliances, were used to make the transition to some open questions. These questions focused on the interest of people in using electricity in a more efficient way and the actions they could take accordingly. They were asked if they viewed themselves more active than other persons in the household. Finally people were asked if they would have liked the idea of producing the electricity they use in their own household and why. They were then presented the currently available option of leasing solar panels and asked wether they would have any hesitations to use this option.

Results

In total 91 valid responses were received, these responses were divided over participants of different age groups and with different educational backgrounds. Over half of the participants were from the age group of 20-29 years old, the other half of the group showed an age variety between 30-70 years old, see appendix III.

More than 70% of the group indicated that they did not know how much electricity their household consumed on yearly basis. When participants were asked wether they thought the electricity consumption of their household was average, most of them indicated that this was the case. Only 21% indicated that the electricity consumption of their household could be above average.

The group that was able to indicate the yearly electricity consumption of their household were also asked wether they thought their household consumption would be comparable to the average or deviate from it. When comparing their indications with the values of the Dutch Central Statistical Office (CBS) it became obvious that the participants which indication was correct had a college degree or higher educational background. The comparison was done with a 15% error margin, taking into account an estimation would always deviate from the statistical average.

To get more insights in the reasoning behind the answers of participants, they were confronted with the average values of the CBS. Most people answered they were not surprised to see those values, but they always tried to justify why there own estimation would differ. Similar reactions were clustered in groups, see table 1.1. To understand wether people can accurately understand what is the proportion between the different electricity consumption rates of devices, they were asked to rank a list of devices. The devices were presented to them in a random order with an indicated time of usage, participants were asked to drag the device with the highest electricity consumption rate to the top and the device with the lowest electricity consumption rate to the bottom. This exercise resulted in a large variety of answers, which would be almost correct for some devices but largely incorrect for others. In table 1.2, can be seen that the distribution of answers over the different devices is particularly wide. Devices like the oven, microwave and hairdryer are estimated correctly by a large group, but an equally large group estimates something completely different.

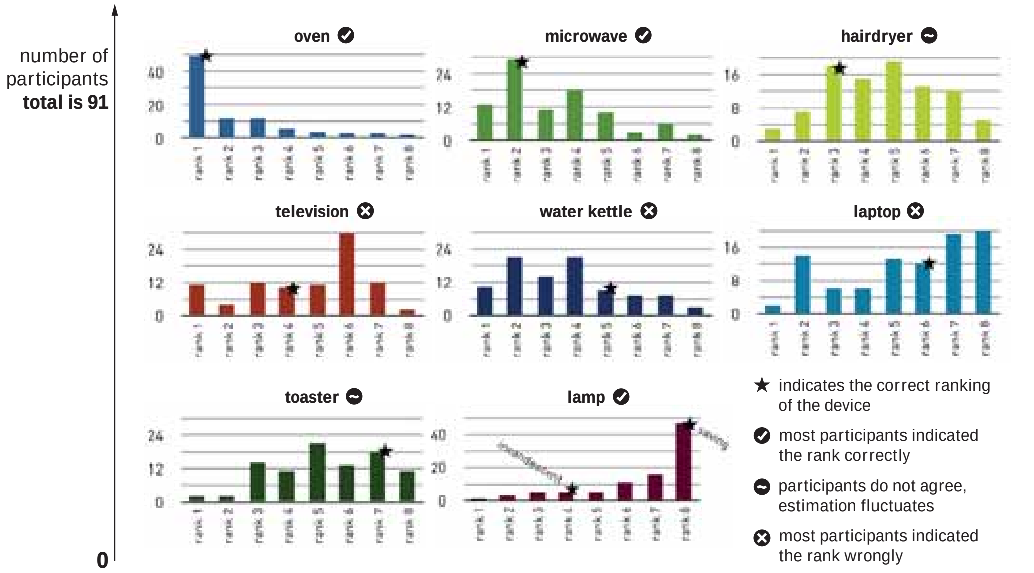
After completing the ranking exercise, participants were asked which form of feedback they would prefer to have for a single device. The most popular feedback, is to see the price of the electricity when the device is used one time (30%). The amount of kiloWatts for one usage of the device and the percentage of the usage from the total electricity consumption that day are second and third popular with both 20% and 17%,

Other preferred forms of information were:

- The percentage in comparison with other common devices at home and the cost per hour.
- The current electricity consumption as percentage of the total current electricity consumption of the household.
- The costs of the device for 1 time use compared to the yearly electricity costs for that device.
- The costs of the device if I were using it continuously.
- The consumption of the device compared with a metaphor that makes pollution more clear.
- Yearly costs of the device or a percentage of the total yearly costs for the household
- Daily use percentage in combination with price.

table 1.2

RANKING DIFFERENT ELECTRICAL DEVICES



To explore wether people can accurately understand what is the proportion between the different electricity consumption rates of devices, they were asked to rank a list of devices. The devices were presented to them in a random order with an indicated time of usage, participants were asked to drag the device with the highest electricity consumption rate to the top and the device with the lowest electricity consumption rate to the bottom.

Producing your own electricity

Participants were asked, if they were not already producing electricity by any means, if they would like to do so and why. About two thirds of the participants answered they would like to do so for a variety of reasons. One third indicated they would not want to. However the reasons they gave might indicate they would actually want to, but there are currently obstacles which hinder them.

The responses are divided by the answer on the question: “Can you estimate the total yearly electricity consumption of your household?”. This was used as some indication of the awareness of people on their usage of electricity, see table 1.3.

To explore the dimension of costs the possibility of leasing was proposed in the following way. “Small companies now offer the option of leasing the solar panels instead of selling them at once. The leasing contract usually also includes the installation and maintenance of the system. The company then requires you to pay a fixed amount of money every month until the system has been paid of.”

Only a small amount of people (10%) would change their mind based on this information. The rest of the participants would object for the same reasons, when people would object without the stimulation of leasing the system.

Acceptance of users regarding the concept of household generation of electricity seems relatively high in this sample group from The Netherlands. The public opinion in the United States on supporting PV according to the SCHOTT Solar Barometer, is drawing to Solar power. 39% indicated they would support solar power if they were in charge of the US energy budget (Kennedy 2012, pg19).

PARTICIPANTS ARE PARTICULARLY REQUESTING FOR REFLECTION POSSIBILITIES REGARDING THEIR ELECTRICITY USAGE, WHEN THEY ARE ASKED TO RANK THE CONSUMPTION OF DIFFERENT ELECTRICAL APPLIANCES. THEY INDICATE THEY DO NOT HAVE ANY MEANS FOR COMPARISON AND WOULD LIKE TO USE EXISTING FEEDBACK POSSIBILITIES, LIKE PRICE AND PERCENTAGES TO UNDERSTAND THEIR USAGE BETTER.

table 1.3

ELECTRICITY GENERATION BY HOUSEHOLDS

Would you want to produce electricity at your own house and why?		When people were asked to estimate their total yearly electricity consumption, they answered:	
		No, I don’t know	Yes , it’s: .. kWh
Just, Yes!	11	6	5
Yes, it contributes to a better environment	32	25	7
Yes, it saves costs	16	13	3
Yes, it makes you independent	12	8	4
Yes, it feels good	2	2	0
Yes, I like the idea of balancing need and production	2	2	0
Total	**75**	**56 (75%)**	**19 (25%)**
No, (but I would consider) my living situation is not stable (rental house or other)	12	10	2
No, (but I would consider) I don’t have the money to invest	5	3	2
No, I would like companies to do it as efficient as possible	4	2	2
No, production of PV panels is bad for the environment	1	0	1
No, I am not interested its too difficult	13	7	6
Just, No!	3	3	0
Total	**38**	**25 (66%)**	**13 (34%)**

About two thirds of the participants answered they would like to do so for a variety of reasons. One third indicated they would not want to. The answers are divided by the answer on the question: “Can you estimate the total yearly electricity consumption of your household?”. This was used as some indication of the awareness of people on their usage of electricity.

THE RESULTS OF THE FIRST USER STUDY ARE USED FOR THE PRELIMINARY EXPLORATION OF THE KNOWLEDGE LEVEL OF USERS AND THEIR MOTIVATIONS TO TAKE DECISIONS. IN CHAPTER (D) USER MOTIVATION IN PART 2, A FIELD STUDY IS DESCRIBED WHERE IN DEPTH RICH INSIGHTS ARE OBTAINED.

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INTERMEZZO

THANKS TO ADVANCES IN TECHNOLOGY A TIME HAS ARRIVED WHERE IT IS POSSIBLE TO GENERATE ENERGY BY VIRTUALLY EVERYONE FOR A COMPETITIVE PRICE. I BELIEVE THAT IN ORDER TO ESTABLISH A DEMOCRACY IN THE ENERGY MARKET EVERY USER IN THE SYSTEM SHOULD BE ABLE TO BECOME AN ACTIVE PLAYER AND USE TECHNOLOGIES TO GENERATE ENERGY, BOTTOM-UP.

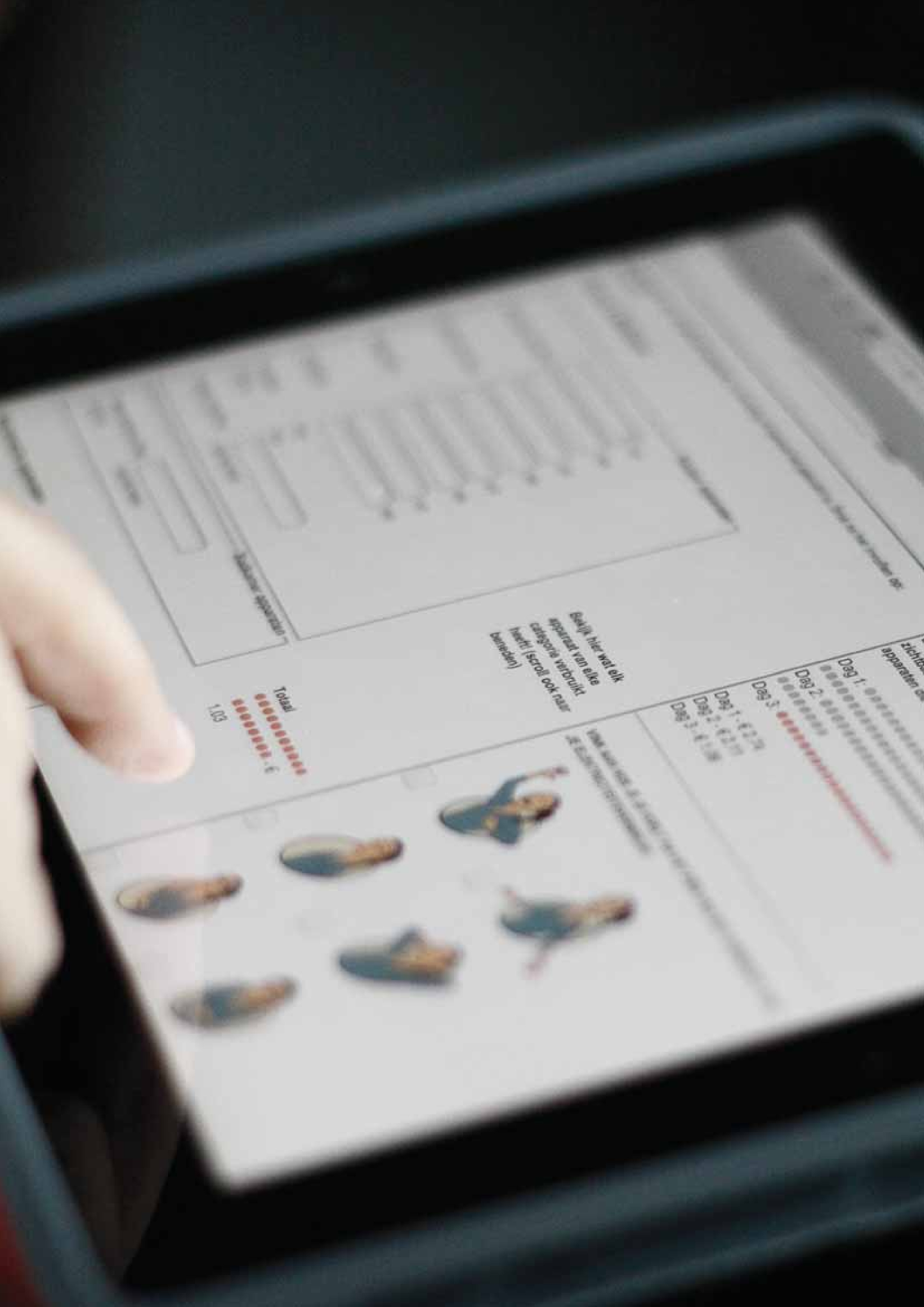
The Dutch electricity grid as we currently know it, is optimised to facilitate the efficient use of fossil fuels as energy source. Those energy sources are however not ready for the future for several reasons and therefore have to be substituted by other 'renewable' energy sources and technologies. To make the Dutch electricity grid reliable and accessible for every user, there are many players involved to keep the system operational and provide electricity for a fair price to the consumer. Although the system is designed to provide the consumer with the best price and reliability, the transparency for the consumer is relatively low. This results in a very passive user, who does not have any influence on the system.

To give the user a more active role in the consumption of electricity and in the energy market, I believe he or she should become a producer of electricity or at least have a say in the production system. To ensure, energy stays affordable, the Dutch energy system needs a revolution and stay in tune with the needs of today and the future. The so called 'prosumer' is introduced, which combines producer and consumer in one user. By giving the user a part of the responsibility to foresee in it's energy need, the user is expected to become an active player on the Dutch energy market. A 'democratisation' is required to create a system where users of electricity also carry some of the responsibility for generating this electricity and establish some independence. The 'democratisation' of the system will not be achieved in this project and is also not the goal for this particular project. It does however form the envisioned context for a product which could function as tool for the user to initiate the first steps to an energy democracy, bottom-up.

Becoming a small scale producer of electricity has become attractive in recent years, with the technological development of new generation systems such as, solar photovoltaic cells and wind turbines. Electricity production with energy from the sun by photo voltaic cells is a very suitable technology in an energy revolution, because it is a technology which can be easily scalable. It is therefore suited for decentralised domestic electricity production. This allows users to install their electricity production facility on even the smallest scale and contribute to an energy market which is shaped bottom-up.

By taking responsibility and suffice in their own energy needs, users can become more aware of their own influence on the energy problem. In this project this will be used as hypothesis to successfully design a product which leverages the expected physiological and sociological effects of the change in responsibility for energy sufficiency.

However to gain acceptance for the larger majority of users a lower entry level is required. The user needs to be provided with tools that make him or her more powerful and influential in the way electricity is consumed and eventually also how it is produced. The form in which these tools have to be provided has to be determined carefully. Therefore this project will focus on creating tools which can facilitate an energy revolution, or more specifically a user driven solar photovoltaics revolution.
To give users control over the electricity generation for their households, they should also have control over the electricity consumption. The tools that can empower the user to be in charge of this balance will be designed in this project.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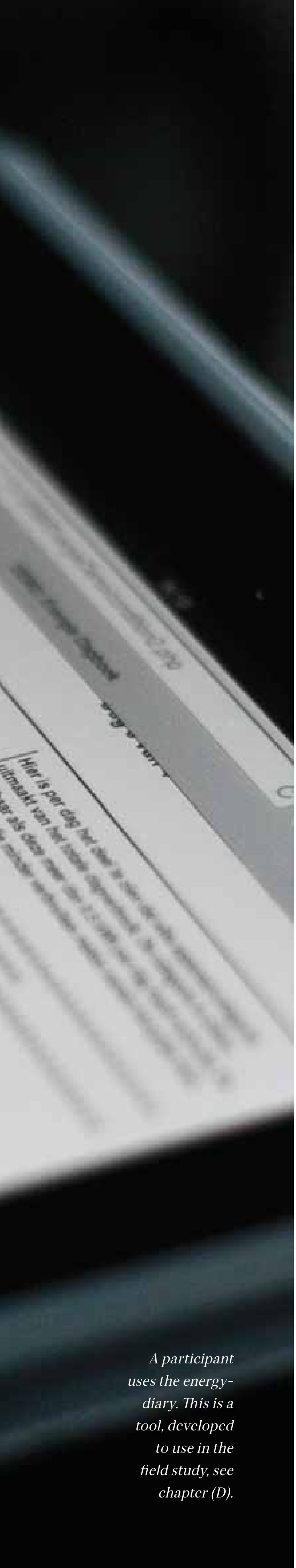


A participant uses the energy-diary. This is a tool, developed to use in the field study, see chapter (D).

photo: Jaap Rutten

PART 2
EXPLORING USER INVOLVEMENT

IN THIS PART OF THE PROJECT IS EXPLORED HOW USER INVOLVEMENT CAN BE TRIGGERED FOR ‘PROSUMPTION’. THE CURRENT STUDIES AND TOOLS WHICH ARE USED TO INVOLVE USERS WITH THEIR ENERGY CONSUMPTION ARE DESCRIBED IN CHAPTER (C) ECO VISUALISATION. THE INSIGHTS OBTAINED FROM TOOLS WHICH CURRENTLY ARE MAINLY USED TO STIMULATE INVOLVEMENT WITH ENERGY CONSUMPTION, CAN BE USED TO DESIGN INVOLVEMENT IN ‘PROSUMPTION’ I.E. ENCOURAGING USERS TO PRODUCE THEIR OWN ELECTRICITY. THE CURRENT PRODUCTS WHICH MAINLY STIMULATE ENERGY CONSERVATION, WILL BE ANALYSED BASED ON AN INTERVIEW WITH THE EXPERT; SONJA VAN DAM.

DESCRIBED IN CHAPTER (D), A FIELD STUDY WHERE USERS PARTICIPATE IN THE COURSE OF A FOUR DAY STUDY, WHERE THEY ARE ASKED TO KEEP AN ‘ENERGY-DIARY’. GOAL IS TO UNDERSTAND THEIR MOTIVATIONS FOR THE ACTIVITIES THEY CURRENTLY DO WITH ELECTRICITY AND THEIR ATTITUDE TOWARDS GENERATING ELECTRICITY IN THEIR OWN HOUSEHOLD.

(C) ECO VISUALISATION

THE CURRENT STUDIES AND TOOLS WHICH ARE USED TO INVOLVE USERS WITH THEIR ENERGY CONSUMPTION ARE DESCRIBED IN THIS CHAPTER. THE INSIGHTS OBTAINED FROM TOOLS WHICH CURRENTLY ARE MAINLY USED TO STIMULATE INVOLVEMENT WITH ENERGY CONSUMPTION, CAN BE USED TO DESIGN INVOLVEMENT IN `PROSUMPTION' I.E. ENCOURAGING USERS TO PRODUCE THEIR OWN ELECTRICITY. THE FOLLOWING RESEARCH QUESTIONS WILL BE ANSWERED TROUGH A LITERATURE STUDY:

Q5 WHAT ARE THE EXISTING TOOLS AND METHODS USED IN INVOLVING USERS IN ELECTRICITY PRODUCTION/CONSUMPTION (PROSUMPTION)?

Q6 HOW IS INFORMATION REGARDING PROSUMPTION VISUALISED IN THESE EXISTING TOOLS?

Froehlich et al. (2010) describes the field of technological solutions which help people to reduce their energy consumption as follows:

" Eco-feedback technology is based on the working hypothesis that most people lack awareness and understanding about how their everyday behaviours such as driving to work or showering affect the environment; technology may bridge this "environmental literacy gap" by automatically sensing these activities and feeding related information back through computerised means (e.g., mobile phones, ambient displays, or online visualisations)."

Three areas can be determined in current electricity consumption feedback research in the field of HCI (Human Computer Interaction) research according to a review of Pierce and Paulos (2012):

1. Consumption feedback. Research in this area is mainly focused on specifically presenting users with feedback based on electricity consumption data, which is typically given through a computational visualisation.
2. Energy awareness and conservation behaviour. Research in this area is typically focused on promoting the individual awareness and energy conservation behaviour.
3. Lack of engagement with emerging energy systems. Research in this area focuses on the integration of future and developing energy systems as smart metering, distributed and renewable energy production and demand respond by consumers.

From these three areas the first and second are most commonly and extensively researched, where the third area is represented to a much lesser extend according to Pierce and Paulos (2012). Especially the user interaction with new distributed and renewable energy production technologies is largely underexposed in literature (Pierce, Fan et al. 2010), which primarily forms the scope of this project when it would be categorised based on the above three areas. The first two research areas provide necessary insights not only when designing for electricity consumption feedback, but also for the third area: user involvement and longer-term engagement with renewable energy systems.

This section serves as an overview section presenting the existing studies and products concerning eco-visualisation. First the current studies in the research areas of ‘consumption feedback and energy awareness and conservation behaviour (Pierce and Paulos, 2012) are presented and consecutively existing products in the market which fit this fields are presented.

1. ENERGY AWARENESS, CONSERVATION BEHAVIOUR AND CONSUMPTION FEEDBACK

Scholars in the domain have showed numerous examples on how energy consumption decreases when people monitor/ or get feedback on their energy usage (Pierce and Paulos 2012). The majority of the presented work in the literature implement computational displays for providing feedback on electricity consumption data (Foster, Lawson et al. 2010). Most of those utilise a screen-based computational visualisation (Kim, Hong et al. 2010); some use ambient displays with lighting (Jönsson, Broms et al. 2010). And in most of these studies an artefact (digital) is designed focusing on domestic use, showing the electricity use in the entire home and also giving more detailed, ‘broken down’ data, about particular appliances at home. What are the common points of these existing feedback technologies? What kind of psychological approaches are followed? Do they work efficiently? How do they visualise the ‘energy consumption’? What are the pros and cons of the existing visualisations?

Eco-feedback technologies are developed based on the hypothesis that most people lack awareness about how their daily activities, how the way they live affect the environment; and existing technologies can help in creating awareness among people by monitoring their daily activities and provide them with feedback about the ‘eco-cost’ of these activities. In return, it is believed that, such approach can trigger a lower energy consumption of users. Froehlich et al. (2010) discuss a number of psychological approaches, which can be used as creating motivation for environmentally conscious behaviour as below:

information: with better information, e.g. via media, campaigns, advertisements, websites, etc., people will act more responsible towards the environment,

goal setting: a comparison of the present and a desirable future, which can be done by individuals, groups, and external agents,

comparison: comparing individuals and groups can motivate especially when combined with feedback on performance,

commitment: a pledge or promise to attain a certain goal; a person can make a commitment to a group, to a society; or the other way around,

incentives/ disincentives and rewards/ penalties: incentives/disincentives come before a behaviour, rewards and penalties come after a behaviour. The first ones have been used effectively to motivate people to make investments for home insulations, or to buy energy efficient appliances. Rewards have also been proved to be good motivators for responsible behaviours towards energy consumption. Eco-feedback is therefore recommended by some authors to feature game-like reward elements (Bang, Gustafsson et al. 2007),

feedback: feedback on performance, which can be in two forms: low-level feedback, which is about giving explicit feedback on a specific behaviour (to change and improve); high-level feedback, this can help to improved to approach a goal, in comparison to others. Fischer (2008) and Froehlich et al. (2010) emphasise that if the feedback is given too rarely (e.g. a electricity bill), and if the feedback is not directly connected to the consumption behaviour, and if the feedback is given to the people who are already consuming less energy than others, the feedback cannot be as effective as expected. Fischer (2008) has also analysed a number of studies to show the most effective feedback characteristics. She could show that the most effective feedback interfaces consisted of multiple feedback opportunities such as consumption over various time (day, week, etc.), comparisons between appliances, personal rooms, etc, and additional energy saving tips. These interfaces were commonly updated frequently, were interactive, were giving more overview data but also breakdown data over the appliances. These emphasised points by Fischer based on the analysis of a number of ‘eco-feedback’ studies have been benefitted in this project in the creation of the required qualities for a concept.

2. EXAMPLE FEEDBACK SYSTEMS

Below examples have been chosen from a set of applied studies and have been analysed in order to decide on the degrees (or whether or not) to apply the above approaches in the design process.

2.1 POWERSOCKET (HELLER AND BORCHERS, 2011)

Heller and Borchers developed the PowerSocket concepts (Figure 2.1a) to visualise the electrical consumption feedback through the plugs. The figures are accompanied with an explanation of each feedback visualisation.

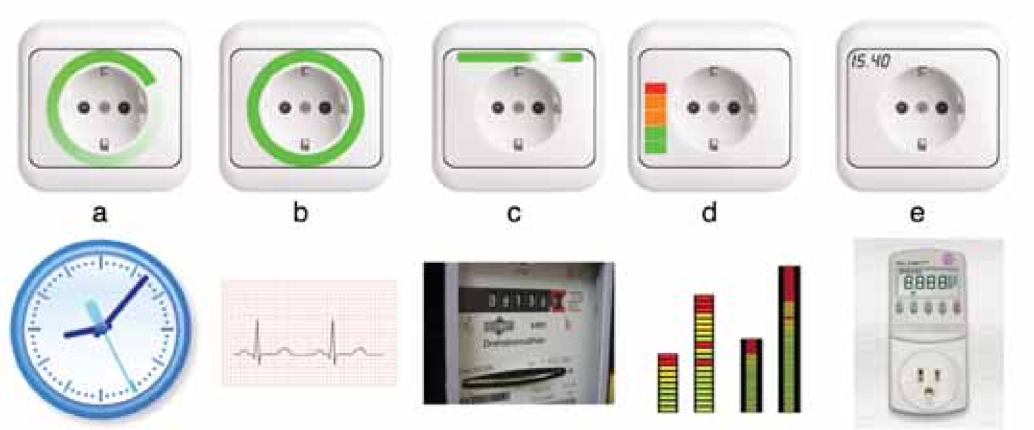
They conducted a study to explore which of the visualisations were more understandable and more aesthetically pleasing. They found that the LCD visualisation was rated significantly easier to read and less obtrusive than the other visualisations. However when the different visualisations were discussed on how they would integrate in a daily life situation it became unclear which visualisation would be desirable. None of the visualisations was giving enough information on its own, a solution should be found in a combination of aspects from the different visualisations. Heller and Borchers (2011) conclude the studies as follows:

“One characteristic of an ambient display is to visualise data in the users periphery without requiring specific attention. This is not the case for the LCD: “I wouldn’t notice it when passing by”.

“The benefits of the ambient visualisations are that they, as expected, allow quick estimation of the consumed power. Even though precise readings are difficult, categorisation is feasible.”

figure 2.1a

POWERSOCKET VISUALISATIONS



(a) Rotation: When low power is consumed, the **rotation speed** is very slow; under high load, the rotation is very fast. Additionally, the **colour fades** from green under low load to red under high load circumstances. This display maps consumption to movement.
b) Pulse: consists of a lit ring around the plug that **continuously fades from no to full brightness**. The colour is mapped to the power consumption but the pulse-length is constant.
c) The spin-animation: Physically, this is a rotating disk with a coloured mark. Our adaption consists of a **slightly illuminated green horizontal bar** above the plug and a white point that simulates the coloured mark of the wheel. This point moves from left to right, and once disappeared at the right end of the bar, reappears on the left end.
d) Bar graph shows an **LED bar** graph on the left side of the outlet. The lower part is of green colour and represents the values below 250W. Values up to 1000W continue filling up the bar in orange colour and finally, values up to the theoretical maximum of 3680W add a red part on top.
e) **LCD** shows the currently consumed power in Watts above the plug. This is very close to the common devices like the Kill-a-Watt and maps power to its symbolic representation in Watts.

The different visualisations and their real-world counterparts used in PowerSocket (Heller and Borchers, 2011).

2.2 WATTBOT (PETERSEN, STEELE AND WILKERSON 2009)

Petersen at al. (2009) designed a domestic electricity monitoring and feedback system called WattBot. It is an application for the Apple iPhone and iPod that allows users to track their home energy usage over time and encourages them to reduce consumption. They emphasise that the key to encouraging people to engage with this information was to make the WattBott portable, available anywhere in the house at any time. The figure 2.1b shows the main screen of the application. The length of the bar represents how much electricity that particular room, device or appliance has used during a given timeframe (Figure 2.1b). The bars are sorted by usage, so the biggest offenders are always at the top of the list. Each bar is colour-coded depending on how much electricity it has consumed.

They tested the usability and clarity of the application. They discovered that the total bar at the top of the screen was confusing to users. In addition their colour scheme was misleading such that a few users misinterpreted the warmer-coloured bars as representing heat output, not electricity usage. The most of the participants also indicated that they wanted to be able to access usage information for previous days, weeks and months. They also emphasised that comparing current and historical usage in order to gauge their performance in conserving electricity could be a valuable addition in the next version.

THESE BOTH TWO EXAMPLES AND THE ANALYSIS OF THEIR TEST RESULTS PROVIDE VALUABLE INSIGHTS TO TAKE INTO CONSIDERATION IN THE DESIGN PHASE WHICH IS DESCRIBED IN PART 3.

figure 2.1b

WATTBOTT

The length of the bar represents how much electricity that particular room, device or appliance has used during a given timeframe. The bars are sorted by usage, so the biggest consumers are always at the top of the list.

3. CURRENT PRODUCTS

A review of existing monitoring products available in the Netherlands, based on an interview with expert Sonja van Dam*.

3.1 DISTRIBUTION OF CURRENT PRODUCTS

The analysed products are distributed by different organisations/companies, which often changes the philosophy behind the products.

When the products are distributed by utility companies, they always go together with a contract with the utility provider. The utility companies are looking for ways to expand their customer base and these energy monitoring tools have become a way to compete for them.

Integrated with home domotics system (Niko Home Control), the energy monitoring tool has the possibility to deliver a very integrated experience. This possibility is currently not used to its full extend, but is definitely a pro compared to the other products on the market.

Many monitoring solutions are available as plug and play devices on the consumer market. The companies that make them, typically have lesser investment possibilities. The products are less integrated and typically only have the function of energy monitoring, where other products also have other features.

Next to monitoring of energy some devices also provide management solutions, they often require installation and are more targeted for the technical DIY user or can be installed together with e.g. an alarm system for households.

3.2 UNDERSTANDING OF ENERGY CONSUMPTION

The devices which are currently available offer different features which can contribute to a better understanding of consuming energy.

In the table 2.1 (next page), several representative products are shown for the four categories described above. In Appendix IV the full table can be found, which includes all products which have been analysed in this study.

Two axes can be determined based on the review of both existing studies and existing products. For a future product it is important to find a balance on those axes, which ensures that all aspects are represented in the feedback visualisation, see figure 2.2 (next page).

integration // accuracy

The first axis should establishes a balance between integration and accuracy. The visualisation should be able to integrate in its ambient environment and the activities of the user, but also give the user something to hold on to and the ability to compare values. A part of the visualisation allows for a more intuitive use while the accurate part is only needed to give the user a feeling for size.

detail information // overview information for indication

The second axis establishes a balance between the details of your electricity consumption and an helicopter overview to be able to make a reference between different values. The user can not be presented with all available detailed information at once, that becomes overwhelming and repels the user. The details should however be available to create understanding and provide guidance.

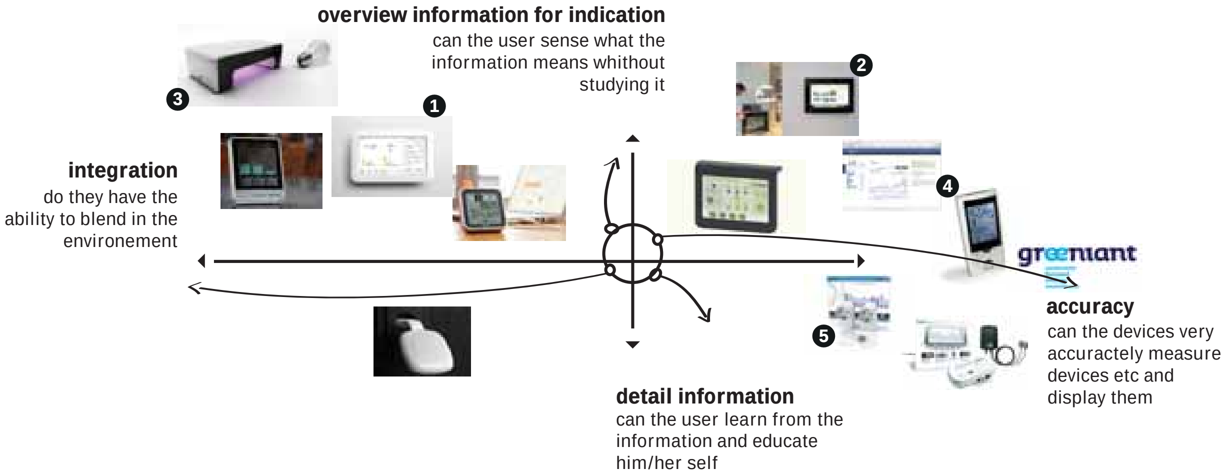
4. CONCLUSIONS

Generally it can be concluded that a single form of feedback yields relatively small improvements for reducing electricity consumption in households. As the examples of the PowerSocket visualisations (Heller and Borchers 2011) show, the ambient displays trigger questions regarding the relatively small amount of information they give. However the digits display triggers questions regarding the placement in the context, it accurately shows the electricity consumption, but it loses its meaning to the user. Balancing the different feedback in the visualisations seems to be crucial to establish a system that is both meaningful and informative.

To determine how the explored insights can be used to design 'prosumption' feedback the following research questions are answered:

figure 2.2

BALANCE OF THE AXES



The above categorisation on the axes, displays where the current products are positioned. While this is by far not the only indication for a product direction, it can give some reference. It is important that a future product has a leg in all axes. Most of the products are currently just representing one or two of the values on the axes.

Q5 WHAT ARE THE EXISTING TOOLS AND METHODS USED IN INVOLVING USERS IN ELECTRICITY PRODUCTION/ CONSUMPTION (PROSUMPTION)?

Currently the methods are focused on creating awareness of real time electricity and natural gas use (some products) and providing historical data to discover trends. Many of the analysed products also have extra features, e.g. remote switching of plugs and combining thermostat and consumption figures.

The extra features typically make the products more attractive to users. They buy the product also for its other features and while doing so they acquired an energy monitoring solution. This can make the product more successful and can stimulate the user to start using the energy monitoring feature.

The methods which are described as effective feature among other aspects:
goal setting: a comparison of the present and a desirable future,

incentives/ disincentives and rewards/penalties: rewards have been proved to be good motivators for responsible behaviours towards energy consumption, to feature game-like reward elements can stimulate the acceptance and involvement of users.

feedback: the most effective feedback interfaces consisted of multiple feedback opportunities such as consumption over various time (day, week, etc.), comparisons between appliances, personal rooms, etc, and additional energy saving tips. Interfaces should be updated frequently, and should be interactive and should give more overview data but also breakdown data over the appliances.

Q6 HOW IS INFORMATION REGARDING PROSUMPTION VISUALISED IN THESE EXISTING TOOLS?

The study did not point out winning or losing aspects for a successful visualisation, it did however emphasise the importance to feature different feedback aspects. It is important to animate the real time energy consumption, but also provide grip by giving the possibility to compare and reflect.

**Sonja van Dam is doing her PhD research at the faculty of Architecture of Delft University of Technology into Home Energy Management Systems (HEMS).*

table 2.1

ENERGY MONITORING SOLUTIONS

MONITORING DEVICE	STRONG POINTS	CAPABILITIES	INTERFACES	INTERACTION LAYERS
Utility companies provide energy monitoring/managing tools				
Eneco Toon ❶	The device combines attractive features, like a smart thermostat with different layers of complexity for gas/ electricity consumption	Thermostat, gas and electricity consumption of total household	Single wall mounted display, which displays all capabilities and information, smartphone application for simplified functionality	multiple, the smartphone application offers a simplified view, the single wall mounted display has multiple layers of information complexity
Energy monitoring integrated with home domotics				
Niko Home Control ❷	The system is integrated with your house domotics system, which gives a high quality experience. The eco display is an accessible first layer for information.	The home domotics system of Niko, also features the possibility to monitor energy consumption. It connects to the already available infrastructure in the house.	Three interfaces can be used to display the information. The eco display, the home control display and a smartphone application.	multiple, the eco display only shows the current energy usage, the smartphone app and the home control display give the same feedback. They provide historical data of your consumption and production.
Plug and Play total household energy monitors				
Wattson ❸	The first layer feedback is an ambient colored light and allows for easier integration in your living environment. For more details you can look at the dynamic power meter, or costs which increase while you are watching	A sensor and transmitter is attached to the main electricity meter.	Two interfaces show the user current usage both in watts and ambient colors, a computer can be connected through usb to create historical data	multiple, the Wattson itself first presents below average, average and higher than average with ambient colors, layer 2 is also on the Wattson and presents you the current power usage in watts, the third layer uses the computer to generate historical charts
Blueline with PlotWatt software ❹	The software works with multiple measurement devices and uses a smart algorithm to distinguish the different devices which consume electricity	The blueline functions as sensor to measure total electricity consumption	The PlotWatt application on your computer provides the interface with a smart algorithm which determines which different devices cause the consumption	multiple, the application shows the current power consumption, then it also splits it up in different devices and presents your daily consumption (history)
Energy managing tools (technology oriented)				
Plugwise ❺	Many expansion possibilities and very detailed measurements, however there is none or only very technical interface available	Can measure electricity consumption per device	Computer can be used to read electricity consumption per plug	1, all (detailed) information can be acquired at once

A review of existing monitoring products available in the Netherlands, based on an interview with expert Sonja van Dam. In Appendix IV the full table can be found, which includes all products which have been analysed in this study.*

Two axes can be determined based on the review of both existing studies and existing products. For a future product it is important to find a balance on those axes, which ensures that all aspects are represented in the feedback visualisation. The product should be able to offer information in different layers. Where the information which is used for indication and a rough estimation is presented first and more detailed information is presented in reasonable sized chunks.

THIS SECTION PROVIDED VALUABLE INSIGHTS ON THE IMPLEMENTATION OF ECO-FEEDBACK IN VISUALISATIONS, WHAT STILL NEEDS TO BE EXPLORED IS HOW TO ENGAGE USERS IN GENERATING THEIR OWN ELECTRICITY FOR THEIR HOUSEHOLDS. THE NEXT SECTION WILL PROVIDE INSIGHT IN THE MOTIVATIONS THAT PEOPLE HAVE AND HOW THEY AFFECT THEIR DECISIONS AND ATTITUDES.

(D) USER MOTIVATION
WHICH TOOLS CAN BE USED TO STIMULATE HOUSEHOLD ELECTRICITY PROSUMPTION

TO GIVE THE USER A MORE ACTIVE ROLE IN THE CONSUMPTION OF ELECTRICITY AND IN THE ENERGY MARKET, HE OR SHE SHOULD BECOME A PRODUCER OF ELECTRICITY OR AT LEAST HAVE A SAY IN THE MARKET OF ENERGY PRODUCTION. THE USER SHOULD BECOME A, SO CALLED 'PROSUMER', WHICH COMBINES PRODUCER AND CONSUMER IN ONE USER, SEE ALSO CHAPTER (A), 3. . TO UNDERSTAND HOW THE CURRENT USERS OF THE ELECTRICITY GRID CAN BECOME ACTIVE PLAYERS OR PROSUMERS, THE CURRENT ACTIVITIES AND ATTITUDES REGARDING ELECTRICITY USE ARE EXPLORED IN A PARTICIPATORY FIELD STUDY. THE FOLLOWING QUESTION IS ANSWERED IN THIS CHAPTER:

Q7 HOW CAN THE USER BE MOTIVATED FOR HOUSEHOLD ELECTRICITY PROSUMPTION?

Many behavioural studies have been done in the past to understand and actively influence user behaviour while preserving the current energy system. In this project behavioural change will not be main focus, since the goal of the project is to trigger a system change: a more democratic energy market. The user behaviour research body can however provide valuable insights, to help understand certain underlying motivations which users currently have regarding their electricity consumption and possible production. Froehlich, Findlater et al. (2010), indicated two categories of behaviours that are addressed in eco-feedback solutions. They describe those categories as follows:

"Gardner and Stern (2008) draw a useful distinction between two types of consumption behaviours: (1) efficiency behaviours, which are one-time actions that provide a lasting impact, such as buying a fuel-efficient vehicle, and (2) curtailment behaviours, which involve forming new routines to reduce environmental impact, such as taking the bus to work. A large majority of the eco-feedback technologies we reviewed in both HCI and environmental psychology have focused on the latter, yet it may be worth focusing on both. Gardner and Stern contend that that the energy saving potential of efficiency behaviours far outweighs the potential of invoking curtailment behaviours. For example, the installation of compact fluorescent lighting (CFL) could be much more effective than remembering to turn off the lights."

In this project a combination of both types of behaviours will play a significant role in successfully implementing, the to be designed product in daily life activities. The goal of the project is not to elicit curtailment behaviours, but to understand how to motivate users to invest in efficiency behaviours. In this project specifically, the targeted behaviour is not done justice by being called efficiency behaviour, but rather could be called: paradigm shifting behaviour. The targeted behaviour in this project is the self guided responsible behaviour, of investing in energy self sufficiency. In the following section both behavioural types are explored and consecutively analysed how they can be used as inspiration for designing.

1. THE ROLE OF BEHAVIOUR

McKenzie-Mohr (2011) describes in his book, 'Fostering Sustainable Behaviour', how changes in behaviour not only have a direct effect on becoming more sustainable, but also affect how people view themselves. People who consciously changed their behaviour for the sake of becoming more sustainable on any aspect in their live, are likely to take on an ambassadors role based on their own engagement in the issue.

In this project is targeted to trigger users of the electricity grid to become prosumers, rather than changing their behaviour inside the existing system. Behaviour change methodology and tools, as described in the book of McKenzie-Mohr (2011), can however be used to determine powerful tools when designing products which will be closely intertwined with daily life activities of users.

While campaigns and products which promote sustainable behaviour are often based on giving users better information, the book of McKenzie-Mohr (2011) describes that information only will rarely evoke action.

1.1 MOTIVATIONS

With numerous examples is shown that education on its own, or giving better and more detailed information does not result in the designated behaviour. So is described that in a study on water-use, participants were provided with knowledge regarding the harmful aspects of water use and methods to guide them in saving water. However this did not result in any impact on water consumption (McKenzie-Mohr 2011).

The economic benefits of sustainable behaviour are often used to promote sustainable practices. In campaigns of products that aim to reduce energy use this motivation has been frequently used to motivate consumers to be more aware of the implications of their energy use. Never more than now are energy costs used as motivator to convince consumers to buy products that help them to reduce energy consumption and consecutively reduce costs. The economic incentive does however not address the barriers that prevent the adoption of the sustainable behaviour. E.g. the promise that a smart meter can help consumers to reduce costs, may increase the number of people that purchase the smart meter. However it does not address the behavioural aspects which have to be adopted by those consumers to yield truly significant results in reduction of energy consumption (McKenzie-Mohr 2011).

1.2 DETERMINING AND DESIGNING BEHAVIOURS

The book of McKenzie-Mohr describes a process to determine the effectiveness of designing for certain behaviours to elicit sustainable breakthrough. This process can be summarised as exploring and detailing behaviours and consecutively determining impact, probability and penetration of the designated behaviour.

To successfully design a product which fosters sustainable behaviour the book describes the encouragement of the designated behaviour while discouraging the behaviour that should be avoided to reach the target. By introducing barriers for the behaviour that should be discouraged and taking away the barriers for the encouraged behaviour, the desired behaviour can become more attractive in contrast to the behaviour which is unwanted. To increase the success rate of the behavioural stimuli, understanding the commitment of users is an important factor. By using techniques which

PROVIDING USERS WITH A MORE GRANULAR VIEW OF THEIR ENERGY USE GIVES THEM INSIGHT IN THE BUILD UP OF THEIR TOTAL ENERGY USE. ACCORDING TO THE EXAMPLE ABOVE THIS SHOULD GIVE USERS A BETTER UNDERSTANDING AND CONSECUTIVELY EMPOWER THEM TO MAKE BETTER DECISIONS. THE UNDERLYING MOTIVATIONS OF USERS ARE HOWEVER NOT TAKEN INTO ACCOUNT IN THE ABOVE EXAMPLES. USERS ARE EXPECTED TO BEHAVE DIFFERENTLY, BUT THEIR GOALS ARE LIKELY GOING TO INFLUENCE THE BEHAVIOUR THEY EXPRESS. IT IS THEREFORE CRUCIAL TO EXPLORE WHICH GOALS AND MOTIVATIONS USERS HAVE AND HOW THEY INFLUENCE THEIR DECISIONS IN DAILY LIFE ACTIVITIES AND THEIR ATTITUDE TOWARDS CURRENT ENERGY CONSUMPTION AND FUTURE PROSUMPTION.

elicit users to become committed, the promotion of sustainable behaviour becomes very effective (McKenzie-Mohr 2011).

1.3 PROMPTING USERS

The action of prompting is described as a crucial part in making the implementation of new sustainable behaviours successful. The requirement for successful prompting according to McKenzie-Mohr, is to target specific behaviours with prompts. In the design of prompts it is important that the prompt is placed as close in space and time as possible to the behaviour they need to promote, especially were repetitive behaviours are targeted.

A given example in the book of McKenzie-Mohr (2011, p. 97), which illustrates the void of information users encounter in the feedback regarding their energy use, is that of a supermarket without price tags. One would do the grocery shopping in a shop which does not feature any price tags for the individual items, all you get as feedback is the total bill for all the items you purchased. This would leave the user with a lack of information regarding the build up of the costs of this bill, he or she is left to estimate the costs of each individual item if any action would be required.

2. HOW DO MOTIVATORS WORK IN PRACTISE, A FIELD STUDY AS INSPIRATIONAL RESEARCH

To gain insight in the underlying reasons for the motivations that determine the actions and decisions of people, a participatory field study has been conducted with participants from different groups. After the first user study which took place as internet survey with a large base of participants, this study only targeted a small amount of participants. They were involved for a longer period of time, to reach in-depth rich insights.

2.1 GOAL OF THE FIELD STUDY

The aim of this study is to understand the current motivations of users for the decisions regarding the use of electricity in their household. The study has as focus to understand what are the underlying motivations to invest (or not to) in personal household energy efficiency and self sufficiency by household production of electricity. To reach to the complexity of this subject users have been actively involved, with as purpose to understand their own current behaviour regarding electricity use. Therefore the first part of the study tested whether different forms of creating awareness and understanding can help to reach to the deeper subject of contributing to energy self sufficiency in households. The following research questions have been explored in this field study:

1. What is the influence of detailed information (feedback) regarding electricity consumption in the current household situation of users to:
   - their mood and decisions they make regarding activities related to electricity use?
   - their attitude towards being particularly efficient with the electricity they used during the study?

2. Can the information that is mentioned in the first question be used to trigger the reflection on acceptance of renewable energy in the form of solar photovoltaic panels?

2.2 SETTING UP THE STUDY

Obtaining rich insights from users by introducing small interventions in their daily life activities, was used to explore current motivations with regard to electricity use and production. Participants were presented with different visualisations of the information to reduce the amount of test variables per participant.

Two conditions (see next page) were tested which featured different visualisations of similar situations (households of participants). Both visualisations were based on a visualisation which uses coloured dots as alternative to commonly used numbers to represent the technical unit kilo Watt hour (kWh). Each dot stands for a certain kWh value, the minimum amount of kWh is determined as 0,02, based on a pilot test where one full washing cycle is compared to a saving bulb of 11W which is used for 2 hours. The points given for a wash cycle of a washing machine with European Energy label F or higher is 1,95kWh/0,02kWh = ~98 points. The simplification of the point system was intended to make the participant aware that the washing machine used 98 times more electricity than the saving bulb.

Both visualisations in the different conditions offer a different possibility for reflection by the participant. The first condition offers as means of reflection, the metaphor of a limited amount of electricity, the second condition provides the means to compare different clusters of devices to address them to certain activities of the participant.

Study condition 1:

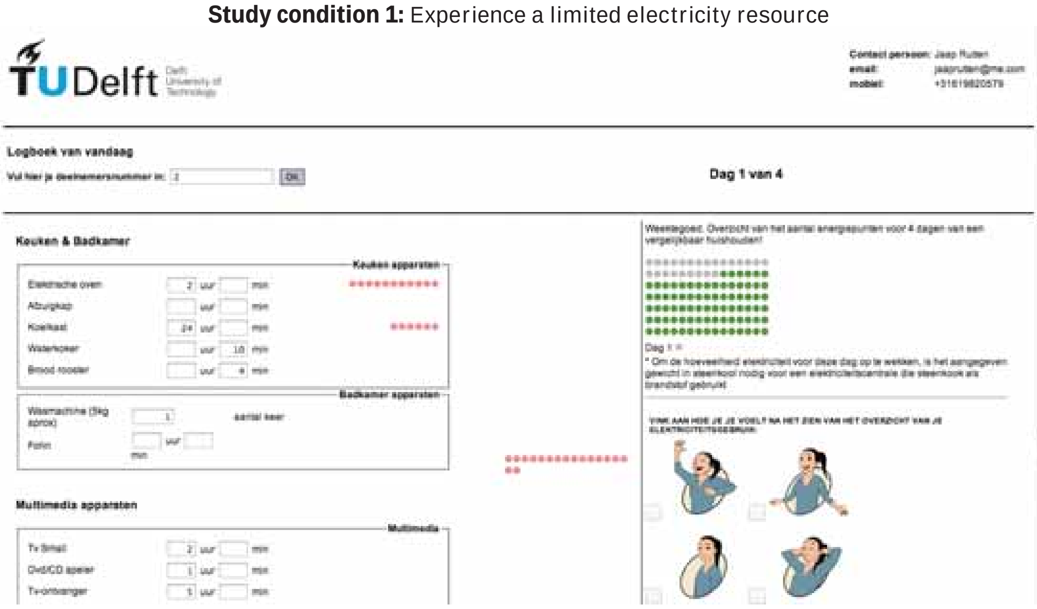
Experience a limited electricity resource through a point system (figure 2.3).

In this study the use of electricity per device was used to present the total electricity use per day. To explore the effect of household electricity production on the electricity use of consumers, a new dimension was introduced. By introducing a certain limit to the available electricity in the presented figure, the concept of a limited amount of produced electricity is mimicked. Similar to when electricity is produced inside the household by e.g. solar PV panels, where a limited amount

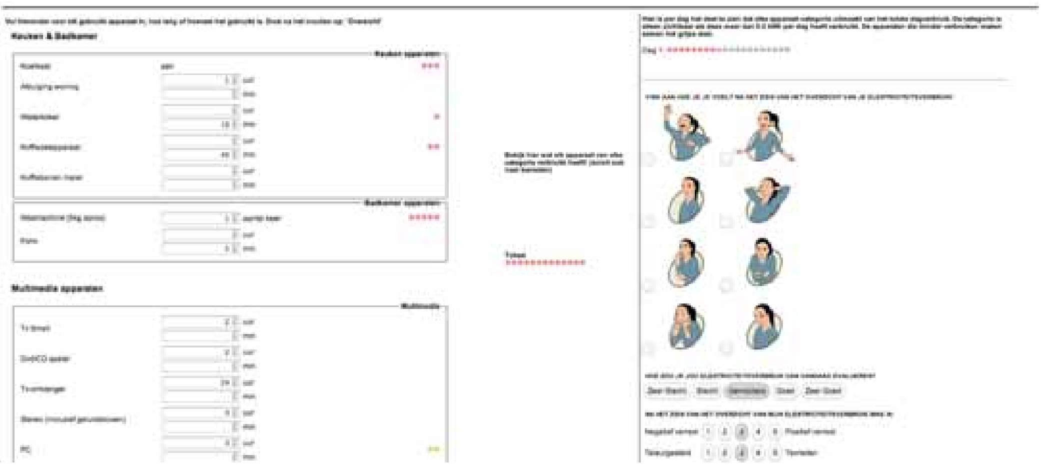
figure 2.3

CONDITION 1 AND 2

Study condition 1: Experience a limited electricity resource



Study condition 2: Use of devices in reference to total use of electricity



A screen-shot of the web-based energy-diary, which shows the aspects of the first and second condition. Respectively the concept of a limited amount of produced electricity is shown and the proportion of the electricity consumption between different appliances.

of electricity can be generated as opposed to the virtual endlessness of electricity from the grid.

Study condition 2:

Putting in perspective use of devices in reference to total use

The consumed electricity was displayed on appliance level, to give participants insight in the proportion of the electricity consumption between different appliances. The electricity consumption data is clustered per device with as hypothesis that it is easier to address to a tangible object or even a ritual the object is involved in than the consumption data as such. The top consuming devices are displayed as part of the daily total consumption and the different days can be compared with each other and used as reference for reflection.

Sub conditions

The study which had a duration of four days featured different subconditions for each day. Those subcondition had as purpose to explore the influence of different motivators for energy saving of users. The first day was giving feedback only with ‘so called’ energy points. On the second day, the points were given a financial unit in Euro which remained also on the third day. On the fourth day an equivalent in fossil fuels was presented which represented the amount of electricity. See the below figure 2.4.

2.3 ACQUIRING PARTICIPANTS, THE NEIGHBOURHOOD OF HEIJPLAAT

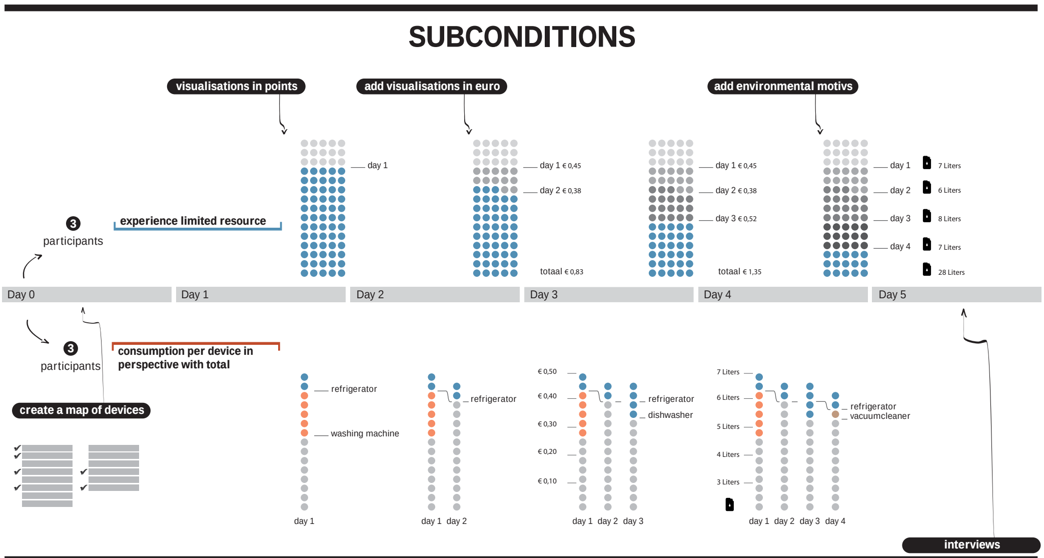
A campaign was held in the neighbourhood of Heijplaat to recruit participants for the study. The local hotspots were used to distribute flyers and mouth to mouth advertisement. The housing association, ‘Woonbron’ which owns most of the buildings in the neighbourhood was contacted to distribute flyers and actively involve people through email. Next to that the community centre ‘De Huiskamer’ was used to contact neighbours and to present a poster, see figure 2.5a.

By using these methods to advertise the study, as researcher I immersed myself in the neighbourhood and obtained valuable contacts. These contacts proved useful to execute this study and future studies with a solid base of participants from the neighbourhood and surroundings.

2.4 METHOD

Six households in the neighbourhood participated in the study for a duration of six days. The first day would consist of an intake conversation with the researcher in the house of the participant. A list was made of all the appliances and lights in the house which could be manually controlled by the participants (automatic ventilation systems, etc. were not considered). The list which was assembled during the intake, would be converted to a digital database to be used for the intervention in the following days. The study for four days uses

figure 2.4



The first day was giving feedback only with ‘so called’ energy points. On the second day, the points were given a financial unit in Euro which remained also on the third day. On the fourth day an equivalent in fossil fuels was presented which represented the amount of electricity.

the intervention to trigger participants to keep a diary of their electricity use. After the four days are completed, an in depth interview is conducted which uses the diary as sensitising tool.

The diary comes in the form of a web-application, which requires the participants to fill in the use-time of each appliance in their house during that day. The webpage features incremental changes after each day that passes, each day more information is given while the basic lay out and information is maintained.
The basic lay out of the web-application features three parts, the first part is where the participants appliances are listed. The second part presents the participant with a simple reflection which is different in the respective first and second condition. The third part consists of some questions to the participant which refer to the mood, feeling and activities of participants.

The first part displayed in figure 2.5b is customised to the specific situation of the household of the participant, the intake conversation had as purpose to provide this customised list. The participant is asked to fill in the use time of each appliance in the list, which is then used to generate the electricity use values for each device.

In the second part, see fig 2.5b, the different visualisations to trigger reflection by the participant are displayed. These visualisations are based on the values obtained in part 1 of the interface. The values are summed up to display the total electricity consumption of the day or are categorised per appliance type. In condition 1 this part of the interface shows the electricity consumption of the day as part of a limited total for the 4 days of the study. In condition 2 this part of the interface shows the electricity consumption of the different days categorised per appliance type. Both offer the participant a means of reflection.

In part 3 of the interface three blocks of questions are presented to the participant. The first block requires the participant to indicate his or her mood after using the interface and being presented with the electricity data. The second block presents the participant with a set of semantic scales, which ask the participant to rate the presentation of the information. They were asked indicate whether they were:

- Negatively surprised or Positively surprised
- Disappointed or Satisfied
- Worried or Relieved
- Confused or Enlightened

The last block of questions would ask participants wether they could indicate which activities had influenced the electricity consumption of that day and if they would change anything during the next day.

After four days the study ends, and an in depth interview was conducted with the participants in their houses. The intervention interface was mainly used as sensitising tool to make people think actively on the subject and make them acquainted with the knowledge regarding electricity consumption.

2.5 INTERVIEW

The interview had a semi-structured set up, the following subjects were used as guidance:

1. Interface;
   - how was your experience with the interface of the intervention tool?
   - what was the most useful and most negative aspect?

2. How was your involvement considering your electricity use during the study? Would you maintain your current habits and let your comfort level in the house prevail or would you try to be more efficient with electricity?

3. If you would get a small solar photo voltaic kit to borrow for a few days, would you accept it?

4. What kind of feedback would you like to have in order to make that decision?

5. Would a solar photovoltaic kit in combination with the intervention tool change something in the way you would use your electricity. Think about the balance between maintaining the comfort in the house and being more efficient with electricity.

After the interviews with participants were conducted, an overview of the gathered information was send through email to the participants that did not already have solar photovoltaic panels installed on their house. In this overview was presented what would change if the participant would acquire a kit of 2 solar photo voltaic panels.

figure 2.5a
Screenshot of one of the places where an advertisement was published to recruit participants. Heijplaat.com is a website about the neighbourhood, which is created by one of the local residents, Nico Prins.

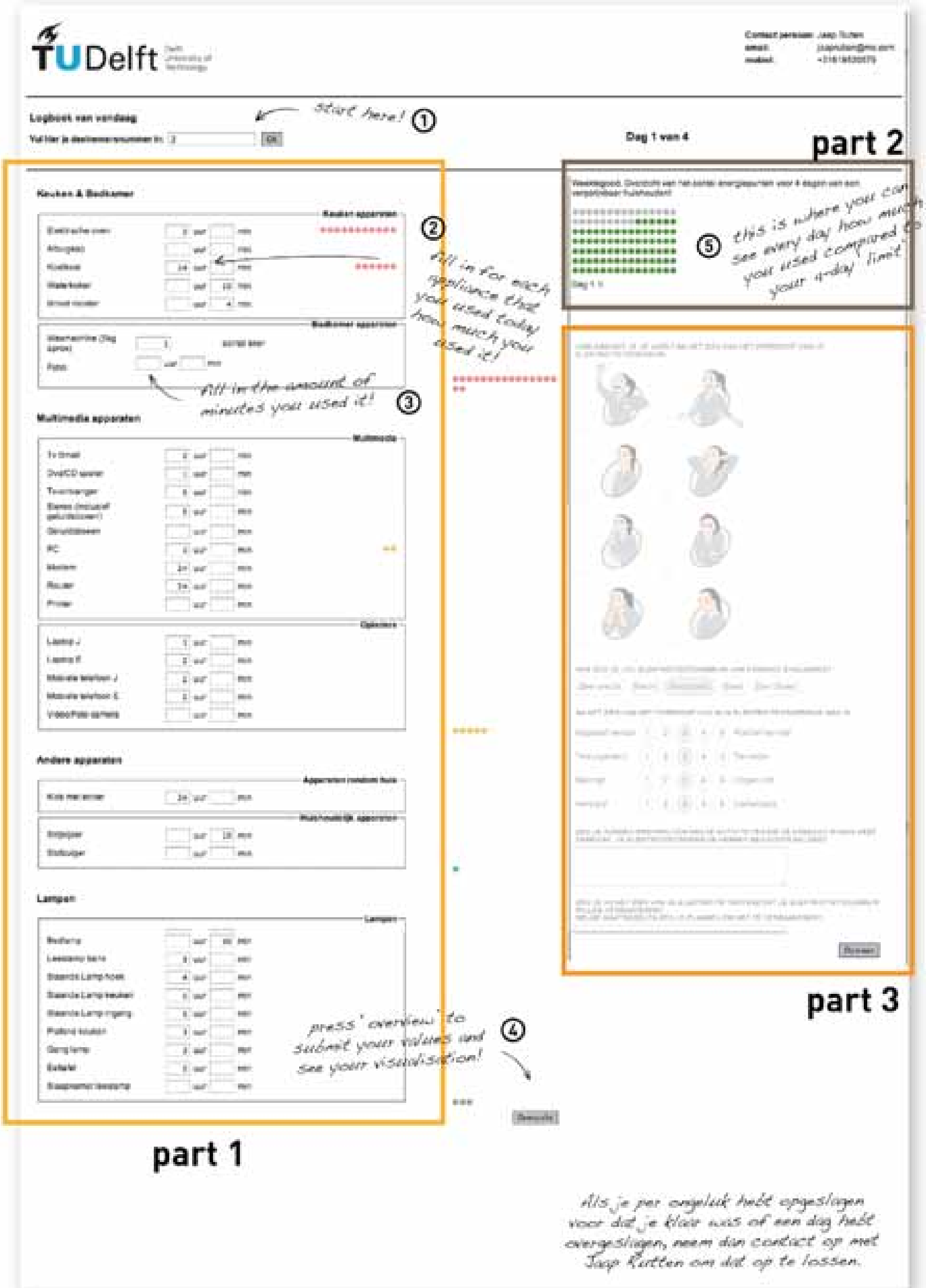
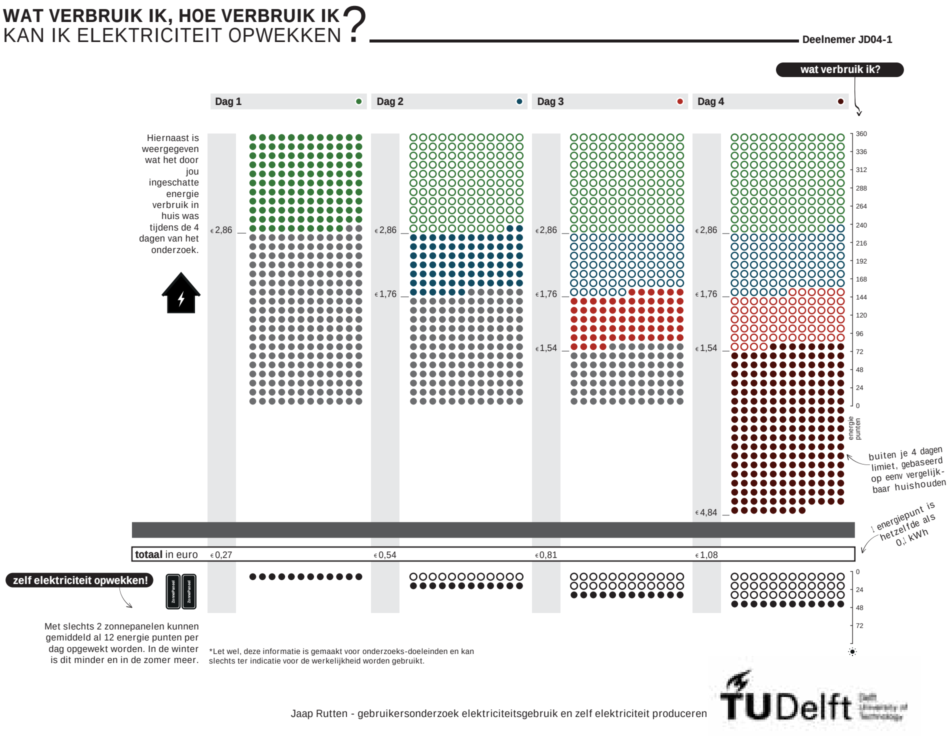
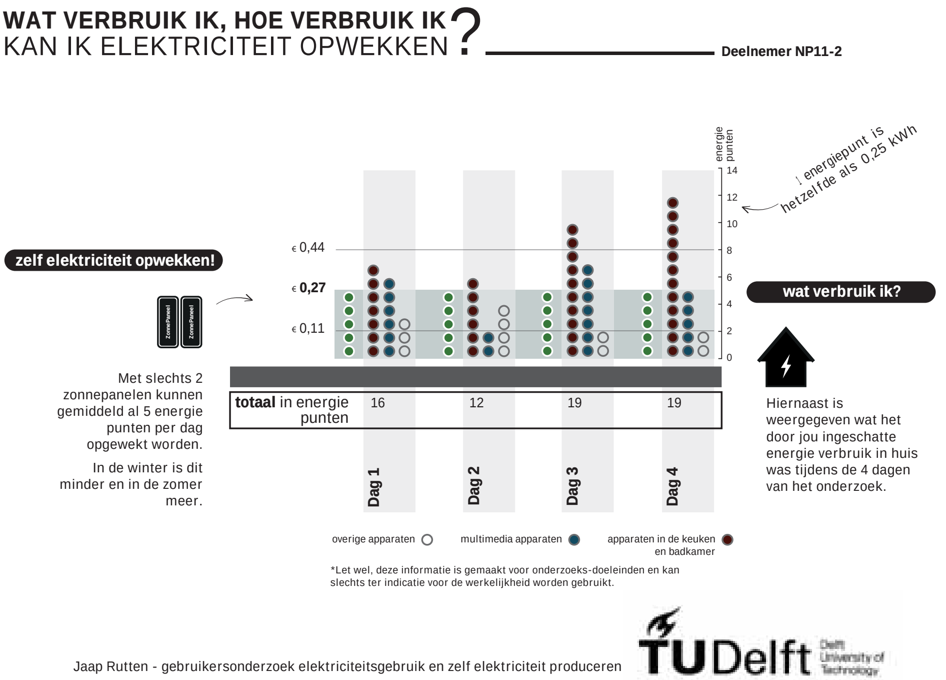


figure 2.5b
The basic lay out of the web-application features three parts, the first part is where the participants appliances are listed. The second part presents the participant with a simple reflection which is different in the respective first and second condition. The third part consists of some questions to the participant which refer to the mood, feeling and activities of participants.

figure 2.6

FEEDBACK OVERVIEW





An overview of the gathered information was send through email to the participants that did not already have solar photovoltaic panels installed on their house. In this overview was presented what would change if the participant would acquire a kit of 2 solar photo voltaic panels.

2.6 RESULTS

Six households from the neighbourhood Heijplaat in Rotterdam participated in the study, one household already had solar photovoltaic panels installed and one household previously lived in a house with solar photovoltaic panels installed. All Households featured different compositions and had different backgrounds. Two families with two or more children, two families with one child, one single person household and one couple without children participated in the study.

The diary

The most valuable results of the study were acquired in the semi-structured interview that was conducted with participants after they had spend four days with the energy diary. The results from filling in the diary can be summarised shortly, an overview table can be found in appendix V.

The six participating households vary from extremely high energy consumers to extremely low energy consumers. In the mood- and feeling-scales can be seen that not all high consuming participants or low consuming participants feature the same moods and attitudes. High consumption can be combined with a worried attitude but also with a calm attitude. Average to low consumption goes with one participant together with excitement, but with another a certain calmness or acceptance can be seen. In appendix V can be seen how the different participants correlate their consumption with their moods.

Depending on the electricity consumption feedback participants would get from the diary they described the influence on their mood differently. A direct correlation can be seen between a 'bad' electricity consumption day and a negative mood indication from participants. Fluctuations between participants can be seen, as would be later explained, because participants with more knowledge on the subject were already expecting the outcome of the visualisation. Participants did say:

"I already knew that I would use a lot of electricity that day because I did the laundry!"

When participants were asked which behaviours influenced their electricity consumption and how they would alter them the next day, they would generally indicate they could not change most of their behaviours. Since they saw the necessity of e.g. doing their laundry and did not see a possibility to reduce electricity consumption. If they did indicate they would change something, the most common answer was regarding the usage of lights in the house. Participants realised that some lights were staying on unnecessarily and they would like to turn off the lights more pro-actively to reduce unnecessary electricity consumption.

The different subconditions yielded relatively small results. During the first day, where participants were presented with points without unit (see figure 2.4), it was unanymously agreed on that it was hard to relate to the points since they did not carry meaning without a clear unit. During the second and third day the financial units (Euros) gave something to hold on to for most participants. Although the price unit for the points did generally not entice participants to think differently regarding their electricity consumption. Displaying the units as 'eco-burden' by showing the amount of fossil fuels which was required for generating the electricity did not yield any result additionally to the previous subconditions.

Since the aim of the study was to retrieve in depth unique insights, the final interview was considered the most important part to retrieve insights. The diary and the questions in the diary were used to sensitise the participants.

The interview

The final interview was conducted in an informal manner, but some structure was applied to be able to retrieve comparable answers from participants, audio records of the interviews are available. The interview was semi-structured and consisted of 5 topics. For the participants who already owned solar photovoltaic panels a question was replaced. Question 3: If you would get a small solar photo voltaic kit to borrow for a few days, would you accept it? was replaced for Question 6: How would you convince other people to invest in solar panels?

The answers to the questions will be described in a grouped and generalised manner with quotes to illustrate the character of the answers.

[1] Interface;

- **how was your experience with the interface of the intervention tool?**
- **what was the most useful and most negative aspect?**

It was generally clear for participants how to use and read the interface of the web-application, they understood this interface was created for research purposes and not as final product. It was however indicated that they would have wanted to see a more targeted indication of e.g. the costs of specific appliances. Although the costs were presented per group of devices, participants indicated they would like to know what one washing cycle of their washing machine would cost in terms of electricity. It was also indicated that the overview for means of reflection, was hard for them to understand and truly use to reflect and compare their electricity consumption during different days.

Participants reacted differently to the manner of measuring their electricity consumption. Some participants would indicate they became very aware of their electricity consumption because they had to indicate the use time of appliances by themselves. Other participants would say, they didn't trust the overview in the diary, because they knew the electricity consumption wasn't actually measured.

"I liked it very much, it worked very well for me. With the different colours and dots, you are going to pay attention to everything you do. I was already trying to be economical, but with this it became even more."

"Now you have to think very hard, what you have been using (what caused the use of electricity). That makes it a bit cumbersome and not very trustworthy."

[2] How was your involvement considering your electricity use during the study? Would you maintain your current habits and let your comfort level in the house prevail or would you try to be more efficient with electricity?

Participants would show different behaviours regarding this aspect, some participants said they were hardly affected since they could not change their electricity consumption without affecting their comfort level/ease of use in the household. Other participants indicated, they used the tool to become even more aware of their electricity consumption and make plans to save on electricity.

It was however commonly indicated that it was very hard or virtually impossible to change the usage of electrical appliances. The participants that indicated they tried to consume less electricity, tried to achieve this by using the lights in the house more efficiently.

"I couldn't do anything but turning off the lights. You cannot turn off the other appliances like you do with lights."

"Keeping track of the time triggers you to start thinking about your behaviour more consciously. In that way you unveil which things are contributing to your comfort and which things are unnecessary."

"My daughter is not controllable in terms of energy. It is more difficult to control your electricity when you live with three (more than 1 or 2) than when you live alone. Because you have three different ways of use with three people."

[3] If you would get a small kit with solar photo voltaic panels to borrow for a few days, would you accept it?

Participants would generally respond to this question with: Yes, but ..
They would all like to contribute to a more sustainable way of generating and using electricity, but they see many obstacles that would be able to keep them from doing it. Participants do question whether the investment brings them benefits and if it would be affordable for them. However the financial aspect is not the only hesitation, participants have. They also question whether the system would be reliable and who would install it. The general theme could be summarised as: Isn't electricity something the government should take care of? I don't want to take all this responsibility on me, if it isn't utterly necessary. However I do want to contribute to a more sustainable world.

"Yes I would be open to such an offer, but only if I know that there is not going to be some tax on the energy I produce sustainably. When I look at television programs regarding this issue, it looks like for producing green energy you get punished because the conventional organisations have to keep earning money. That stops many people from doing it. But considering these obstacles wouldn't be there, I would definitely do it if it is for a reasonable price!"

"If it would be affordable, I would do it. But my hesitation would still be the reliability of the sun. Why does the government not invest in tidal energy here in the Maas (river in Rotterdam)."

"I think I would like that, but I think in practice it wouldn't be feasible. If there is a day without sun, I am left without energy and I would have to rely on the grid anyway. I think the problem is: people don't care where energy comes from, its unlimited in their eyes. It just comes out of the socket in the wall and it never finishes."

[4] What kind of feedback would you like to have to make the decision of investing in your own solar photovoltaic panels?

Participants would generally repeat the downsides of the previous question and say they would like to be better informed regarding those issues. In other words, it was difficult to make the bridge between the advantages and the downsides they thought there were.

"Well if you would earn them back in 6 years, it would be OK for me. It would be even better if I could loan/lease them, so I would not have to do the investment."

"Yeah sure! I saw once an article in 'bright', which described a box which showed with light effects what your electricity use shows. Kids and elderly should understand it right away."

An example of the application of the use of solar photovoltaic panels was then given to elicit a positive approach to the issue. Participants were given the example:

When you buy a washing machine in the electronics store, you have a variety in prices ranging from €300 to €1200. One of the variables in the differences between the machines is their efficiency, generally the cheaper machines are less efficient with electricity than the more expensive models. The price difference can be as much as €900, with this money the same shop could also offer you a cheaper washing machine and a set of two solar photovoltaic panels for roughly the same price as the most expensive machine. The advantage would be that you would not have to pay the electricity costs for running the washing machine anymore, since the solar panels will generate it.

"I would be convinced with such an offer and I think many others as well. If you would be able to provide your biggest electricity consumers in the house (washing machine, dryer, dishwasher, etc) with electricity from a renewable source I think its a very positive thing!"

"If you talk about LED bulbs. It is first about the money. If you can't invest then its not possible. But if you have the possibility, its great. It would be the best if you can do it without your energy provider. Just get rid of the companies which charge you money that you don't want to give them."

Participants would generally react positively to this offer, they would view the issue differently and started to become enthusiastic. They questioned: "why aren't these things advertised in a better way?"

[5] Would a solar photovoltaic kit in combination with the intervention tool change something in the way you would use your electricity. Think about the balance between maintaining your level of wellbeing in the house and being more efficient with electricity.

It was generally difficult for participants to discuss this issue, it was hard for them to see the self-generated electricity as a justification for using it.

"Its in the end about the price. If I would be able to afford it and it would be possible on my house, I would do it to be independent from fossil fuels."

"If a Solar park would be established in the harbour of Heijplaat, I would consider to invest in it. Then I would use the money I give to Eneco now, to invest in the Solar Park in the harbour."

"Two important factors: If people don't see the added value and don't earn something from it, they are probably not inclined to join the cause."

"The smart meter is not for the people, if you would buy your own system you would also get a present for your self and thats important. You get a reward."

[6] How would you convince other people to invest in solar panels?

Participants that already made use of solar photovoltaic panels or had used them before, where asked why they were convinced to buy the system and how they would convince others to do the same. The two participants in this group indicated their initial motivation was their ideals regarding sustainability, but they also indicated that there could be other motivators for people. They understood not everybody shared their ideals, but they thought many people would be convinced if you would present them understandable information.

According to these participants it is very rewarding to produce electricity your self, once you see that the electricity that powers you appliances comes from your local electricity generating solar panels. As one of the participants indicated, the feeling of self sufficiency and independence the PV modules give you is also very satisfying. It however becomes only clear when you have some kind of feedback, one of the participants used a third parties website to read out the smart meter which was installed by Eneco (Dutch utility company) in his household.

"You always have front runners and followers. You need those front runners and speak with an honest voice. Eneco people come with tie and suit and we don't trust them."

"That was great! Because you saw the electricity meter counting backwards. It was exciting to see that. To have the Solar Panels installed was great on itself! Because you contribute something to the environment. You feel good about it!"

"If you come with a clear and honest voice and have a clear plan to convince people of the benefits of alternative energy and the need of their investment, I think you will get a lot of people interested. What happened in the last years in The Netherlands, is that the society has been kept dumb in terms of sustainable energy solutions. Now it has the image of a organic alternative, sort of flower power movement."

"If you don't need the big energy boys (utility companies) that feels great! And 9 out of 10 people would think thats great. Some years ago, a friend of mine had PV panels on his roof. When we were looking at the electricity meter counting backwards, we were like happy children. It gives you a kick (boost), it counts back!!!"

3. DISCUSSION

To discuss the results of the field study, the initial research question and sub-questions will be discussed with the insights from the field study.

Q7 How can the user be motivated for household electricity prosumption?

With sub-questions framed as following:

1. What is the influence of detailed information (feedback) regarding electricity consumption in the current household situation of users to:
   - their mood and decisions they make regarding activities related to electricity use?
   - their attitude towards being particularly efficient with the electricity they used during the study?

2. Can the information that is mentioned in the first question be used to trigger the reflection on acceptance of renewable energy in the form of solar photovoltaic panels?

1. The information which was presented during the study was very influential for all participants, because the information was adapted to their particular household situation. This triggered participants to actively think about their activities and record them as accurately as possible in the diary. The approach taken was however different for every participant and this influenced their mood, the decisions they took and their attitude towards being efficient with electricity in their household. As was highlighted in the first section of the results, 'the diary', the participants with high electricity consumption can be combined with a worried attitude but also with a calm attitude. Participants with an average to low consumption goes with

one participant together with excitement, but with another a certain calmness or acceptance can be seen.

The different subconditions did not affect participants subtantially differently from each other. It was generally indicated by participants that the representation of their data was more understandable when the points had a value in the form of money (Euros). This was mostly because the Euro was a familiar value to them, not so much because they wanted to benefit financially from using less electricity. “To see the effect of electricity saving financially a long term comparison should be made”, many of them argue; “The few cents for my light bulbs don’t really trigger me to do something”.

Although the different participants reacted differently to being presented with their electricity consumption, they all came to a similar conclusion. They could reduce electricity consumption to a certain extend, but there are many activities which simply just have to be done anyhow. Either they concern a functional activity which is hard to avoid such as running the washing machine, or they concern an activity which is directly related to their wellbeing.

Many participants tried to unravel their patterns regarding the use of their lights. Electric light becomes a necessity after the sun sets, but it is not perceived as directly proportionate to wellbeing like for instance watching television or preparing an extensive meal. The activities which deliver an obvious contribution to wellbeing are by some participants rated as equally important to the functional activities. Other participants try to eliminate as much consumption activities as possible, especially the ones which are not utterly functional. The different participants have different motivations for their attitude and approach to this, depending on different factors. Those factors are very valuable insights for designing, they will be made explicit in the next section by forming a context for designing.

2. Two out of six participants had experience with generating their own electricity by means of solar cells. The other participants would initially react troubled, although they were actually genuinely interested in contributing to the environment by generating energy individually. They saw many obstacles which led them to believe it would not be something for them to take responsibility for.

It became clear that the information they had been presented with and be actively involved with did teach them the details of their consumption. It did however not bridge the gap between the technologically and financially daunting solution of electricity generation by PV modules and their own electricity dependence.

When participants were presented with the easy to grasp analogy of purchasing a washing machine, they started to become very enthusiastic. The full example is described earlier in the section results, ‘the interview’. They thought many people would be convinced, if the example would be tangible and applied to their personal context.

It is the experience that takes place in the gap between the worlds of daily life activities and a far ‘expensive’ technology (solar cells) that needs to be created and designed.

TO ENABLE USERS TO BECOME MOTIVATED FOR HOUSEHOLD PROSUMPTION, A CONNECTION SHOULD BE MADE BETWEEN THE TECHNICAL CONCEPT OF GENERATING ENERGY AND THE REAL LIFE SITUATION OF DAILY ACTIVITIES WHERE ELECTRICITY CONTRIBUTES TO THE GENERAL WELLBEING OF THE HOUSEHOLD!

IN PART 3 THESE FINDINGS WILL BE FURTHER EXPLORED. TO GET GRIP ON THEM THE FACTORS THAT ARE AT PLAY WILL BE STRUCTURED AND A CONTEXT WILL BE DEFINED.

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INTERMEZZO

THE RESULTS OF THE SECOND USER STUDY (PREVIOUSLY DISCUSSED) FEATURE MANY INTANGIBLE ASPECTS, WHICH HAVE NOT ALWAYS BEEN SPOKEN OUT OR DOCUMENTED. THEY ARE ASPECTS THAT LARGELY DETERMINE THE MOTIVATIONS AND BEHAVIOURS OF PEOPLE, BUT THEY ARE NOT EXPLICIT. TO BE ABLE TO HARVEST THESE ASPECTS FROM THE RESULTS OF THE STUDY AND MAKE THEM MEANINGFUL, THE VISION IN PRODUCT DESIGN (VIP) METHODOLOGY WILL BE USED (HEKKERT, LLOYD ET AL. 2010). IN THE FOLLOWING CHAPTER (E) PART 3, THE VIP METHOD WILL BE PUT TO USE PRECEDING THE CONCEPTUALISATION OF A PRODUCT.

consumptie
996
keuken
wasruimte
verbruik per kamer
vandaag

The concept of the designed product; Ampul is prototyped in the Concept House. On the background Marc is programming the required software.

photo: Jaap Rutten

PART 3
DESIGNING USER INVOLVEMENT

AFTER A THOROUGH EXPLORATION OF THE CURRENT PLACE OF THE USER IN THE ENERGY MARKET, DESCRIBED IN PART 1 AND 2, I CREATE A CONCEPT- WHICH I NAME AMPUL- THAT AIMS TO CONNECT PERSONAL OR SMALL-SCALE ENERGY PRODUCTION WITH PEOPLE'S DOMESTIC ENVIRONMENT IN A MEANINGFUL AND NATURAL MANNER. THE CONCEPT HOUSE IS USED AS A CONTEXT TO PROTOTYPE AND TEST THE CREATED CONCEPT WITH USERS IN A REAL LIFE HOUSEHOLD SITUATION.

IN THIS PART THE FOLLOWING QUESTIONS WILL BE EXPLORED:

Q8
WHAT ARE THE FINAL 'DESIGN AND EXPERIENCE' REQUIREMENTS FOR A SYSTEM THAT INVOLVES USER ACTIVELY?

Q9
DOES THE FINAL DESIGN ACHIEVE THE MAIN AIM?

(E) BOTTOM UP
DESIGNING FOR USER INVOLVEMENT IN ELECTRICITY PROSUMPTION

AS DESCRIBED IN THE PREVIOUS PART, TO EFFECTIVELY IMPLEMENT DESIGN INTERVENTIONS IN DAILY LIFE ACTIVITIES OF PEOPLE, IT IS EXTREMELY IMPORTANT TO TAKE INTO ACCOUNT THE UNDERLYING ASPECTS WHICH INFLUENCE DECISIONS AND ACTIONS OF PEOPLE. IN THE PREVIOUS STUDIES THE MOTIVATIONS OF USERS AND THEIR ATTITUDES TOWARDS BOTH ENERGY CONSERVATION AND ELECTRICITY GENERATION AT THEIR HOMES HAVE BEEN EXPLORED. IN THIS SECTION, THE DESIGN REQUIREMENTS WILL BE DEFINED AS (1) SYSTEM REQUIREMENTS (BASED ON THE CONDUCTED STUDIES AND LITERATURE) AND (2) EXPERIENTIAL REQUIREMENTS (BASED ON THE VIP METHOD) TO FOSTER THE CONCEPTUALISATION OF THE FINAL DESIGN.

1. SYSTEM REQUIREMENTS

In chapter (C) of Part 2 is determined that the level of difficulty of information in a system should be adapted to the user. Following that, to apply the findings from the studies described in the previous part, not only as inspiration but also as guidance in conceptualisation, a fundamental framework and vision will be developed in the following section. The framework will be used as high-level design requirements, meaning it will determine on a system level how the design will work. This determines the number of components of which the design consists, how the components work together and what are the different tasks of the components.

An example could be the design of a supermarket, where the system of the supermarket, which determines the flow of customers, the different sections (e.g. fresh produce, diary, meats, etc.), the place for checking out, the number of check out points, etc., would be defined in high-level requirements. The selection of particular products, the ergonomic design of shopping baskets and check-out registers, would however be determined in low-level requirements.

1.1 FUNDAMENTAL FRAMEWORK: SYSTEM DESIGN REQUIREMENTS

The framework will describe the high-level design requirements and will be determined by using the insights obtained from the previous chapters, particularly chapter (C) and (D). The findings from behavioural science, human computer interaction research and existing eco-visualisations and energy monitoring products, can be summarised in a framework, see figure 3.1.

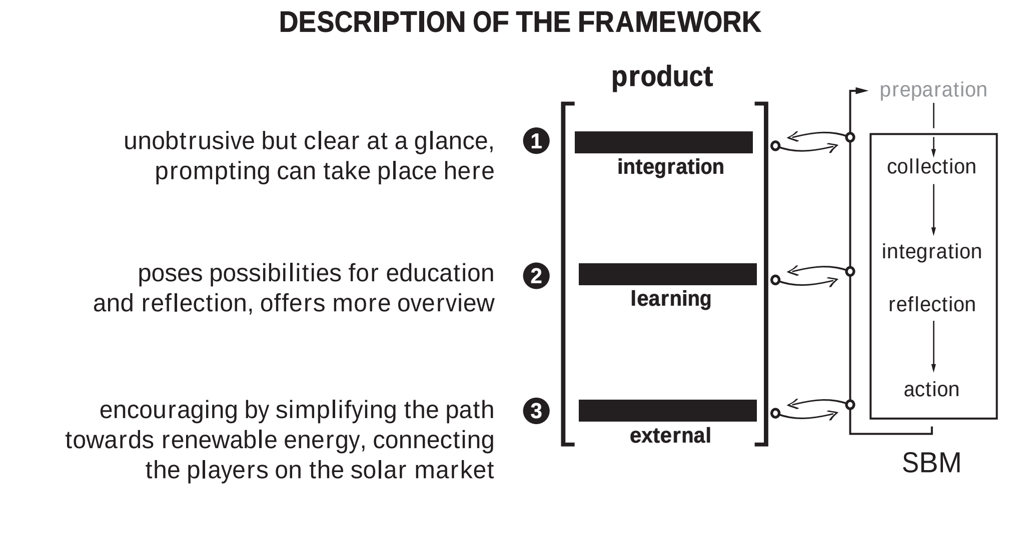
The framework describes three layers each of which contribute to a product-system bridging the gap between the distant technological solutions of electricity generation and the nearby, very tangible activities done with electricity in households. The layers represent the closeness to the daily activity of the user or integration-level in the household. The first layer, the integration layer is tightly interwoven with daily life activities of users, it is close in space and time to the activity which is being done with electricity in the household. The third layer, the external layer represents the players on the market for the distantiated technology of solar cells, which can be obtained by users to generate the electricity for the activities in the household. This layer encourages the desired renewable energy technologies and discourages the use of energy from conventional parties. The layer in between, the learning-layer provides the connection between the first and third layer. It is not as tightly integrated with the activities in the household as the first layer, but is still accessible at any time. The purpose of the second layer is to educate users in a playful manner and give them possibilities to reflect on their electricity consumption and production (prosumption) activities.

The first layer, where integration takes place with the daily life activities of users can facilitate the use of prompts. Froehlich et al. (2010) describe the importance of prompts to create effective feedback solutions as follows:

"Investigations into general prompting strategies have shown that prompting has limited influence on behaviour but can be made more effective by improving specificity, timing, and placement (Geller, Winett et al. 1982). For example, Winett et al. (1978) showed that placing signs next to doorways with specific information about when and who should turn out the lights (e.g., the last person leaving the room) resulted in a 60% reduction in the number of days when the lights were left on compared to signs that were placed above light switches and contained only general messages about saving energy. This is a particularly rich opportunity for eco-feedback technology, which could provide feedback proximal in location and time to the target behaviour. That said, deciding on how and where to present eco-feedback is a research question within itself and will likely need to balance attentiveness, cognitive load, user motivation, information relevancy, and cost."

The above example shows how the proper implementation of a 'prompt' can be used to translate presented information successfully into an action done by the user. In this project the desired actions of users after being prompted is more complex than in the above example, it will therefore be important to understand the process of decision making and the underlying motivations of the user. The research field of Human Computer Interaction (HCI) can provide valuable insights in the way people deal with information in their daily life activities. After all the act of consuming electricity is tightly interwoven with our daily lives. The Stage Based Model developed by Li et al. (2010), can therefore be used as valuable input in the fundamental framework which frames the system requirements for conceptualisation.

figure 3.1



The first layer, the integration layer is tightly interwoven with daily life activities of users, it is close in space and time to the activity which is being done with electricity in the household. The third layer, the external layer represents the players on the market for the distantiated technology of solar cells, which can be obtained by users to generate the electricity for the activities in the household. The layer in between, the learning-layer provides the connection between the first and third layer. It is not as tightly integrated with the activities in the household as the first layer, but is still accessible at any time. The purpose of the second layer is to educate users in a playful manner and give them possibilities to reflect on their electricity consumption and production (prosumption) activities.

1.2 THE STAGE BASED MODEL

The Stage Based Model (SBM) (Li et al., 2010) describes the design of human informatics products. These products help users to collect personal information and reflect on it. The model describes which steps are taken by the user and the product and provide guidance to make these systems more effective. The model describes five steps: preparation, collection, integration, reflection and action.

The preparation step comprises of deciding which information the user wants to obtain and at which moment. The collection step involves gathering the information, which is in this case executed by the system which measures the electricity data. A proper integration is responsible for making the gathered information meaningful to the user. Reflection is an important step in making the information meaningful and put it into perspective. It is emphasised that both short term and long term reflection should be considered, where short term reflection informs the user about their current status and allows for immediate response and long term reflection allows for revealing trends and patterns. Finally the step of action is reached which is of major importance in this project, since it determines if the user is able to connect an action to received information from the product.

The steps of the stage based model are to be kept in mind when such a product is designed. The steps are iterative and will take place in all three layers of the framework. For users to be able to use the different layers in a meaningful and smooth manner it is of importance to present electricity prosumption data according to the developed framework.

2. EXPERIENCE REQUIREMENTS

The developed fundamental framework captures the design requirements for conceptualisation, however the requirements which determine the user experience are not described by the framework. These experience requirements will be of crucial importance to the integration of the final product in daily life activities of people in households. The experience is manifested in rather intangible qualities, which are hard to capture in the conventional structure of literature research. These low level qualities are humane factors which could be encountered and mapped as result of the in depth interviews with participants of the field study, see Chapter D of Part 2.

The experience factors take place in all layers (1 to 3) in the framework, but are represented to a higher extend in the first two layers, which are the integration and the learning layers. The prompting, in the integration layer, has as main purpose to integrate the structure of the framework in daily life activities in households. It has to be always present for direct feedback, but also be unobtrusive to blend in to the household without affecting the wellbeing of people. Layer 2 serves as connecting platform between integration-layer 1 and external-layer 3, therefore it does not need to have the characteristic of blending in, to the same extend as integration-layer 1. It is however expected to work in close collaboration with the first layer and therefore has to share some of its characteristics. As an external factor the third layer does not serve the same purpose as the integration-layer 1, it will be connected through the learning-layer 2 but will be considered outside of the direct scope of the experience requirements for now.

For developing concepts that fit both the requirements of the framework and deliver the proper experience, the Vision in Product Design (ViP) method (Hekkert, Lloyd et al. 2010) is applied . This method is particularly useful to determine the experiential qualities by analysing the findings of conducted studies. In order to grasp these experiential qualities relevant to this project, the findings from the conducted studies in Part 1 and 2 are analysed through ViP method in the following section.

In the conceptualisation process through ViP, a context is determined which will form the base for defining interaction and product qualities (Hekkert, Lloyd et al. 2010). The context is formed from the factors which are extracted from the findings of the previous research in Part I & II of this project. The factors are then clustered to discover patterns which allow structuring through the process.

2.1 APPLYING VIP PRECEDING CONCEPTUALISATION

The ViP methodology is used to create a frame of reference for the future product to be designed. As mentioned in the book Vision in Design, a [redacted] F

[redacted] F

[redacted] F

[redacted] J

People want to make the things they use more personal, to shape them better to their lives. [Trend]

When you do something by choice, you are likely to feel better about it, than when you do it because you are obliged to. [State]

When something is personal it feels: unique, safe and clear for the person it is addressed to. [State]

The Smart Meter is not for the consumer! If I would buy my own system, then its a present for me! [State]

The movement of you electricity meter which counts in the backward direction, expresses a very strong symbolic message! [State]

If you can produce electricity on your own and don't need the big electricity companies, that feels great, like a victory! [Development]

[redacted] R

Green = Good, Not Green = Bad, Grey = Ugly [Trend]

Using energy more efficient than you did in the same situation before can be used as justification to increase your comfort by using other forms of energy. [Development]

People like to feel that they are relevant to the society they belong to. [State]

In a sample group of 91 persons, people were faced with the fact, that their electricity consumption defers from the average. They tended to look for reasons to justify the difference. [State]

Roughly all persons in a sample group of 91 indicated to have an average or lower than average electricity consumption, although most of them did not know what their own electricity consumption was. [State]

level of conciousness

J **joyfull**
// the information era
// comfort and costs
// hedonism

F **following**
// campaign of ignorance
// from savings to loans
// economy of scale

R **routinely**

[redacted] J

The only straightforward thing to influence your electricity consumption is to use the lamps in the house carefully, the other devices are still needed. [State]

Comfort prevails! Investing in efficiency but keeping or increasing comfort is what I prefer! [Development]

[redacted] J R

Increasing complexity elicits the monitoring of 'things' around you, to be updated about the status of these 'things' [Development]

If people do not get feedback on their actions, they will react precarious or rejective depending on their relation with the counterpart. [Principle]

[redacted] R

A tangible product has the advantage to be always present, even when turned off. [State]

After using the Energy Diary (tool) you become more aware and want to start saving, you think of tricks to make the household more efficient. [Development]

The person in the household that used the Energy Diary (tool), becomes more aware, but the others in the house don't. This creates tension and demotivates. [State]

If you want to improve you electricity efficiency, it should be integrated in your life. In every room you should be prompted. [State]

In a sample group, 50% indicates of all devices they use their laptop most frequently in a day, respectively 3-5 hours. [Development]

[redacted] S

Taking responsibility, also: the opportunity or ability to act independently and make decisions without authorization (dictionary), requires for the person in question to be knowledgeable. [Principle]

Do It Yourself. To create something yourself gives you almost guaranteed more satisfaction than buying it ready made. [State]

Doing the process yourself can make you aware of something you took for granted before. [Trend]

I would love to have Solar Panels, but its too expensive for me! [Trend]

I would rather invest in local energy than give the same money to Eneco [Trend]

2/3 of the sample group would like to produce their own electricity, with as primary reasons: 1) Contributing to the environment. 2) Saving costs. 3) To become more independent. 4) To feel good! 5) To contribute to the energy balance demand & production. [State]

[redacted] S

Values and Units are relative unless you can reflect them. [State]

When people were asked how they would like to be informed about the electricity of a device the majority indicated they would like to see costs and kWh per use cycle, although most people don't have a clue about their household use, expressed in these units. [State]

Money is considered as clear unit to express the used electricity, because the unit is familiar to virtually everyone. [Development]

The amount of money per use cycle, or per day is so small you don't care until you see the yearly bill. [Development]

[redacted] S

Trust is established when a firm belief in the reliability, truth, ability, or strength of someone or something is evident (dictionary). [Principle]

To convince people to change their attitude towards Solar Panels, you need front runners in a community with an honest voice and a clear plan! [Trend]

level of independence → S **self reasoning**

// cultural norms
// daily life
// the information era

// taking responsibility
// making it visual
// it takes a pioneer to make a paradigm shift

figure 3.2
These factors are determined with not only the field study as input, but with the entire preliminary research in mind. Together they will form a contextual base which will be used as fundament for the next steps in the design process. The clusters are used to define two axes which show the organisation and relation of the clusters to each other

guidebook for innovators (Hekkert, Lloyd et al. 2010):

"ViP is a human-centred design method that makes you carefully examine and determine what meaning to offer people in a future world."

The value of this method is the way it helps you as designer to articulate and structure the very fragile and often intangible values and meanings which you want to use and translate in the final design. In the book this is explained by using several example cases, but to understand the following steps the general process of ViP will be stated.

When the method is used to (re) design a product or to design a product inside a product portfolio or company, the process of deconstruction is applied first. In this project the deconstruction process will not be applied, the method will solely be used to structure and articulate the findings described so far and translate them in to products. In figure 3.3 is visualised which stages are part of the process, in this project the right halve, designing will be used. In the same figure can also be seen which 8 steps will be part of the process, step 1 to 3 will be used to define a context from the relevant factors which have been discovered during the different (user) studies.

2.2 CONTEXT FACTORS

Before starting the design phase, a context will be created by formulating factors and clustering them. The factors are determined with not only the field study as input, but with the entire preliminary research in mind. Together they will form a contextual base which will be used as fundament for the next steps in the design process.

The clusters are used to define two axes which show the organisation and relation of the clusters to each other. These axes can be seen as another categorisation layer of the already clustered factors. This results in four groups of clusters, which are defined as joyful, routinely, following and self reasoning. Below is defined what meaning those words convey:

Following versus Self-reasoning

The word following is chosen to represent an attitude of the user. A rather following attitude is exhibited where users become more dependent on the facilities in the world around them. This is triggered by the character of the clusters, where the economy of scale results in increased accessibility of products, but also increased dependency of the user. The trend is supported by tendency to be dependent on loans, rather than being self standing supported by your own savings. The campaign of ignorance helps to make as much people believe there is no other way than being dependent.

The other extreme of the graph is represented by a self-reasoning attitude of the user, which is represented by a well informed character which is confident enough to take responsibility. The self reasoning attitude is expressed in a cluster as: making it visual, which intends to make facts visible in a manner which is understandable by a large group of users and thereby creates a group of informed users. These users can take responsibility and some can become pioneers which will lead paradigm shifts.

Routinely versus Joyful

This axis is representing the quality of the experience which users can have. The axis is increasingly influenced by the information era, which is growing in many areas. The information

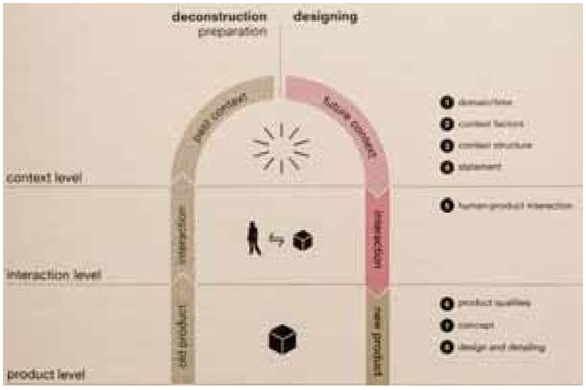


figure 3.3
8 steps of the ViP method which will be part of the process, step 1 to 3 will be used to define a context from the relevant factors which have been discovered during the (user) studies.

era influences how users are informed, how they communicate and how they execute many tasks in daily life. The quality of an experience is significantly different when the experience is done in a routinely manner, which is something that is done almost automatically without paying special attention. Or when it is something that is done with a rather hedonistic and very conscious approach, which prioritises comfort while maintaining a certain financial control. A joyful experience is therefore significantly different when compared to an experience which is defined by a routinely manner. The consciousness of the routinely experience is relatively low compared to a moment of joy which is consciously experienced.

In figure 3.2 and 3.4a, can be seen that the contradictions of each group, are mapped as respectively an axis which describes the level of independence and an axis that describes the level of consciousness.

The purpose of this extra layer of categorisation is to take a statement as designer and decide which direction for conceptualisation should be taken. In this project where democratisation of the energy market was one of the starting points, the direction will be defined as the upper right corner of the graph, see figure 3.4a. The combination of a high level of independence and a high level of consciousness results in a direction which creates a certain confidence to initiate and enjoy real world achievements and discoveries as opposed to made (game like) achievements. This joy stems from achievements which can only be realised after doing an investment in the form of educating one self and learning how to cope with the newly envisioned context. But also enjoying the decision of a made financial investment which comes back as temporary moments of energy independence.

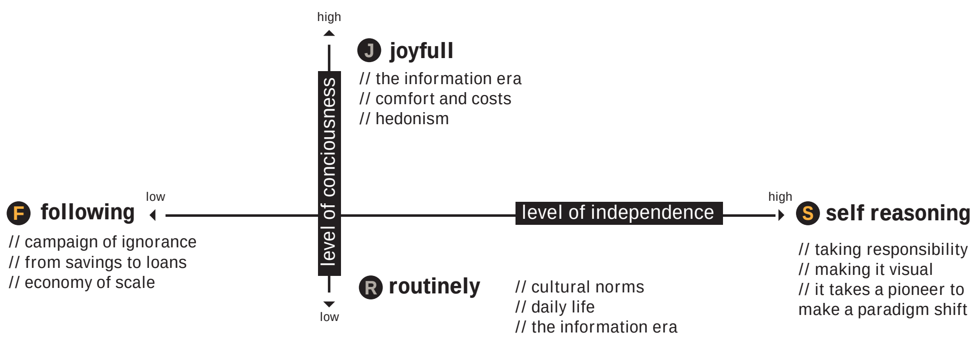
2.3 INTERACTION QUALITIES

The determined direction is consecutively used to further detail the envisioned interaction which should be established between user and product, to empathise with the future interaction that people should have with the product a analogy is created. The analogy does not describe the product in any way, but it does describe the type of interaction you want the user to experience when he or she uses the product, see figure 3.4b.

The analogy of a guide dog is chosen to explore the proper interaction qualities for the new product. The analogy is not intended to emphasise the dependency and handicaps of the user, but to use the positive qualities of this relationship to conceptualise a product which can elicit similar positive qualities. The guide dog develops into a sixth sense for the blind person, who is trying to function as good as possible in a society which is designed based on people who do have the ability to see. In order to become this sixth sense, the dog and it's owner have a relationship which is based on certain qualities. They understand each other intrinsically and establish a mutual trust. In order to use the dog as substitute for your eyes, a certain sensory communication needs to exist in order to have the intrinsic understanding and be able to trust the dog to base your decisions on.

figure 3.4a

THE STATEMENT



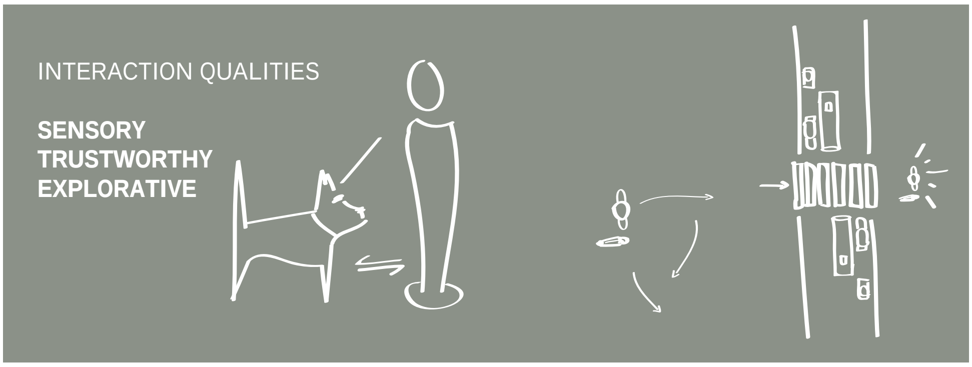
I WANT PEOPLE
TO **DISCOVER** THE **REWARDS**
OF SELF-**SUSTENANCE**
CONFIDENTLY

In this project where democratisation of the energy market was one of the starting points, the direction will be defined as the upper right corner of the graph.

figure 3.4b

DETERMINING INTERACTION

LIKE **DISCOVERING** YOUR **NEIGHBORHOOD**
AS **BLIND PERSON** WITH YOUR **GUIDE DOG**
AND FROM TIME TO TIME
CROSS A **BUSY STREET**



PRODUCT QUALITIES: **DIRECTIVE, SUPPORTIVE, LIVELY, NEAR**

The interaction with the product should be such that it is desirable in a comfortable household situation, but also gives the user an experience which rewards and inspires.

The before described qualities allow the blind person to explore the world which is based on people with sight, something almost impossible without having the blind dog. The value of the dog becomes even more clear when the dog and its blind-sighted owner achieve to cross a very busy street together. Something which would not have been possible before. Imagine what it must feel like to cross the street for the first time! But it surely will stay an adventure every time you encounter the street again. The blind person has to dare to trust the guide dog and cross the street, but a rewarding feeling of victory will take place after the street is crossed. The qualities sensory and trustworthy, provide a fundament for a certain explorative interaction. The interaction with the product should be such that it is desirable in a comfortable household situation, but also gives the user an experience which rewards and inspires. To imagine a product which elicits these rather intangible aspects three experience concepts were created based on the described interactions and a set of product qualities. The product qualities are the aspects which allow the product to establish a certain interaction with the user (figure 3.4b). The product qualities were defined to understand which qualities make the dog successful for the user. It is not intended to create a substitute for the dog in another context, but rather to understand better how a product can establish the interaction which lets the user experience the initial statement: ‘Discovering the rewards of self-sustenance confidently’

3. CONCEPTUALISATION

Three concepts were developed based on the defined system and experiential requirements. They are displayed in figure 3.5. Each elicits a slightly different experience, with the same essential keywords: explorative, trustworthy and sensory, with the possibility for a full filling reward. The concepts present the different layers of information and are designed to explore the desired experiential qualities which would best fit to the product.

3.1 C1 - THE NEW WORLD

The product lives with the user like a wrist watch

In the first concept, all three layers of the framework are implemented in a single device, the phone.
The concept’s intention is to let the user explore his or her house through different eyes and thereby explore the energy behaviour of the house and the user.

This is established by the use of a smartphone application which guides the user through the house with notifications and virtual reality techniques. And thereby unveil a new layer of reality in the real world, where the phone is the guide in this new layer. The new layer is one where the information regarding the prosumption of the household becomes visible, whereas this is currently largely invisible and therefore remains abstract. The application can give both live data of the electricity prosumption in the house and historical overview screens where possibility for reflection is implemented.

3.2 C2 - THE PARLIAMENT

The product reminds the user in every room, like a wall clock

The second concept, distributes integration-layer 1 and a part of learning-layer 2 to the wall-mounted-display, but leaves part of the second layer and external-layer 3 to a mobile device, e.g. mobile phone or tablet. Like a parliament which has in essence a common goal, the household has the common goal to consume the self generated electricity as efficient as possible. Every room competes with each other to become the most efficient and reach the common goal.

This concept is realised by several small screens (the size of a power outlet) which are distributed throughout the rooms in the household. The rooms do not have to represent different persons, but to each room a set of habits and daily life activities is attributed. Like cooking in the kitchen, drying hair in the bathroom, using the TV in the living room, etc. Thereby the electricity consumption is attributed to those rooms and activities, and made more tangible to the user.

3.3 C3 - PLAYING HIDE AND SEEK

Addresses the user at each device

TO TEST AND EXPLORE THE COMPREHENSIBILITY AND USER-INTEGRATION POTENTIAL OF THESE THREE CONCEPTS A CREATIVE SESSION WAS ORGANISED WITH THREE DESIGN THINKERS AND AN EXPERT* ON THE SUBJECT.

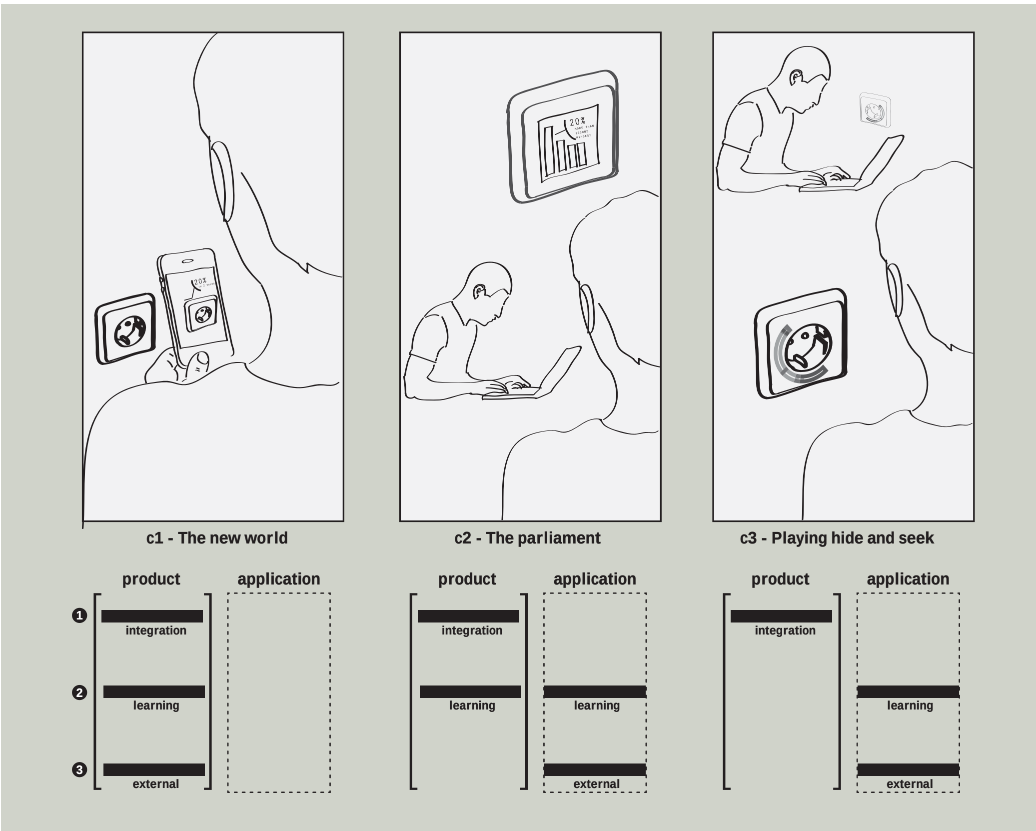


figure 3.5
Three concepts were developed based on the defined system and experiential requirements. Each elicits a slightly different experience, with the same essential keywords: explorative, trustworthy and sensory, with the possibility for a full filling reward

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** Peers from Industrial Design Engineering faculty and a PhD researcher on the related subject of user participation in emerging smart grid technologies, Daphne Geelen.*

Concept 3 distributes only layer 1 to the prompt and layer 2 and 3 are totally distributed to the external device, see figure 3.5. Like children which play hide and seek, the user will seek the large electricity consumers in the house and will also find a reward when the devices are consuming less electricity than the solar panels on the house are generating.

The concept is realised by a visualisation on each power outlet, which both presents the total electricity consumption and production in the household and the consumption of that particular plug.

4. INITIAL IDEAS ON CREATED CONCEPTS: CREATIVE FACILITATION

In order to facilitate the creative session, a scenario was developed that could function as script for a role play. Of each concept a paper prototype was made to be used during the role play and provide feedback about the concept, see figure 3.6.

The three main evaluation criteria to judge the suitability of the concepts for the desired context are:

1. Can the level of wellbeing in households be maintained, while making users more active in their electricity use? The concepts are adding extra variables to the current use situation of electricity in households, which could result a decrease of the level of wellbeing in the household.

2. Does the form of the concept, where different levels of information are distributed over different layers, prove to have the proper balance for understanding? The concepts consist of small prompts and a platform which provides more detailed information and an overview.

3. Does the concept provide the user with a base of understanding and trust which enables an explorative attitude? The mockups of the different experience concepts cannot provide an interactive prototype but the imagination of the participants will provide insights on whether the targeted values are present.

This initial evaluation of the concepts within a creative session proved to be an important contribution to the final product. It gave good indication on whether users would accept the product, it would be ultimately part of households and influence wellbeing and daily life activities. Following are the answers helped in determining these crucial points:

4.1 ANSWER TO 1ST CRITERION:

CAN THE LEVEL OF WELLBEING IN HOUSEHOLDS BE MAINTAINED, WHILE MAKING USERS MORE ACTIVELY INVOLVED IN THEIR ELECTRICITY USE?

This criterion was met completely in two of three concepts according to the unanimous opinion of the participants of the creative session. In 'c3-hide and seek', it could become a problem that the information is everywhere and becomes very hard to oversee and therefore can disrupt the general wellbeing of a household. The participants however agreed that the level of visualised information contributed to the acceptance of such products in the household. It was even hinted by some participants to implement more detailed information in some parts of the interface, like kWh values and price information. They forecasted that prompts from the wall-mounted displays would probably disappear in the, much like clocks on microwaves and thermostats do already.

4.2 ANSWER TO 2ND CRITERION:

DOES THE GENERAL FORM OF THE CONCEPT, PROVE TO BE SUCCESSFUL?

All participants acknowledged the general form as being a contribution to the successful implementation of the concept in households. However balancing the levels of information over the different layers of the framework is very important. The type and amount of information that is shown on each layer should be thought trough. None of the concepts was yet featuring the perfect balance between the different layers. Where concept 2, the parliament was seen as more comprehensible at a glance, concept 3 was preferred for the amount of information that was presented in the prompt on the wall-mounted-display.

4.3 ANSWER TO 3RD CRITERION:

DOES THE CONCEPT PROVIDE THE USER WITH A BASE OF SENSORY UNDERSTANDING AND TRUST WHICH ENABLES AN EXPLORATIVE ATTITUDE?

figure 3.6
A role play with concept c3-the parliament

figures 3.7
Mockups of the interfaces of different concepts. On the left; the interface of concept c3-the parliament. On the right; the interface of the application on a smartphone.

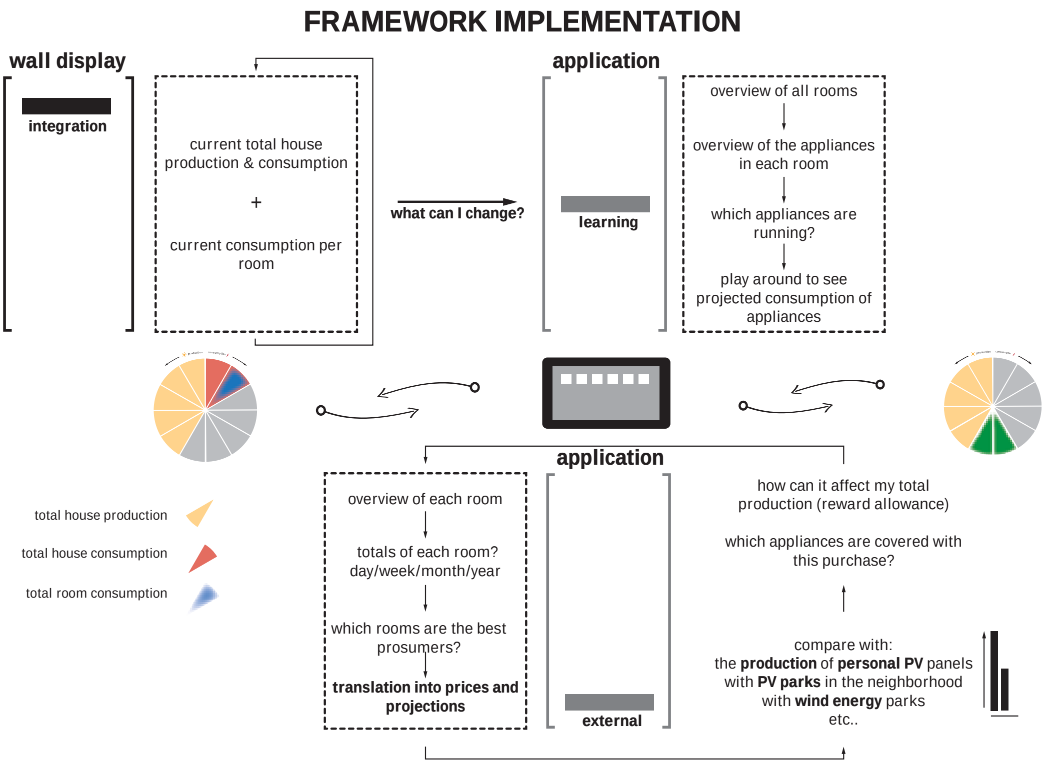
Participants imagined this would only be visible in 'concept 2 - the parliament'. This was according to them the concept which simplified the information to an extend which would be easily understandable and attribute new meaning to the information. The information is attached to activities and rooms, which provide tangible and understandable meanings but also allow for exploration by comparing rooms and experimenting with different activities and their respective electricity use. It also has a good balance between being available as sixth sense, but not clutter the environment and lower the understanding as would be easily possible with 'concept 3 - hide and seek' where many different displays would react on the actions of the user.

During the discussion other aspects that would contribute to the concept were proposed. The participants thought they would like to have certain intelligent features which would make the system think with you:

1. "You would want some personalised advice on how you could consume your electricity most responsible, based on the different device types in your house"
2. "Daily habits should be used as important input for the system, it could be self learning and propose meaningful things to the user."

As continuation of the creative session a new concept was developed which implements the findings from the creative session. The creative session provided valuable insights regarding the use of such a system. It became clear that from a user perspective the visualisations of the interfaces for the concepts were not as logical as had been anticipated beforehand. For instance the colour coding was interpreted differently than intended. The colour green was used for solar power (also called green electricity) and the colour yellow for battery power. The colour yellow was perceived as electricity from the sun, since the sun is associated with the colour yellow. Furthermore the concept of having a battery as well as having solar cells, caused confusion. Since batteries for domestic energy storage are not likely to become a commodity in the near future, the concept of having a separate battery in the system was taken out. When a battery is decided to be a part of the system, then it can be presented to the user as electricity generated by the solar cells.

figure 3.8



A small wall-mounted-display would be distributed throughout the different rooms of the house where electricity is consumed. The 'room-displays' are accompanied by an application on a smartphone or tablet.

5. SELECTED CONCEPT

Finally a concept was developed which implemented the insights that were gathered during the creative facilitation session.

5.1 IMPLEMENTATION OF FUNDAMENTAL FRAMEWORK

A balance was found to distribute the different levels of information over the different layers which were defined in the 'fundamental framework' (figure 3.8). A small wall-mounted-display would be distributed throughout the different rooms of the house where electricity is consumed. These 'room-displays' show the current total production and consumption of the household and the electricity consumption of the designated room. In each room the total household 'prosumption' information is the same, but the consumption information is specified to each room and is therefore different in each room. These three streams of information are visualised in a single 'prosumption' visualisation. No 'direct' active interaction can take place between the user and the 'room-displays', the user only gets feedback trough those screens.

The 'room-displays' are accompanied by an application on a smartphone or tablet. The application gives the user a wider range of possibilities and allows 'direct' active interaction. The user can click through the application to learn more about the details of each room in the house and educate him or her self. The application on the tablet will also show historical data and device specific consumption. The device specific data can be used to estimate whether devices can run on electricity from the solar cells, or need also electricity from the electricity grid.

5.2 PRODUCT EXPERIENCE

The envisioned product experience by providing a 'simple' interface in every room, is to establish a sort of sixth sense which is not 'shouting' for attention but always there to provide a 'sensory' understanding (see experience requirements) regarding the 'prosumption' behaviour of the household (figure 3.9). The extension of the 'sensory' understanding is a certain feeling of control and confidence which can be enhanced and made stronger by learning more details when using the application on the smartphone or tablet. Because the interface splits the electricity consumption by room, orderly clusters of information appear. They are easy to trace because they are connected to the tangible, understandable concept of rooms which are in turn connected to a certain set of activities. A kitchen is connected to a certain set of activities,

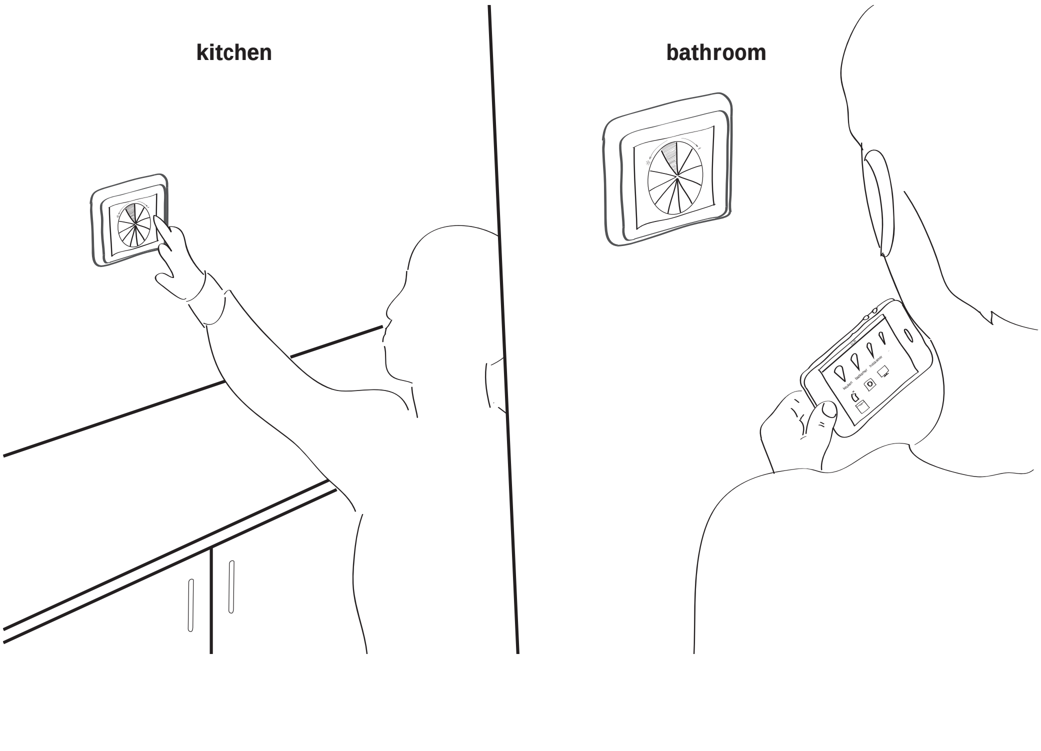


figure 3.9
The envisioned product experience by providing a 'simple' interface in every room, is to establish a sort of sixth sense which is not 'shouting' for attention but always there to provide a 'sensory' understanding (see experience requirements) regarding the 'prosumption' behaviour of the household.

like cooking a meal, boiling water for tea, running a dishwasher, a refrigerator, etc. Those activities carry a high contextual meaning and are therefore highly suitable to use in visualising the electricity consumption connected to those activities.

5.3 VISUALISING PROSUMPTION: AN ONLINE SURVEY

A visualisation was sought to communicate the production and consumption of electricity in such a way that it could be understood at a glance. This meant the visualisation had to meet the following criteria:

1. It should be made visible and emphasised that you are producing electricity, rather than focusing on your consumption (as is traditionally done).
2. The relation between production and consumption should be easily understood: it should be become clear that the solar electricity can be used up in the household (and its a good thing!) before it goes back in the grid.
3. It has to be visible how much of your electricity consumption is being provided by the solar cells and how much is provided by the electricity grid.

As can be seen in the earlier visualisations of the final concept a wheel-like visualisation is used to present production of electricity as a counter clockwise movement and consumption as a clockwise movement. This visualisation is inspired by the earlier concepts, where particularly in ‘concept 3-playing hide and seek’, a visualisation was used which used rotation to communicate movement of flowing electricity. In the new visualisation the movement does not indicate the ‘flow’ of electricity but rather the direction, see figure 3.10.

To obtain insight in the understanding of users for such a visualisation an online survey was done with several visualisations of the same situation.

The survey was at first send to family, friends and acquaintances, which were consecutively asked to forward the survey to their circles (snow ball sampling), 31 valid responses were received. The ‘Qualtrics’ (2013) tool, a web based questionnaire design tool, was used to create the survey.

The participants were informed about the situation as follows:

In your household electricity is generated by means of solar cells. At the same time electricity is being consumed in your household, for example by your refrigerator or washing machine. All appliances in your household together form your total electricity consumption, next to that you will see how much the current room you are in is consuming.

1. The total production of electricity in your household by the solar cells is displayed in yellow.
2. The total consumption of electricity in your household is displayed in red.
3. The electricity consumption of the room you are in now, is displayed in white.

In figure 3.11 the different visualisations can be seen.

Participants of the survey were asked to rate the visualisations on respectively understand-ability and desirability in a household environment.

Results

Visualisation ‘B’ was rated highest for both understanding and desirability by respectively 18 out of 26 participants for understanding and 13 out of 23 participants for desirability. The second best for both understanding and desirability was visualisation ‘C’.

The visualisation is optimised and will be used as basic visualisation throughout the entire interface. The visualisation can be seen as an adaptation of a simple pie chart, which has multiple layers which can rotate in clockwise and counter-clockwise directions. The ‘pie-chart’ which represents production starts from ‘0’ and

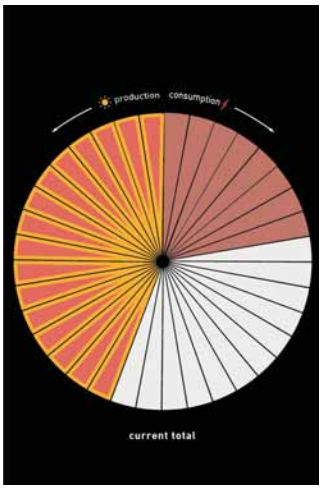
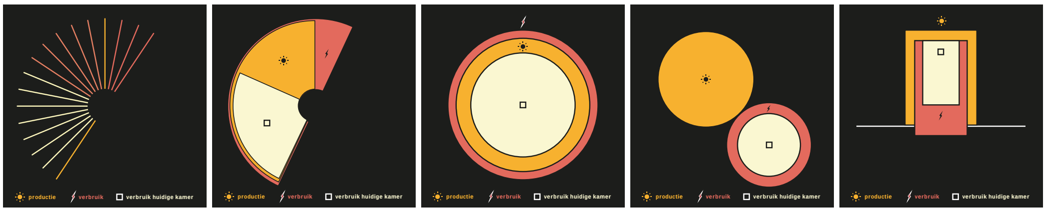


figure 3.10
A wheel-like visualisation is used to present production of electricity as a counter clockwise movement and consumption as a clockwise movement. This visualisation has been used to get early insights from peers, by using my iPhone to display several states.

figure 3.11

VISUALISING PROSUMPTION



(A) (B) (C) (D) (E)

To obtain insight in the understanding of users for such a visualisation an online survey was done with several visualisations of the same situation.

turns counter clockwise, the 'pie-charts' for consumption rotate clockwise and start from the negative value which is given by the production. Thereby the visualisation explains how the net-consumption is calculated. A 'zero-line' is positioned where the point of parity with the electricity grid is reached. If this line is passed, electricity from the grid is used. If it stays on the negative 'solar-side', electricity is delivered back to the grid. The overlapping of the different layers of the pie chart is optimised to improve understanding of the separate 'pie-charts'. The radius of the different 'pie-charts' for production and consumption will be smaller for every 'pie-chart' which comes on top of a previous one. Further will the 'pie-chart' which represents the electricity production of the solar cells always be underneath the 'total-consumption' and 'room-consumption' 'charts'. This emphasises that the production of electricity can be used for consumption and reveals an empty surface of yellow when less electricity is consumed than is produced. Thereby hinting users they have available electricity which can be consumed.

6 FINAL DESIGN: AMPUL

The new product is named ‘Ampul’ which is derived from the Turkish word ampul, which translates as light bulb and is in turn related to the French Ampoule which means; glass capsule. Ampul consists of two visible parts: a wall display and a application on a smart phone, which complement each other in their working principle, see figure 3.13.

The wall display represents the ‘sensory’ experience for users and becomes an extension of their own senses to understand their ‘prosumption’ situation and be in control of it. The extension of the ‘sensory’ understanding is a certain feeling of control and confidence which can be enhanced and made stronger by learning more details when using the application on the smartphone. This application provides users with a layered interface, which balances the amount of presented information. Different layers represent an overview of the total household and become more detailed by presenting the overview of the ‘prosumption’ situation in different rooms and an overview of the situation inside the room; respectively the devices which are responsible for the consumption. When the application is turned on, the first layer on the screen presents the total household ‘prosumption’, see figure 3.15 (0) on the next page. After that the user can navigate downwards to see more details regarding rooms and devices in those rooms, see figure 3.15 (A) and (B). When navigating upwards a specific overview of the electricity generated by the solar cells is presented (figure 3.15 (Z)). In this overview is place to provide the user with information regarding return on investment, maximum production hours and days, etc. To understand how much a device consumes on average either the historical data is presented in the colour beige (B) (standard) or the data can be projected in blue when clicking the designated device.

The application can also be used to discover trends in both production and consumption of electricity. Users can compare e.g. how much electricity did the activity of cooking consume on different days, or discover how their consumption patterns are related to the patterns of production (figure 3.14). It can be expected that the highest production of electricity will take place during the day, but the highest consumption may take place at night

wall display
multiple distributed
through house

smartphone
application

figure 3.13
Ampul consists of two visible parts: a wall display and a application on a smart phone, which complement each other in their working principle

when people start cooking or run the dishwasher in the evening. The functionality that allows users to go back in time to obtain historical data is not fully designed in this project. The focus is to first design and validate the fundamental interaction which users have with the product. Therefore first the real time electricity prosumption (now) and the prosumption during one day (today) are designed, see figure 3.14.

Users can use the visualisation to stimulate themselves to balance their consumption of electricity with the production. Currently this is not encouraged by the electricity grid operators in The Netherlands, because the majority of electricity is produced by power-plants which use fossil energy sources and can supply electricity according to the peaks of the demand. In the future it can however become important to match the consumption of electricity to the production, because more electricity will be generated using solar cells and wind turbines. This is a long term development that is encouraged as part of the democratisation of the energy market. The product does not need to emphasise this feature yet, since the need is not there now. Ampul is however ready for the future regarding this aspect and encourages a future where it will be important to directly balance production and consumption by prosumers, stimulated by the pie-chart-like visualisation.

The different parts of the product are developed to test and validate whether its underlying philosophy works in reality. To be able to see the product in reality, in the following Chapter (F) an interactive prototype will be developed and tested with users in a realistic household environment.

figure 3.14
Users can compare e.g. how much electricity did the activity of cooking consume on different days. The functionality which allows for historical data is only designed in its preliminary form. In this project only the (now) and (today) views are fully designed. Only the view (now) which shows the real time electricity prosumption is prototyped, see chapter (F).

the yellow, red and white disk remain to display total prosumption and room consumption, a blue disk is added to display a projection of electricity consumption of any selected device: below the electricity consumption of the oven is projected

the ‘white’ disk, which below represents the kitchen, is disaggregated in appliances which have consumed electricity: the use time and electricity consumption are displayed in minutes and kiloWatt hours

(B)

devices

what **can I do** about my electricity **consumption**?

which **devices** are using most and when can I **turn** them **on** to use **solar electricity?**

the yellow and red disks remain to visualise the total ‘prosumption’ of the household, while an extra ‘white’ disk is presenting the consumed electricity per room

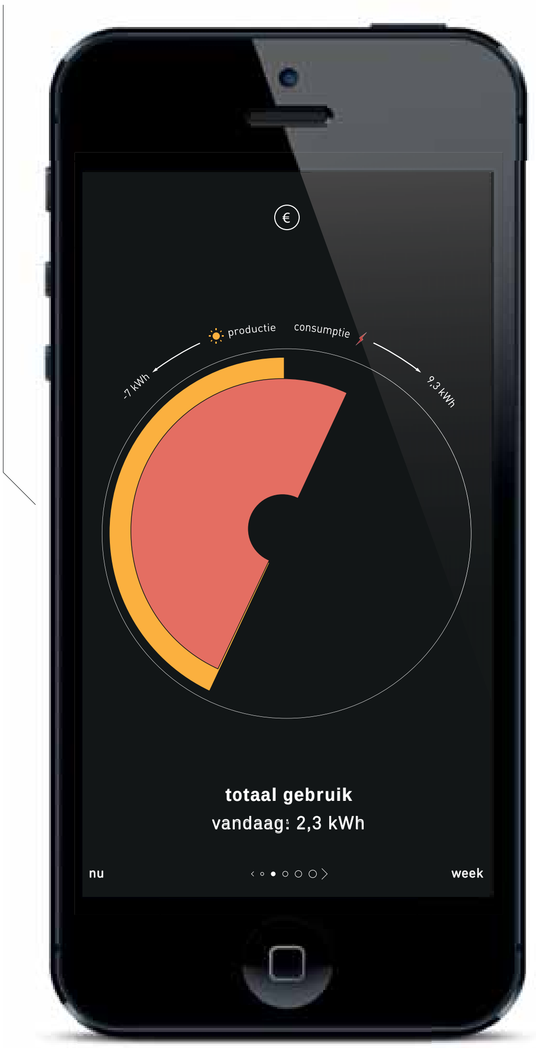
(A)

rooms balance

what **can I do** about my electricity **consumption**?

which **rooms** are using most?

the yellow disk turns counter clockwise to indicate the total producted electricity while the red disk turns in the clockwise direction to indicate consumed electricity: the ‘prosumption’ of the household is visualised



(0) start screen

total balance

what is the **balance** between **total solar** electricity production and **total electricity consumption** in the household?

the yellow disk turns counter clockwise and indicates the total producted electricity of today, while the lighter yellow disk displays the maximum daily production ever registered

(Z)

solar

solar electricity information, what was **maximum production**

when I’ve **earned** the PV **panels back?**

figure 3.15
The data of (today) is presented, see also figure 3.14. When the application is turned on, the first layer on the screen presents the total household ‘prosumption’ (0). After that the user can navigate downwards to see more details regarding rooms and devices in those rooms (A,B). When navigating upwards a specific overview of the electricity generated by the solar cells is presented (Z). To understand how much a device consumes on average either the historical data is presented (B) (standard) or the data can be projected in blue before actually turning on the designated device.

(F) VALIDATION
USER TESTING OF AMPUL

IN THIS CHAPTER WILL BE DESCRIBED HOW A PROTOTYPE OF THE CONCEPT, AMPUL WAS MADE. THE CONCEPT HOUSE IS USED AS A CONTEXT TO PROTOTYPE AND TEST THE CREATED CONCEPT WITH USERS IN A REAL LIFE HOUSEHOLD SITUATION. GOAL IS TO VALIDATE IF THE CONCEPT ACHIEVES ITS MAIN AIM: PROVIDING A TOOL TO UNDERSTAND AND MOTIVATE PROSUMPTION.

1. FINAL STUDY, USER TESTING OF AMPUL

The developed concept is tested using a prototype of the concept in a participatory user study. The participants in the study are asked to continue their daily life habits as much as possible, while using the prototype in their living environment. In this particular study, participants are asked to live in a preconditioned environment, the Concept House which resembles a 'normal' household situation to a high extend.

1.1 RESEARCH QUESTIONS TO BE ANSWERED IN THE STUDY

Three keywords are important in all questions to be answered in the participatory user study. These keywords are: Joy, Understandability and Integration, determined by the formed context (fig 3.2, pg 70) and the three layer framework (fig 3.1, pg 68). They are important qualities which determine wether the use of the concept can be accepted by future users.

The study is consisting of a situation 'A' and a situation 'B'. The setup and procedure of both 'A' and 'B' is identical, but the product that is tested differs. In situation 'A' the existing interface of the Niko Home Control system is tested and in situation 'B', the new interface, the final concept 'Ampul' is tested.

The general questions which will be answered for both situation 'A' and 'B' are the following:

1. Does the interface of the prototype achieve to elicit a feeling of reward for the self produced electricity in the house?
2. Do people find joy in balancing the electricity demand of a device, with the supply of electricity which is produced by the solar cells?
3. Do participants understand that the electricity that is produced in the house can also be consumed in the house and create a temporary independence from the electricity grid?

The following questions are specified for situation 'B' only where the 'new' interface 'Ampul' will be tested. These questions are specified for specific features which are new in the designed prototype:

4. Do participants understand that the application on the smartphone/tablet provides them with more knowledge to understand the real meaning behind the prompts?
5. Do people feel disturbed by being reminded in several rooms by the prompts? Do they feel being observed?
6. Does the transition between the 'first layer' on the prompts and the 'second layer' in the application seem logical and fluent?

Expected findings

It is expected that the new interface (situation 'B'), yields more positive answers than the existing 'Niko' interface (situation 'A'). The new design which is part of situation 'B' is specifically designed to positively stimulate users by emphasising their production of electricity, where the existing 'Niko' interface is likely designed with other targets in mind. The newly designed product: 'Ampul', features information about the current electricity consumption (real time) as well as historical information. The historical information which allows users to see the electricity 'prosumption' of the current day and earlier days in the week, month and year, will not be accessible in the prototype due to the limited time-frame in which the concept had to be prototyped. It is expected that this will result in a drawback for the user understanding, but it will not hinder the possibility to answer the research questions.

The execution of both situation 'A' and 'B' can serve as means to compare the two prototypes and determine the success of the newly designed prototype 'Ampul'.

1.2 PREPARATIONS

Preparing the house for the study

Since the Concept House in the neighbourhood Heijplaat, is the facilitator for the participatory study it was prepared accordingly. The house features all the necessary equipment for a normal household to function comfortably. The Concept House provides a great opportunity to execute the tests, because it features all the aspects of a 'normal' household, but next to that the newest technologies are installed in the house, which will in this particular study be used to provide electricity consumption and production data.

Different participants lived in the house for a duration of 2 days (including 2 nights), one family followed after another. The house therefore featured a double set of all personal items the participants would use, e.g. bedsheets and towels. Those items could then be washed by the participants, which will give them a valid reason to use the available appliances in the house.

A set of tasks was provided adapted to the particular set up of the Concept House, to let participants go through a set of daily activities which involve the use of electricity and they would normally exhibit to keep their household running comfortably. The house was prepared with all the items necessary for these activities, such as a washing machine, cooking equipment and a television.

Preparing the prototype for the study

When participants entered the house, the prototype was running independently. It consists out of several interfaces which run on Google Nexus tablets. Two tablets appear as wall mounted and a single tablet is available for portable wireless use (figure 3.18c). The wall mounted tablets form the 'layer 1', prompts, of the concept and are not recognisable as tablets, they seem integrated with the electrical system (Niko Home Control) which is present in the house. The wireless portable tablet runs the 'layer 2' application which allows people to get detailed insights in their electricity status and use, which is also displayed in simplified form on the prompts. In figure 3.18b can be seen how the prompts are prepared to appear as wall mounted devices.

A working prototype which is interactive in a real life situation where electricity consumption and production of users takes place requires electricity measurement data. This data can be provided by the electrical domotics system of the company Niko, which currently is installed in the Concept House. The installed system, Niko Home Control, provides the user with power sockets, light switches, intelligent switches and information displays. With the designated modules installed, the system is capable of measuring the electricity which is consumed and produced in the house.

figure 3.17 preparations of the Concept House

The system was originally monitoring the Net total consumption of the house and the total production of the solar panels installed on the roof. For the prototype in this study more data

figures 3.18a
Preparation of the prototype, extra measurement modules are installed in the Niko Home Control system.

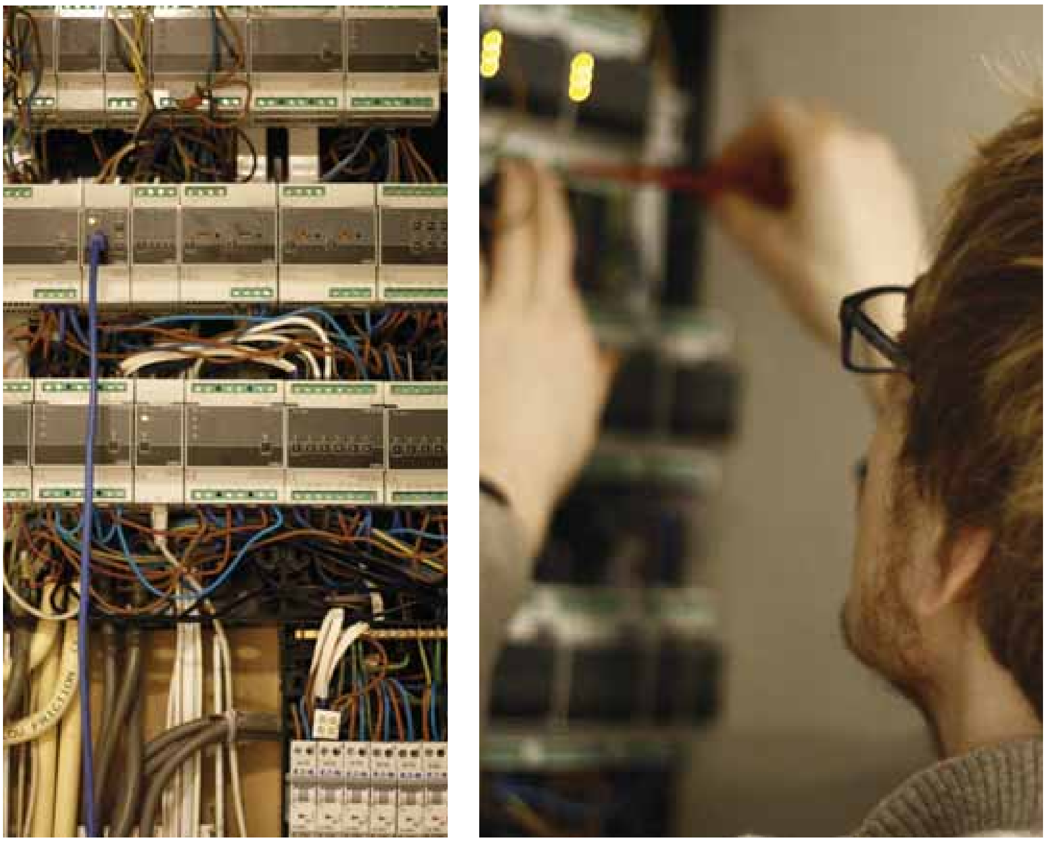


figure 3.18b
Preparation of the prototype, the wall displays need to have a fixture to be able to stand independently in the house.

needed to be available. Ideally the electricity data of every room and every device in the house would have separate measurements to have access to very granulated data. However the current possibilities in the house only allow for 9 extra measurement channels (figure 3.18a). This still allows to monitor the two rooms which consume most of the electricity on average in the house.

The appliances which consume the largest amount of electricity in the house are currently the following:

- The heat pump, responsible for the space heating and the warm water supply.
- The washing machine, to wash laundry.
- The dishwasher, used daily for dirty service and cutlery
- The combination oven and microwave, to prepare meals.
- The refrigerator, which is permanently switched on.
- The kettle, to boil water.
- The furnace, which requires high power but is only used for a short time every day.
- The vacuum cleaner, which has a relatively low use-frequency
- The television, which requires only low power but can be used extensively
- Any charger, for laptops, tablets and phones.
- The hairdryer, used for drying hair after showering in the bathroom

The lights installed in the house are all energy saving LED lamps and therefore contribute only marginally to the electricity consumption in the house. Many rooms have motion sensors installed that automatically switch lights on and off.

All appliances except for the hairdryer, chargers and lights, are located in two rooms in the house. The storage room and the combined kitchen and living room. The prototype measures all electrical outlets in those rooms, the fixed appliances are attached to a fixed outlet that are measured separately. The available outlets throughout the combined kitchen and living rooms, are counted as a single measurement.

The measurement data is distributed over an ethernet protocol by the Niko Home Control system. A software application can read the data and use it to visualise the electricity consumption and production (prosumption) data. In order to create a working interactive prototype a software application was developed which can run on tablet devices with an Android operating system. The software application which was used in this study features one part of the final concept design. Due to the limited time frame of the project, only the part of the application was developed which displays the current 'live' electricity prosumption in the house, see figure 3.14 (now) in chapter (E). In the final concept design it is also possible to look up historical data of the current day, the past week, month and year.

The decision to create the part which presents the 'live' information is made, because it is expected to contain enough features of the final design to obtain rich insights from users and answer the research questions for this study.

1.3 PARTICIPANTS

In the weeks before starting the participatory user study, participants have been recruited. Participants from the neighbourhood of Heijplaat have been given priority, since they

figure 3.18c
Two tablets appear as wall mounted (on top)and a single tablet is available for portable wireless use (bottom). The wall mounted tablets form the 'integration-layer 1', of the concept and are not recognisable as tablets, they seem integrated with the Niko Home Control system, which is present in the house. The wireless portable tablet runs the 'learning-layer 2' application which allows people to get detailed insights in their electricity status and use.

figure 3.19
A mix was created of people from the local neighbourhood and people from the surroundings who showed interest in participating in the study.

are already familiar with the neighbourhood and location of the Concept House and all live on walking distance from their own houses. One of the involved parties, the local housing association ‘Woonbron’ was involved in recruiting participants to stimulate involvement of the local neighbourhood with the research in the Concept House. The people from this neighbourhood form a diverse group and are therefore suited to form the initial participants of a representative group for the Dutch population. Finally a mix was created of people from the local neighbourhood and people from the surroundings who showed interest in participating in the study (figure 3.19).

People which participated in situation ‘A’, varied in age and family composition. Participants in the following circumstances took part in the study; a couple between the age of 45 and 55, a large family of seven with children under the age of 10 and parents between the age of 35 and 45 and a family with three children between the age of 5-15 and parents between the age of 35 and 50.

In situation ‘B’ people participated in the following family compositions:
Single male participant of the age 57, a couple between the age of 25 and 30, a family with a single child around the age of 15 and parents between 50 and 60 and a single female participant of the age 56.

The participants were involved using a campaign with posters in the neighbourhood and through the internet. The housing association ‘Woonbron’ used mouth to mouth advertisements and announced the study on their website and social media pages. The local website ‘heijplaat.com’ also announced the study.

1.4 METHOD

To obtain valuable insights in this particular study, participants are asked to reflect on the use of the prototype two times, once after having executed several tasks and once just before ending their stay. The first reflection takes place during their stay in the house when they go through several household tasks. Participants are asked to reflect shortly on the use of the prototype by taking notes on provided cards. The second reflection is more elaborate and takes place on an evaluation form. The form gathers all the answered cards. The answers of the first reflection on the cards, are then used as guideline to elaborate on certain topics of interest.

Experience Sampling Method

The methodology that is used to prescribe the used method during this study is inspired by the Experience Sampling Method, developed by Larson and Csikszentmihalyi (1983). The methodology is described as:

“A research procedure that consists of asking individuals to provide systematic self-reports at random occasions during the waking hours of a normal week. Files created from sets of these self-reports from a sample of individuals become an archival file of daily experience. The ESM obtains information about the private as well as the public aspects of individuals’ lives, secures data about behavioural and intrapsychic aspects of daily activity, and obtains reports about people’s experiences as they occur, thereby minimising the effects of reliance on memory and reconstruction.” (Larson and Csikszentmihalyi 1983)

This particular methodology is used to inspire the method used in this study, because it allows the researcher to ask very specified questions related-to and integrated-with daily life activities. It is of importance to obtain feedback close in time to the execution of the activity. This method provides a structured test environment to test the prototype during the same activities for different participants and also lets them reflect on their experience, right after using the prototype during an activity.

ESM cards

The implementation of ESM in this study led to a set of cards (ESM cards) for four daily life activities which involve the use of electricity or electrical appliances in the household. The cards are placed on the location in the house where the activity takes place, e.g. next to the furnace a set of cards related to cooking is placed (figure 3.22). Each set of cards consists of four cards, with a question presented on the front of the card and a space to answer on the back of the card. The first card presents a simple task formulated as question that guide the participant in doing the task while using the prototype ‘Ampul’. The three consecutive cards from the same activity ask the participant to rate the use of the prototype on a certain scale, e.g. satisfaction

figure 3.20
If you watch television at night, you do not generate electricity with solar cells. While watching, do you use more electricity than you have generated accumulated over the entire day?

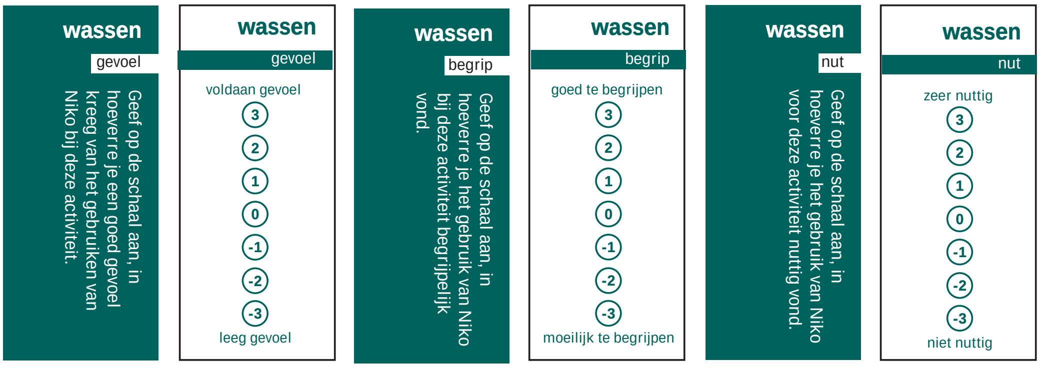


figure 3.21
The three consecutive cards from the same activity ask the participant to rate the use of the prototype on a certain scale, e.g. satisfaction or understanding

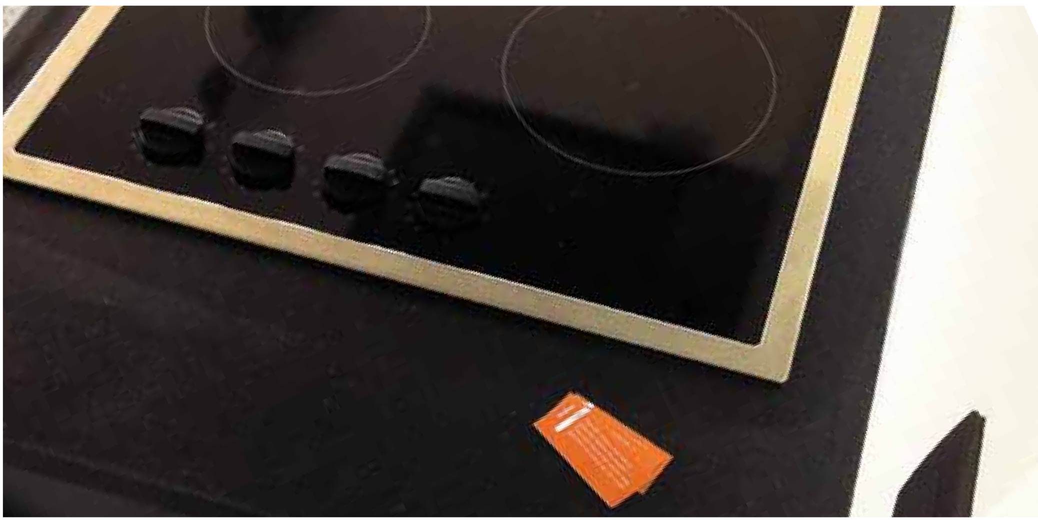


figure 3.22
The cards are placed on the location in the house where the activity takes place, e.g. next to the furnace a set of cards related to cooking is placed

or understanding (figure 3.21). This set of tasks was determined in detail after a 'test living' experience in the Concept House. The purpose of the tasks, is to create a realistic set of daily rituals in the house without affecting the comfort and experience of wellbeing of the participants.

The participants can execute each activity on any given point in time, but the activities are generally bound to a certain time of day. Cooking and watching television, are activities which generally take place in the evening. The task related to washing laundry, asks participants to use electricity which is generated by the sun, requiring them to do the activity during the day.

In total participants were asked to do four tasks related to four different activities. The tasks were identical in situation 'A' and 'B' and were related to the following activities: cooking, preparing tea or coffee, doing laundry with the washing machine and watching television.

The specific tasks which were present on the ESM cards were:

Cooking
How much electricity did you use during the process of cooking? Indicate how you found the answer and what did you think!

Tea/Coffee preparation
Can you find out what is the contribution of preparing tea or coffee to your total consumption of electricity? How did you find out?

Laundry
Can you manage to run the washing machine without using electricity from the electricity grid? How did you find out?

Tv
If you watch television at night, you do not generate electricity with solar cells. While watching, do you use more electricity than you have generated accumulated over the entire day? (figure 3.20)

Each task was followed by the following three questions, that could be answered by using a semantic scale. The scales were the same for each activity on purpose, so the tasks for the different activities could be compared while evaluating the cards later.

The three scales where:
Feeling
Could you rate to what extend you got a satisfied feeling or an empty feeling?

Understanding
Could you rate to what extend Ampul was easy to understand or difficult to understand?

Use
Could you rate to what extend Ampul was very useful or not useful?

Evaluation form

The evaluation form provides a designated space for each of the ESM cards (figure 3.23), an example of a filled in form can be found in Appendix VI. The participants were asked to glue each card on its designated spot, which resulted in a clustering of themes. The themes were then used as structure to evaluate the cards between each other and consecutively for the interview which would take place before the participants left the house. The themes for evaluation were: comparing the answers and performances of the four different tasks, comparing the four different tasks on understanding, usefulness and feeling. Participants were then asked to rate their experience on four semantic scales: surprise, satisfaction, peace of mind and information. The last question posed them with the question if they had changed their mind towards the self-generation of electricity after using the interface in either situation 'A' or 'B'.

Interview

After the individual reflection of the participants an interview was conducted with the structure of the evaluation form as guidance, the interviews are audio recorded. Participants are asked to elaborate on their answers given in the individual reflection. Thereby the participants are given the chance to explain their reasoning behind the answers they have written down.

Next to the guidance provided by the individual reflection, the research questions will be used as guidance. Important qualities to address in the interview are:

figure 3.23
Participants were asked to glue each card on its designated spot, which resulted in a clustering of themes. The themes were then used as structure to evaluate the cards between each other.

1. Feelings of reward and victory as result of being informed about your 'home grown' electricity.
2. Annoyance as result of constantly being reminded of your energy consumption.
3. Guidance and self confidence as result of the prompts that give constant live feedback.

1.5 PROCEDURE

Participants were asked to stay in the house for a duration of 2 days and 2 nights. They were asked to bring anything they like, but at least their daily necessities as if they were going to a hotel. All participants are welcomed in a similar manner, to give different participants the same information consistently.

Welcoming participants

When participants enter the house to start their 'test living' experience, they should be provided with an explanation to understand the house and the prototype. A quick tour of 15 minutes trough the house is required for this; the following order was used for consistency:

1. A quick tour to explain the general setup of the house (bedrooms, wardrobes, bathroom, the living room, kitchen and finally storage room)

2. A more detailed tour is given to explain the following:
- How do the kitchen appliances work
- How does the washing machine work
- That the warm water supply and heating is powered by electricity
- The electrical system: how do the light switches work, the electrical shades and the ecomode of the house, how does the thermostat for the heating work?

3. If their are no questions regarding the house the interface prototype can be explained:
- What are the prompts displaying? The currently produced and consumed electricity in the house and the currently consumed electricity in the room. Changing in real time.
- How does the application work: The start screen displays roughly the same as the prompts. By pressing the menu in the lower-right corner you can find different screens to make the overview more detailed: [1]overview of all rooms, [2] overview of devices in the clicked room, [3]click devices to see their average use displayed as part of the daily total, this will now also be showed in the respective prompt in the designated room. [4] by going up from the home screen, you will be shown information regarding your solar electricity

4. The participants are informed that they will be expected to execute a set of household activities, that will require to use electricity. The activities are guided by the ESM cards.

   The participants were shown the locations and the intention of the ESM cards.

5. To prepare participants for the information they will get trough the interface prototype they are shortly informed regarding the use of self produced electricity by solar panels.
- The Solar Panels, always produce electricity in daylight condition but the amount of electricity varies on the strength of the sun (the summer generally delivers better results than winter).
- The electricity which is produced by the Solar Panels is used by the appliances in the house, if no appliances are running the electricity goes back in the grid. In The Netherlands you than receive money back according to the 'Salderings' regulation, see also chapter (B). In practice, this means your utility company pays you the same price per kWh as you pay them (on average 0,22 ct in 2013).

Reflection moments during the study

Participants were asked to use the house as if it was their own and do any activity they would like to do. They were asked to do the activities with the cards and the interface prototype of both situation 'A' or 'B' as integrated with their 'normal' daily life activities as possible. Participants were told they could do the 'tasks' on the ESM cards whenever they wanted to during their stay, but to always reflect shortly after doing a task on the cards. The cards function as a first reflection moment.

A second reflection moment takes place when all the requested activities have been completed and the ESM cards are filled in. A reflection form is available which requires participants to glue their filled in ESM cards in a designated place. The form then asks them to evaluate and compare their results on the different cards.

1.6 RESULTS

The results will be discussed separately for the situations ‘A’ and ‘B’. Where situation ‘B’ is expected to answer all of the initially posed research questions and situation ‘A’ solely the first three. A short comparison between the different situations will be made in the section; discussion. The both study-situations have been conducted under near identical circumstances, with as only difference: the designated prototype, which was tested was different in both situations. Also the participants which took part in the study, were different people in each situation. The answers to the questions are supported by quotes of participants, they have codes which link back to their audio file.

Situation ‘A’

1. Does the interface of the prototype achieve to elicit a feeling of reward for the self produced electricity in the house?

   [No] Participants take it for granted that the solar cells are producing electricity. They have looked from time to time what is being produced out of curiosity, but do not get the necessary feedback to realise that they are producing electricity on every moment of the day.

   DG1315 [06.25]
   “The value was still a negative one, because of that I concluded I was not using more electricity than I was producing at that moment.”

2. Do people find joy in balancing the electricity demand of a device, with the supply of electricity which is produced by the solar cells?

   [No] Participants need to switch from one screen to another to see both the consumption of a device and the production of the solar cells. This resulted in a higher focus on the consumption of the device than on the relation between production and consumption.

   DG1315 [07.00]
   “I would get a real kick from lowering my consumption as much as possible, by metering everything I use.”

figure 3.24
An example of the interface in situation ‘A’, of the Niko Home Control system. The screen which tells the user the most is where the net-total is presented, this subtracts the production from the total consumption.

3. Do participants understand that the electricity that is produced in the house can also be consumed in the house and create a temporary independence from the electricity grid?

   [Partly] Participants are using the feedback from the net-total value of the house to see whether they produce more than they consume or less or equal. They can however not understand the size of the production at the same time as looking up the net-total.

The interface of the application of the company ‘Niko’, does provide the user with data (figure 3.24). It however requires the user to remember many values, because the user needs to switch screens to obtain data from different sources. E.g. to compare the consumption of the refrigerator with the current electricity production, the user has to lookup both values separately. The screen which tells the user the most is where the net-total is presented, this subtracts the production from the total consumption. Thereby the user can see if the current consumption allows for an over-production of electricity or if electricity from the grid is needed.

Situation ‘B’

1. Does the interface of the prototype achieve to elicit a feeling of reward for the self produced electricity in the house?

   [Mostly], for many participants it does achieve that. Not all participants were sensitive to this aspect, some were more sceptical, others did not oversee the wider scope of the prototype and reflected solely on what they saw in the house. But in general ....

   MA2427 [15.30]
   “It makes you feel more connected to nature in a very satisfying way! When you see the yellow part of your circle growing, you realise that the sun is working for you! After 16.00 in the afternoon, you see it going down again and you realise that the sun is slowly losing strength.”

   AC2122 [24.05]
   “When using the application on the tablet it shows me the numbers of my consumption, but what can I do with it? I can’t interpret the numbers and I feel a bit frustrated because everything is using so much electricity while I cannot change it. I want to use the appliances for cooking anyway.”

2. Do people find joy in balancing the electricity demand of a device, with the supply of electricity which is produced by the solar cells?

   [Yes] when people achieve to do so they feel satisfied, but with many devices it was virtually impossible to achieve this since they have a high peak load and need a sudden high amount of electricity.

   NP1819 [no recording, pilot-study]
   “With the kettle, you see a large and sudden demand for electricity which is hard to generate with the sun (on this particular day). However when I was running the washing machine in the morning I felt really happy that it could run by using the sun’s power. Only for heating it needed some electricity from the grid.”

   MA2427 [14.32]
   “It’s pleasant to see that you are producing more than you are using in the house, that gives a very good feeling! It feels a bit like saving money on a bank account and seeing it grow over time.”

3. Do participants understand that the electricity that is produced in the house can also be consumed in the house and create a temporary independence from the electricity grid?

   [Yes] participants see that as a small victory. They become enthusiastic when they achieve to stay on the left side of the graph, meaning they don’t use electricity from the grid but from the solar cells.

   KL2224 [no recording, q1]
   “The participants son explains to him: The production turns towards the negative side and your consumption starts from the point where the production ends. In that way you understand which part of you consumption is generated by your solar panels. Its very nicely done because now you understand the zero line differently. Normally you would

just see the net-consumption, the zero line represents the net-consumption. However you can also see what really happens with your produced and consumed electricity."
AC2122 [25.20]
"It's a bit frustrating that you can not store the electricity, because even if you produce a lot during the day you have to use the grid at night anyway. Most people use the electricity probably when they come home from work, when the sun is mostly already set."

MA2427 [XX]
"I you would have a frame, then you would know how you are doing. I mean you could see how much you have been producing already during the day and how much you have been consuming. Then you will be more careful when your battery is almost empty and you feel good when it is properly filled."

4. Do participants understand that the application on the smartphone/tablet provides them with detailed information concerning the prompts?

   [Partly] because people did not always feel confident enough to use the tablet to its full extend. Two out of four participants did not have any experience with using a tablet at all. This affected the overall appreciation of those two participants. Below are some quotes from the ones who used the application:

   KL2224 [no recording, q4]
   "I prefer the application on the tablet, since it provides you with the numbers of your consumption as well as the visual. The visual on the prompts is understandable straight away but you also want to know their respective meaning, hence the wish to see the numbers on the tablet."

   NP1819 [no recording, pilot-study]
   "It's nice to use the tablet application to track down the small devices which constantly consume electricity. We could find that the TV set and the signal receiver, were using 9W constantly when switched off." (figure 3.25)

5. Do people feel disturbed by constantly being notified about their electricity consumption?
   [Partly] participants did not indicate that they were disturbed or that they feel monitored or checked upon. However some participants indicated that they could feel a little frustrated when using devices with a fixed running schedule, like the washing machine or dishwasher. The visualisation on the prompt would display large peaks in electricity consumption when e.g. the heating element of the washing machine would turn on, they could however not do anything against it since the washing machine was just running its pre-defined program.

   AC2122 [14.20]
   "During cooking it certainly puts the pressure on you. Seeing how much you are using with the oven and stove makes you feel a bit guilty."

   AC2122 [16.20]
   "When a person does not know that all devices which generate heat by using electricity, are big consumers, would be huge shock to them to see this!"

   KL2224 [no recording, q2]
   "The prompts can be confusing when using appliances with a fixed program, like the washing mating or the dishwasher. They have a mind of their own and have a fluctuating consumption during their runtime. You would want to know an average for those devices rather than their current actual consumption."

6. Does the transition between the 'first layer' on the prompts and the 'second layer' in the application seem logical and fluent?

   [Yes] The participants that did understood how to use a tablet, experienced the combination of both parts as seamless. They used the tablet to learn the numbers which represent the visualised values on the prompts. After a while they knew intuitively what the prompts were telling them.

   AC2122 [14.05]
   "I felt good that the consumption of my devices was visible, but when you realise the difference between cooking and e.g.

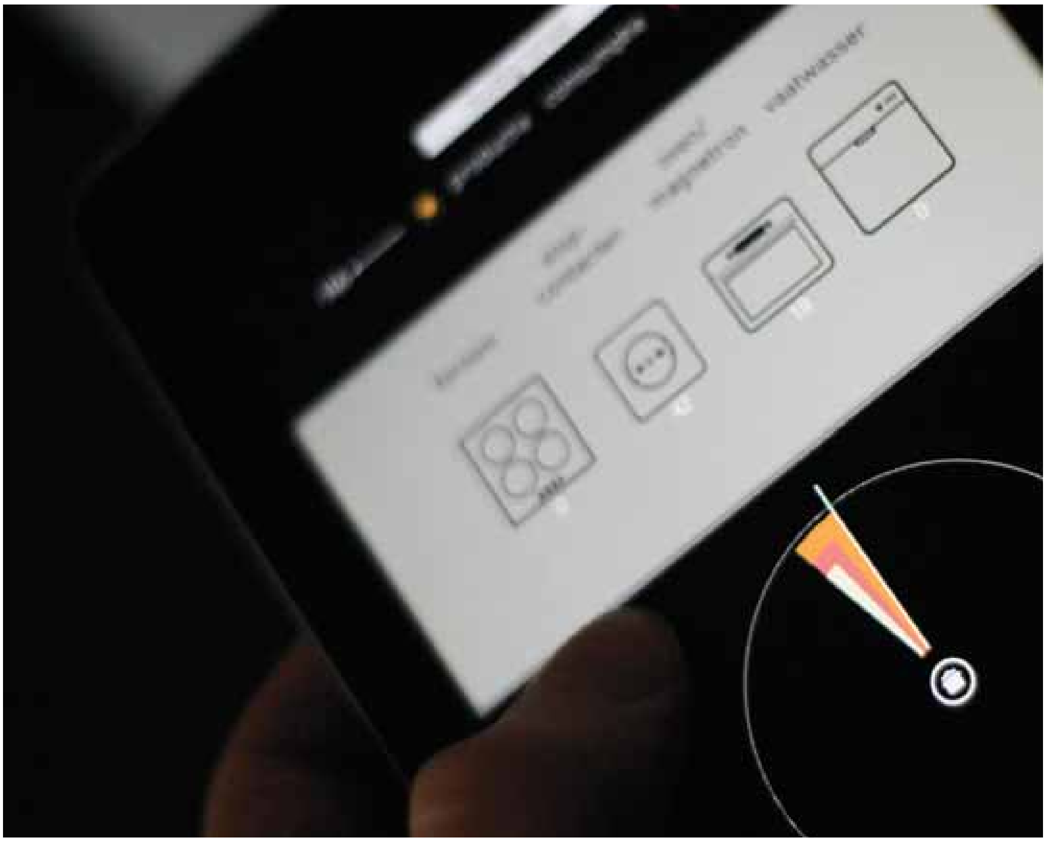


figure 3.25
The application is able to show the smallest details but also maintain the overview.
"It's nice to use the tablet application to track down the small devices which constantly consume electricity."

figure 3.26
The prototype featured part of the total design, which enabled users to monitor their current electricity consumption and production (prosumption) in real time. In this figure is visible how the heating element of the washing machine is working. In a glance can be understood that this is almost done with solely solar energy.

watching TV you are left with a bit of a guilty feeling. During cooking, the dial almost shows you an entirely filled circle but watching TV is barely visible."

KL2224 [no recording, q3]
The participants explain: "We find the prompting-displays with the current power consumption quite confronting. It is not pleasant to keep looking on them while using the appliances in the house, because we don't want to be confronted when it's already decided to use the designated appliance."

Instead they would like to use the application to discover trends on device level over the term of a week or month. Based on that decisions can be made regarding changing your consumption behaviour."

2. DISCUSSION

Testing of the prototype has answered the initially posed research questions for this study, but also resulted in new insights. From the results can be seen that the research questions could mostly be validated with the answers and insights from the participants for situation 'B'. For situation 'A', the research questions have been answered rather negatively, mainly because the interface is likely designed with other questions in mind than the posed research questions in this particular study. When situation 'A' is treated as a baseline study for situation 'B' it can provide means for comparison between the different interfaces which the prototypes in situation 'A' and 'B' feature.

2.1 COMPARING SITUATION 'A' AND 'B'

The interface of the Niko Home Control application, which is used as prototype in situation 'A', provides the user with accurate data regarding both electricity consumption and production. It however fails to provide the user with means to compare and reflect on their electricity consumption which is determined by their daily activities. It also does not encourage users to consider the electricity which is produced as valuable source of energy to use in the household. Users did however appreciate the possibility to look back in time, which enabled them to compare the electricity consumption for example for cooking on different days.

When comparing situation 'A' and 'B', it becomes clear that 'Ampul' in situation 'B' is specifically designed to answer the research questions and achieves to do so. The energy monitoring module of the Niko Home Control application which is used in situation 'A', does achieve to make participants enthusiastic about tracing their energy consumption. It does however not achieve to emphasise their own electricity production and does therefore not elicit feelings of reward or stimulate independence.

2.2 SITUATION B: AMPUL IN DETAIL

In situation 'B' the participants were presented with a prototype of a newly designed interface. The prototype featured part of the total design, which enabled users to monitor their current electricity consumption and production (prosumption) in real time. As expected, it proved to be a major drawback for users, not being able to see what they had 'prosumed' during the day, or during earlier days. Many of them felt the information regarding their current 'prosumption' disappeared and left them with the task to remember it or make an estimation. This proves the value of providing users with their history of prosumption. The actual design of the Ampul interface also contains, among other features, the possibility to view an accumulation of the 'prosumed' electricity from the current day and earlier days in the week, month and year.

Apart from not being able to view historical information, the prototype functioned above expectation and achieved to make all participants very enthusiastic.

The manner in which the 'prosumption' information is presented to participants, proved to elicit a direct understanding of balancing the electricity source of the household, even for the ones who are not familiar with such devices. The visualisation presents both production and consumption in such a way that it becomes clear how production is responsible for providing a certain amount of electricity for consumption (figure 3.26). Participants were able to read that information in a glance and were thereby constantly aware of their influence on the electricity consumption and their (in)dependence

on the electricity from the grid.
As one of the participants said:
“Its nice to see in a glance how much of the electricity that you are consuming is generated by the solar cells, you feel better when the part which is being produced by the solar cells is bigger than the part which is coming from the electricity grid.”

As was also quoted in the results; one participant mentions that it is good to feel connected with your energy source, you see it growing when the sun appears and shrinking when it goes. In that way you feel kind of connected to nature and you become aware of our dependence on the energy which nature provides us with.

Next to emphasising the production of electricity during the sunny hours, the interface also achieves to provide control and understand regarding the consumption of appliances. This connects the abstract concept of electricity prosumption to tangible activities in the house. Currently the wall-displays present the real time consumption and production of electricity, which can result in sudden peaks caused by the consumption of devices. This can be frustrating for participants, especially when the peaks of consumption out-rise the production. This is distracting participants from the core and intention of the design, because it let’s them focus on the peaks of consuming devices rather than enjoying the constant production of electricity by the solar cells. This would be partly resolved if the prototype would have featured the historical views, which would allow users to keep track of their prosumption status during the length of one day. This finding could however lead to the conclusion that the wall-displays should put less emphasis on the sudden peaks of electricity which typically have a relatively short duration. In the next section ‘Implementation’ will be elaborated on a posible future design direction.

2.3 INTERFACE DESIGN

The design of the interface and the visual organisation of the prototype, was well understood and appreciated by all participants. Two participants did not have initial experience with tablet-computers. Therefore they first did not use the application which was running on a Google Nexus tablet. One of them later on tried and achieved to use it. The wall-displays were however well understood and used extensively by all participants. The combination of two wall-displays and an application on a tablet was understood and seen as valuable. However participants indicated that the basic view which presents a pie-chart-like visualisation is the most valuable part of the interface. ‘To read electricity values (Watts) easily’ was indicated as a valuable addition which makes the interface complete. In the current prototype, the values were only presented in the application on the tablet and not on the wall-displays.

The essence of the pie-chart-like visualisation was understood well by all participants, but some participants interpreted the details differently. Where the prototype currently presents only the current consumption (real time), a mis-understanding of some participants was that the visualisation accumulated the total consumption or room consumption.

As one participant said:
“If the pink surface (total consumption) would be more steady and accumulate the entire consumption over the day, you would be able to compare with the white surface (room consumption) and see the consumption for your activity in relation to the total consumption of the day. In the current visualisation the pink surface (total consumption) almost moves in the same way as the white surface (room consumption) which makes you question: what is the purpose of the pink surface if it does almost the same as the white surface?” (MA2427 [07.05])

The participant argues to use the charts which represent total electricity production and consumption to display the accumulative of the day and use the chart which displays the electricity consumption of one single room to display the current use. Thereby combining current electricity use with historical electricity use in one single view.

Participants were positively surprised with the workings of the prototype and the effect it had on their feelings and decisions. It can therefore be concluded that the overarching question: How can users of the electricity grid be motivated for

IN THE FOLLOWING CHAPTER WILL BE ELABORATED ON THE IMPLEMENTATION OF THE VALIDATIONS AND FINDINGS IN A FUTURE PRODUCT.

household electricity prosumption?, has been sufficiently answered with the last user study of this project.

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verbruik per kamer

A participant uses Ampul, the prototype. She is looking at an overview of the electricity consumption in different rooms of the Concept House and the relation to the electricity production by the solar cells of the house.

photo: Jaap Rutten

IMPLEMENTATION
CONCLUSIONS ON A FUTURE PRODUCT

PARTICIPANTS WERE POSITIVELY SURPRISED WITH THE WORKINGS OF THE PROTOTYPE OF AMPUL AND THE EFFECT IT HAD ON THEIR FEELINGS AND DECISIONS. IT CAN THEREFORE BE CONCLUDED THAT THE OVERARCHING QUESTION: HOW CAN USERS OF THE ELECTRICITY GRID BE MOTIVATED FOR HOUSEHOLD ELECTRICITY PROSUMPTION?, HAS BEEN SUFFICIENTLY ANSWERED WITH THE LAST USER STUDY OF THIS PROJECT. QUOTED FROM ONE OF THE PARTICIPANTS:

“IT MAKES YOU FEEL MORE CONNECTED TO NATURE IN A VERY SATISFYING WAY! WHEN YOU SEE THE YELLOW PART OF YOUR CIRCLE GROWING, YOU REALISE THAT THE SUN IS WORKING FOR YOU! AFTER 16.00 IN THE AFTERNOON, YOU SEE IT GOING DOWN AGAIN AND YOU REALISE THAT THE SUN IS SLOWLY LOSING STRENGTH.”

IN THE FOLLOWING CHAPTER WILL BE ELABORATED ON THE IMPLEMENTATION OF THE VALIDATIONS AND FINDINGS IN A FUTURE PRODUCT.

The implementation of the different layers of the framework proved to be successful after the user study, described in the previous chapter (F). The combination of two wall-displays and an application on a tablet was understood and seen as valuable. It was evaluated as a good balance between the different levels of information. The decision to provide easily to comprehend information on visible displays close to the place of activity, was generally perceived as valuable. Depending on the skill and familiarity with the use of a mobile device like a tablet, users indicated the application on the tablet alone would be valuable as well without the wall displays. The organisation of the different levels of information, which features detailed information on the tablet-application and simplified information on the wall displays was evaluated as very pleasant. Especially in comparison with the existing Niko Home Control system (or other comparable systems), where the detailed information is often presented on a wall-display.

“When comparing with the Niko system, it’s nice to have such a straightforward visualisation. It’s understandable at a glance. Also it is nice to have a portable device (tablet) which you can take with you to the table or sofa, instead of having to stand in front of the wall with the Niko display.”

Participants indicated that the basic view which presents a pie-chart-like visualisation is the most valuable part of the interface. The essence of this visualisation was understood well by all participants, but some participants interpreted the details differently. Where the prototype currently presents only the current consumption (real time), a mis-understanding of some participants was that the visualisation accumulated the total consumption or room consumption.

figure 4.1

DIRECTION ONE: TWO MODES

The wall display can feature two modes, which can consecutively present the real time prosumption and the prosumption over the course of a day in separate visualisations. The chosen mode stays displayed until the user presses again to switch from mode.

Participants indicated they would like to have the frame of reference from the time in which they had used the electricity. They understood well how to balance their electricity consumption versus their production in real time, but were not able to get feedback about their status over the course of a few hours or a day. This was largely due to the missing element of historical data in the prototype, which would normally be available in the final product.

One of the participants said the following:
"If the pink surface (total consumption) would be more steady and accumulate the entire consumption over the day, you would be able to compare with the white surface (room consumption) and see the consumption for your activity in relation to the total consumption of the day."

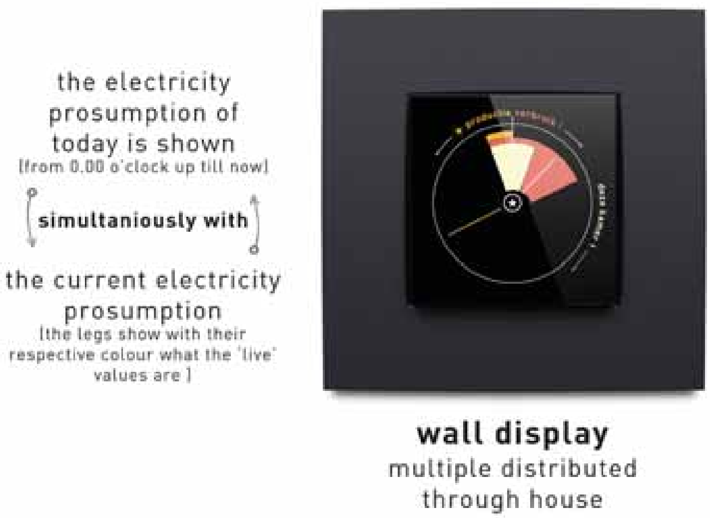
When taking in consideration the findings regarding the time element in the concept Ampul, design optimisations can be proposed. To integrate the time element not only in the application on the mobile device but also in the wall displays, the visualisation on these displays can be slightly adapted. Two possible design directions can be proposed:

1. The wall display can feature two modes, which can consecutively present the real time prosumption and the prosumption over the course of a day in separate visualisations. This can be done, very much like the different modes in the application on the mobile device (figure 4.1).
2. The wall display can feature a blended view, where the accumulation of the prosumed electricity is taken as basic view and provides a time-frame for reference. On top of this basic view the real time prosumption is visualised with hands (like on a clock), to show the user also direct feedback which is important to understand the consumption of appliances (figure 4.2)

These adaptations concern the wall-displays. The application of Ampul for mobile devices is proposed to retain the same basic views, but can be constantly developed to stay up to date with future developments. The application as it is currently designed can be seen as a solid fundament, with many possibilities for implementation of new features. It is important to maintain the core qualities of the application like the different layers of detail, the basic visualisation and the possibility to swipe back and forth in time (figure 4.3, next page).

figure 4.2

DIRECTION TWO: BLENDED VIEW



The wall display can feature a blended view, where the accumulation of the prosumed electricity is taken as basic view and provides a time-frame for reference. On top of this basic view the real time prosumption is visualised with hands

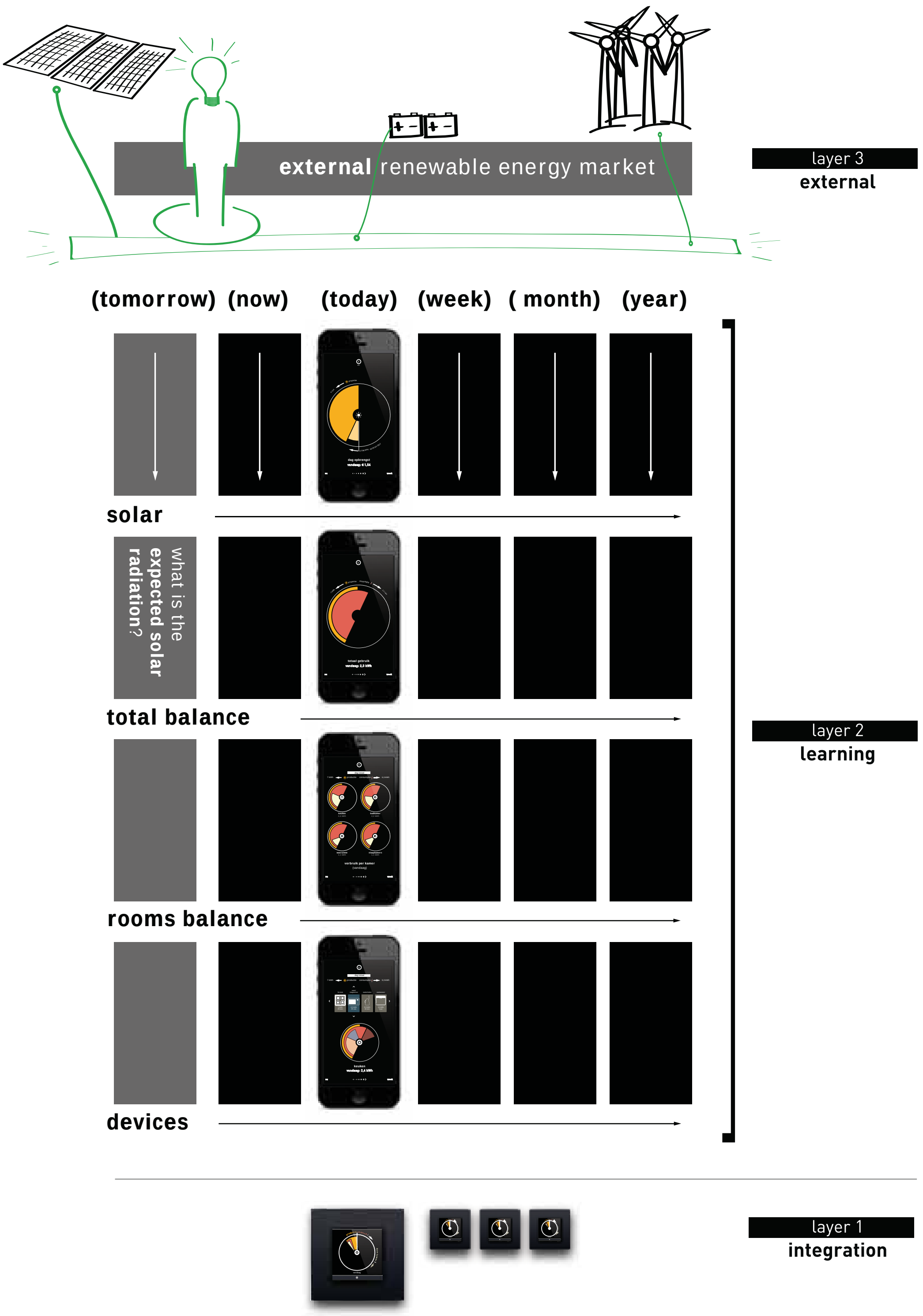


figure 4.3
The application as it is currently designed can be seen as a solid fundament, with many possibilities for implementation of new features. To make the democratisation a more integral part of Ampul the external-layer 3 should be connected to the Ampul application

Those core qualities are however implemented in a way, which allows for the integration of many new features, like the addition of a solar-radiation forecast in all layers which would enable users to make better decisions regarding their consumption of electricity (figure 4.3). Also could be implemented, that from within the application devices can be turned off. Using the current device layer of the application to see which device is consuming most, to consecutively switch it off or set a timer which determines when it is allowed to switch on again. Before those 'new' features are developed, the week, month and year view should be carefully thought trough. They require another iteration of design and validation to develop them in a logical extension of the (now) and (today) views. The fundamental visualisation has proved to feature the right elements for future prosumers, those should be retained in the (week), (month) and (year) views. Those views will however present a larger data set and should provide layers inside their view, to present these larger sets of data in a clean and understanable manner.

2. DEMOCRATISATION

To realise the democratisation of the energy market bottom up, Ampul is a small step but it begins from the right starting point. To make the democratisation a more integral part of Ampul the external-layer 3 should be connected to the Ampul application (figure 4.3). The application features a platform, where a large set of data is gathered. This data can be translated in meaningful and targeted advise regarding investments in energy sources. The advice does not necessarily be restricted to the purchase of solar- or wind-power. The nearest energy generation facilities of electricity which use renewable sources, can be gathered and presented in an overview. A platform can be created where suppliers of renewable energy can advertise their products. For them it can be an opportunity to present themselves to users in a uniform and understandable way, with targeted offers based on the data which is made available by the user. The user profits from an understandable visualisation of the different players and possibilities on the energy market. Thereby the user is enabled to participate as active player in this market and an opportunity is created for new players to enter the market and stimulate innovation.

IN ORDER TO DESIGN THE THIRD EXTERNAL-LAYER OF AMPUL A NEW RESEARCH SHOULD BE DONE TO EXPLORE THE FINANCIAL MODEL, GOVERNMENT REGULATIONS AND THE INVOLVEMENT OF CERTIFICATION BODIES. THE THIRD LAYER DOES NOT NECESSARILY HAVE TO BE IMPLEMENTED IN THE SAME APPLICATION. IT CAN ALSO BE A WEBSITE WHICH INTEGRATED WITH THE APPLICATION OF AMPUL THROUGH AN ONLINE CLOUD-BASED SERVICE.

THE THIRD LAYER AND THE HISTORICAL DATA VIEWS, NEED MORE EXPLORATION BEFORE THEY CAN BE DESIGNED. THIS CAN UNFORTUNATELY NOT FIT IN THIS GRADUATION PROJECT, BUT IS RECOMMENDED TO BE EXPLORED FURTHER IN A FUTURE PROJECT OR CONTINUATION PROJECT.

ACKNOWLEDGEMENTS

Doing this project has been a great joy. Like the other design projects during my education at the Industrial Design Engineering faculty of the Delft University of Technology I have learned a lot about my self and about the people I worked with. This project was however special. Although the project was carried out by me individually I met many new, inspiring people. I would like to thank them for their contributions.

I would like to thank Prof. David Keyson and Dr. ir. Natalia Romero Herrera for their great involvement in my project and their trust in me. David, thank you for the many opportunities you gave me, and your dedication to my graduation project. Natalia, thank you for understanding my believes and goals in this project even before I understood them myself, your involvement was great and you were always there to provide quick advice. An un-official supervisor in this project was Ir. Stijn Melis, from the company Niko in Belgium, Sint-Niklaas. Thank you for your great interest and input in this project, both intellectually and with technical support to make possible the prototype in the Concept House.

This project would not have been possible without the countless hours of programming of Marc, with his skills the developed concept in this project could be prototyped into a truly interactive prototype.

A special thanks goes to all my newly made acquaintances in the Rotterdam neighbourhood of Heijplaat. Many thanks to Corina, Liset, Nico, Rutger and Suzanne who have been of great help in arranging participants for the user studies I have done in Heijplaat. The people which have participated in my studies stay anonymous, but I would like to thank them for their essential role in this project.

The project was made possible by the support of the SuslabNWE project, international infrastructure of living labs.

APPENDICES

APPENDIX IA

5.2.1 Zonnestroom

	Bijgeplaatst vermogen	Opgesteld vermogen	Elektriciteits-productie	Bruto eindverbruik	Vermeden verbruik van fossiele primaire energie	Vermeden emissie CO_2
	MW		*mln kWh*	*TJ*		*kton*
1990	.	1	0	1	3	0
1995	0,4	2	1	4	10	1
2000	3,6	13	8	28	70	5
2005	1,7	51	34	122	304	21
2006	1,5	52	35	125	306	21
2007	1,4	53	36	128	309	21
2008	4,4	57	38	138	340	23
2009	10,7	68	46	165	398	27
2010	20,7	88	60	216	508	34
2011**	43,3	130	90	323	760	51

Bron: CBS.

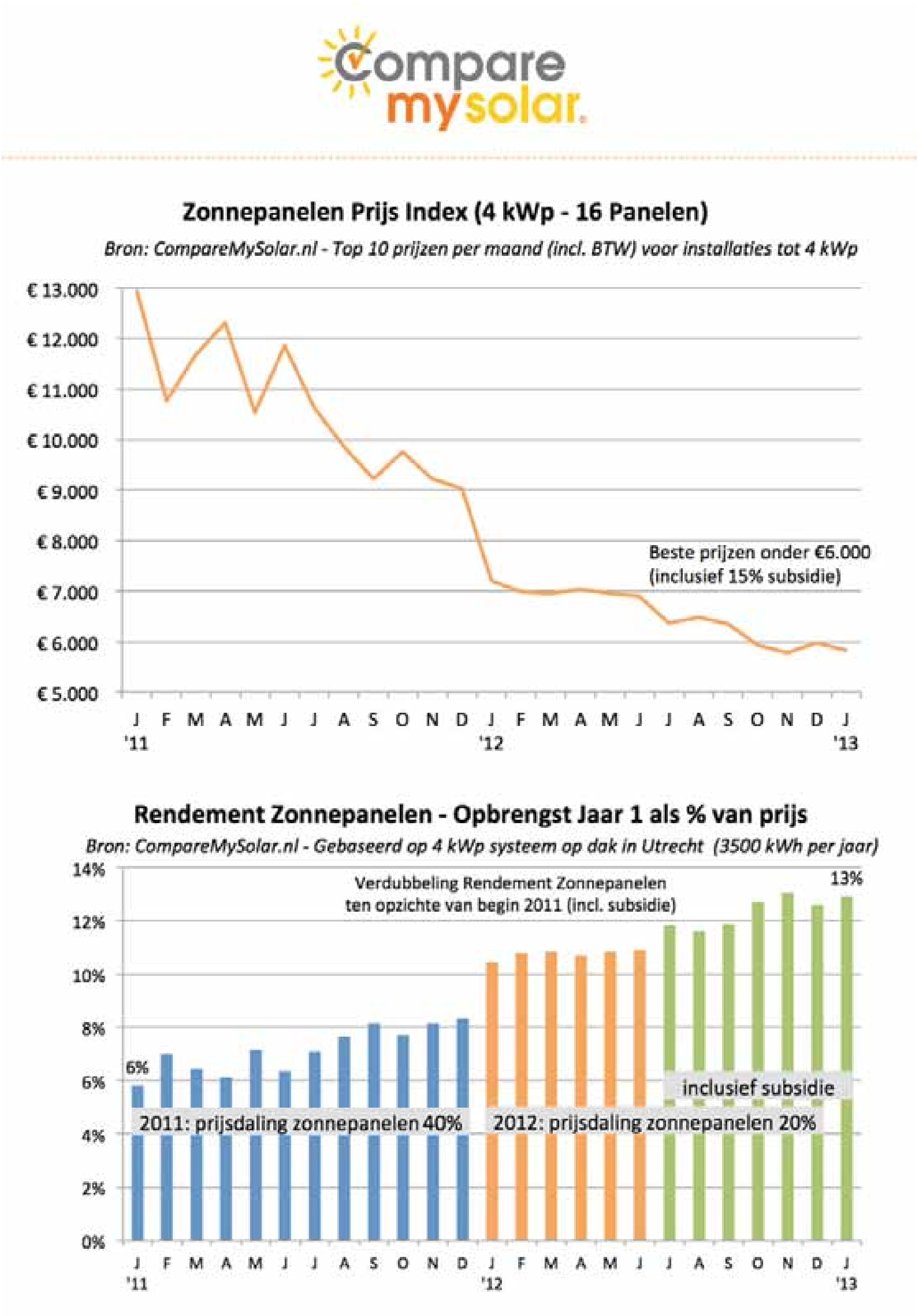
APPENDIX IB

5.2.2 Handel in zonnepanelen

	2005	2006	2007	2008	2009	2010	2011**
	kW						
Import	23 677	25 052	x	x	x	x	x
Productie	x	x	x	x	x	x	x
Export	20 942	22 148	34 005	64 089	72 493	117 665	187 872
Afzet binnenland aan eindgebruikers	1 663	1 521	1 399	4 444	10 669	20 682	43 106
Uitsplitsing binnenlandse afzet naar type eindverbruik							
Niet-netgekoppeld	323	278	558	239	91	291	86
Netgekoppeld	1 340	1 243	841	4 205	10 578	20 391	43 020
Uitsplitsing binnenlandse afzet naar afzetkanaal							
Via installateurs	.	.	.	.	6 916	11 308	17 440
Direct naar eindverbruikers	.	.	.	.	3 753	9 374	25 666

Bron: CBS.

APPENDIX II



Compare mysolar
Zonnepanelen Prijs Index (4 kWp - 16 Panelen)
Bron: CompareMySolar.nl - Top 10 prijzen per maand (incl. BTW) voor installaties tot 4 kWp
€ 13.000
€ 12.000
€ 11.000
€ 10.000
€ 9.000
€ 8.000
€ 7.000
€ 6.000
€ 5.000
Beste prijzen onder €6.000
(inclusief 15% subsidie)
J F M A M J J A S O N D J F M A M J J A S O N D J
'11
'12
'13
Rendement Zonnepanelen - Opbrengst Jaar 1 als % van prijs
Bron: CompareMySolar.nl - Gebaseerd op 4 kWp systeem op dak in Utrecht (3500 kWh per jaar)
14%
12%
10%
8%
6%
4%
2%
0%
Verdubbeling Rendement Zonnepanelen
ten opzichte van begin 2011 (incl. subsidie)
13%
6%
inclusief subsidie
2011: prijsdaling zonnepanelen 40%
2012: prijsdaling zonnepanelen 20%
J F M A M J J A S O N D J F M A M J J A S O N D J
'11
'12
'13

APPENDIX III

Results, Total electricity use of the household

Are people aware of their total use according to their indication?

3. Could you estimate how much electricity your entire house with all electrical devices consumes on yearly basis in kWh?				
Answer	Apartment	Terraced House	Detached House	Percentage
No, I don't know	44	26	5	72,8%
Yes, its:	10	15	3	27,2%
Total	54	41	8	100,0%

Do people have a realistic view of their knowledge regarding electricity use?

4.1 How do you think your electricity use is compared to other households? When total use was estimated by participant			
Answer	Apartment	Terraced House	Detached House
Indication (Average/Below A./Higher than A.):	10	15	3
Correct:	4	10	1
Correct percentage:	40,0%	66,7%	33,3%
Educational level of the people that answered correctly per house type:	1 College or Bsc 3 Master's	2 Some College 3 College or Bsc 4 Master's 1 Doctoral degree	1 Master's

People who indicated they knew, the total electricity consumption of their household per year. The majority indicated their use incorrectly as average or below or higher than average.

4.2 How do you think your electricity use is compared to other households? When total use was NOT estimated by participant!				
Answer	Apartment	Terraced House	Detached House	Percentage
Indicated Average	20	12	1	45,9%
Indicated Below average	16	7	1	33,3%
Indicated Higher than average	7	5	3	20,8%
Total	43	24	5	100,0%

People who did not know, or thought they did not know, the total electricity consumption of their household per year. Remarkably the majority indicated their use as average or below average although they did not indicate their own total consumption per year.

Jaap Rutten 1317490 internet survey analysis November 30, 2012

Influence of educational level and age on the knowledge of total yearly electricity consumption

4.2 How do you think your electricity use is compared to other households? When total use was NOT estimated by the participant!			
Educational level:	**When people were asked to estimate their total yearly electricity consumption, they answered:**		**Percentage of participants that did not know:**
	No, I don't know	Yes , it's: .. kWh	
High school	3	7	30%
Some college	7	2	77,8%
College or Bsc degree	35	8	81,4%
Master's degree	25	16	61,0%
Doctoral degree	5	2	71,4%
Age group: 20-29	45	6	88,2%
Age group: 30-39	10	4	71,4%
Age group: 40-49	5	3	62,5%
Age group: 50-59	8	10	44,4%
Age group: 60-69	4	4	50,0%
Age group: 70-79	1	0	100,0%
Total	**75**	**28**	**72,8%**

When people were presented with average values for their type of housing determined by the Dutch Central Statistics Office (CBS), they were asked if they were surprised upon seeing those values after they filled in their own values.

The answers can be divided in people who answered no and yes and in a number of reasons which people gave for their answer.

4.1.1 The average amount of kWh per house in 2010 according to the Central Statistics Bureau (CBS) is: 2250 kWh per year for apartments, 3350 kWh per year for terraced houses, 4550 kWh per year for detached houses. You answered before.. Are you surprised to see the values from the CBS? Could you explain why?			
Typical answers for: *"yes, I am surprised"*	nr.	Typical answers for: "*no, I am not surprised"*	nr.
The average is lower than I expected, my consumption is higher than average! Maybe because the number of people in my house is quite high?	3	My house is much bigger than average, thats why it is higher, or: In my house live a lot of people (studenthouse), so we use more.	7
The average is higher than I expected, I did not know I would score below average!	2	I already knew my own use and the average numbers!	5
But I am not interested in this at all!	1	Because, I am not familiar. I don't have a feeling of reference yet.	2
How come the differences between the different housing types are so big? I would say the only difference is the amount of lamps, which only make up a small part of the electricity consumption.		We bought very efficient appliances on purpose, or: I have a few solar panels for electricity production.	2
		I am not surprised, but I think many people do not have the awareness of their electricity consumption!	1

Quote:
The average is lower than I expected, my consumption is higher than average! "*For how many persons in the household is this? I think I might have underestimated it but we are students, living on two floors so you could consider it to be in between an apartment and terraced house. (maisonette woning). I think our two old refrigerators use up the most."*

Results, electricity use of devices in the household

1. Choose one of the following electrical appliances, which you interact with most frequently in a day. 2. How much do you use the device?					
Device	**Participants**	**3-5 hours/day**	**2-3 hours/day**	**1 hour/day**	**< 1 hour/day**
Laptop	63 (62%)	50 (79%)	15 (24%)	1 (2%)	0
Lamps (for lighting)	22 (22%)	20 (91%)	1 (5%)	0	1 (5%)
Television	9 (9%)	4 (44%)	4 (44%)	1 (11%)	0
Water Cooker	5 (5%)	0	0	0	5 (100%)
Oven or Microwave	2 (2%)	0	0	1 (50%)	1 (50%)
Toaster (for bread)	0				
Hairdryer	0				
Total	**101 (100%)**				

In the following questions you will be asked to estimate how much electricity the device you selected consumes, when you use it for the amount of time you indicated. E.g. How much kWh does your laptop consume when you use it for 3-5 hours? If you are not able to estimate the amount of electricity simply fill in 'no'.					
Device	**Laptop**	**Lamps**	**Television**	**Water Cooker**	**Oven/ Microwave**
3-5 hours/day					
2-3 hours/day					
1 hour/day					
< 1 hour/day					

Jaap Rutten 1317490 internet survey analysis November 30, 2012

If you could be informed about the electricity use of your device, which information would you prefer?	
The costs of the electricity that is used when I use the device 1 time	48 (32%)
The amount of kiloWatts	30 (20%)
The percentage of my daily use	26 (17%)
The percentage of my yearly use	21 (14%)
The percentage of my weekly use	14 (9%)
Other..	10 (7%)
Total	**149 (100%)**

Other:

The percentage in comparison with other common devices at home and the cost per hour.

The current electricity consumption as percentage of the total current electricity consumption of the household.

The costs of the device for 1 time use compared to the yearly electricity costs for that device.

The costs of the device if I were using it continuously.

The consumption of the device compared with a metaphor that makes pollution more clear.

Yearly costs of the device or a percentage of the total yearly costs for the household (2 participants)

Daily use percentage in combination with price.

none (2 participants)

Results, attitude towards household electricity production by PV

Do you currently produce electricity at home and if so, with which system (solar or other)?		
Yes , with:		No, I don't
Pv panels	7	78
With our neighbors/community we produce electricity by means of Pv panels	2	
With our cohousing community we produce electricity by means of Pv panels	1	
One Pv panel for electricity and one solarpanel for warm water	1	
We use a woodstove which is connected to wall and floor heating	1	
	12 (13,3%)	**78 (86,7%)**

Participants were asked if they were not producing electricity by any means if they would like to do so and why. About two thirds of the participants answered they would like to do so for a variety of reasons. One third indicated they would not want to. However the reasons they gave might indicate they would actually want to, but the current obstacles hinder them.

The answers are divided by the answer on the question: *“Can you estimate the total yearly electricity consumption of your household?”*. This was used as some indication of the awareness of people on their usage of electricity.

Would you want to produce electricity at your own house and why?			
		When people were asked to estimate their total yearly electricity consumption, they answered:	
		No, I don’t know	Yes , it’s: .. kWh
Just, Yes!	11	6	5
Yes, it contributes to a better environment	32	25	7
Yes, it saves costs	16	13	3
Yes, it makes you independent	12	8	4
Yes, it feels good	2	2	0
Yes, I like the idea of balancing need and production	2	2	0
Total	**75**	**56 (75%)**	**19 (25%)**
No, (but I would consider) my living situation is not stable (rental house or other)	12	10	2
No, (but I would consider) I don’t have the money to invest	5	3	2
No, I would like companies to do it as efficient as possible	4	2	2
No, production of PV panels is bad for the environment	1	0	1
No, I am not interested its too difficult	13	7	6
Just, No!	3	3	0
Total	**38**	**25 (66%)**	**13 (34%)**

Consecutively participants were asked if they were aware, PV panels can be leased from companies.

Are you aware that you can lease an electricity production system based on PV panels to install and use on your own house?	
Yes	55 (61%)
No	35 (39%)
	90 (100%)

What would be your main hesitations for entering such a deal?	
more options were selectable	
I don't know if I will live in my current house for that long	44 (30%)
I have a rental house, so its not my property	47 (32%)
I want to wait for systems which are more efficient and deliver more electricity per m2	17 (12%)
I have no hesitations	9 (6%)
I don't trust the company that leases the system	3 (2%)
Other..	**27 (18%)**
I prefer to buy them at once if I would want to, I believe that is much cheaper in the end..	*10 (7%)*
I have to get used to the idea first / Its too much hassle	*5 (4%)*
My house is not suitable (technically), orientation of the roof is not the most optimal	*3 (2%)*
I already have PV panels.	*3 (2%)*
Is this true? I don't believe it / Information is not enough.	*2 (1%)*
Return on investment takes way to long!	*2 (1%)*
Other..	*2 (1%)*

APPENDIX IV

energy monitoring device	strong points	capabilities	interfaces	interaction layers
Utility companies provide energy monitoring/managing tools				
Eneco Toon	The device combines attractive features, like a smart thermostat with different layers of complexity for gas/ electricity consumption	Thermostat, gas and electricity consumption of total household	Single wall mounted display, which displays all capabilities and information, smartphone application for simplified functionality	multiple, the smartphone application offers a simplified view, the single wall mounted display has multiple layers of information complexity
Nuon E-Manager	This energy monitoring and managing device is distributed by the utility company Nuon, they can profit from their trustable image as utility provider. The device is rather technical but it does allow users to set different schedules for e.g. day and night.	It can measure both gas and electricity values in households. It measures by collecting data of the main electricity and gas meters in the house, but also provides plugs which can be connected to outlets to turn off connected devices and measure their electricity consumption.	1, a set of sensors is connected to the main electricity and gas meters and to a limited amount of power outlets. The interface is provided as computer, tablet and smartphone application, which lets you monitor and schedule electricity consumption.	1, all (detailed) information can be acquired at once through the application.
Onzo	The device is portable and can be placed anywhere in the house (e.g. next to big consumers), the website concepts offer easy reflection possibilities (money, activities, environment)	Measures total electricity consumption and sends it wirelessly to a small portable display	A single portable display presents all values and has different modes. On the website of Onzo values can be compared and reflected in other means	multiple, the portable display features 4 modes which can be switched by the user, the website provides more referencing material.
Energy monitoring integrated with home domotics				
Niko Home Control	The system is integrated with your house domotics system, which gives a high quality experience. The eco display is an accessible first layer for information.	The home domotics system of Niko, also features the possibility to monitor energy consumption. It connects to the already available infrastructure in the house.	Three interfaces can be used to display the information. The eco display, the home control display and a smartphone application.	multiple, the eco display only shows the current energy usage, the smartphone app and the home control display give the same feedback. They provide historical data of your consumption and production.

energy monitoring device	strong points	capabilities	interfaces	interaction layers
Plug and Play total household energy monitors				
Wattson	The first layer feedback is an ambient colored light and allows for easier integration in your living environment. For more details you can look at the dynamic power meter, or costs which increase while you are watching	A sensor and transmitter is attached to the main electricity meter.	Two interfaces show the user current usage both in watts and ambient colors, a computer can be connected through usb to create historical data	multiple, the Wattson itself first presents below average, average and higher than average with ambient colors, layer 2 is also on the Wattson and presents you the current power usage in watts, the third layer uses the computer to generate historical charts
Wattcher	Very approachable, installation is plug and play for almost all users however the interface is rather technical (only Watts are displayed)	measures total current electricity consumption and exports history data to computer	A single plug is located in an electrical outlet and displays current power, computer is used for overview	multiple, the plug gives live feedback, the computer can give overviews in spreadsheets etc.
Blueline with PeoplePower mobile energy management	The application works with multiple measurement devices. There is a strong gaming and comparison element in the application which also allows you to compare new devices before you buy them	The blueline functions as sensor to measure total electricity consumption	The PeoplePower application on the smartphone provides the interface	multiple, inside the application there is a current power usage feedback, a comparison with other households and a scoring mechanism (game)
Blueline with PlotWatt software	The software works with multiple measurement devices and uses a smart algorithm to distinguish the different devices which consume electricity	The blueline functions as sensor to measure total electricity consumption	The PlotWatt application on your computer provides the interface with a smart algorithm which determines which different devices cause the consumption	multiple, the application shows the current power consumption, then it also splits it up in different devices and presents your daily consumption (history)
Ewgecko	The device is portable and can be placed anywhere in the house (e.g. next to big consumers)	Measures total current electricity consumption and production and gas/ water consumption	A single portable display presents all values as a bar chart.	1, all total consumption and production values are shown as bar chart on 1 screen.

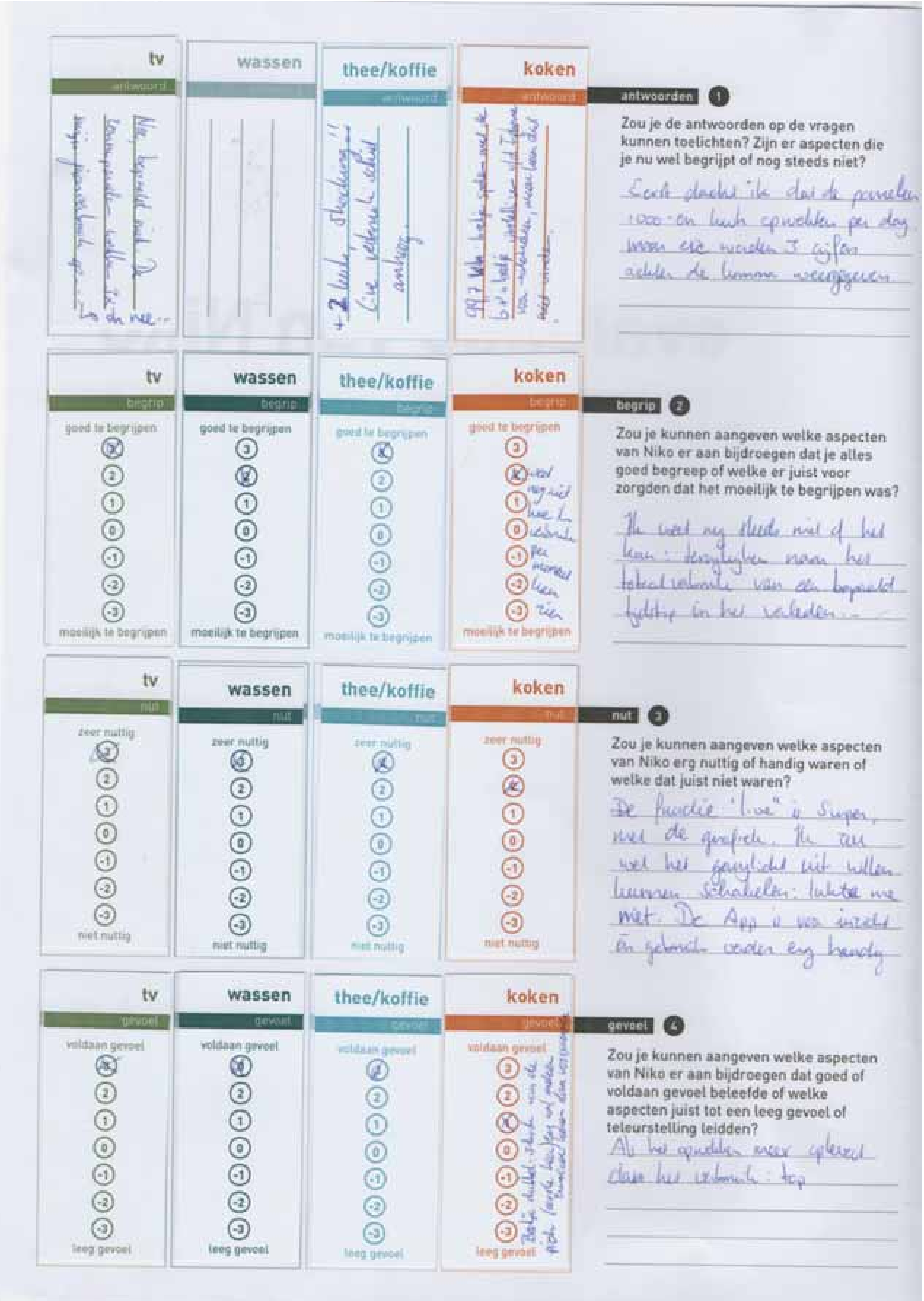
energy monitoring device	strong points	capabilities	interfaces	interaction layers
Energy managing tools (technology oriented)				
Greeniant	the system has many technological possibilities, but their website is unclear about the interface which should be provided by 3rd party applications	A plug and play installation system for households. A central unit is installed on the main electricity meter of the house. Through a smart algorithm different devices which consume electricity are recognised, which can provide more detailed information regarding the households electricity consumption.	1, smartphone application can receive the data of the system and present it to the user	unknown
Plugwise	Many expansion possibilities and very detailed measurements, however there is none or only very technical interface available	Can measure electricity consumption per device	Computer can be used to read electricity consumption per plug	1, all (detailed) information can be acquired at once
Marvin	very technical, not very approachable, all (technical) information comes at once	measures total current electricity and gas consumption, has thermostat, gives weather information and home security system implementation	Single wall mounted display, which displays all capabilities and information	1, all (detailed) information can be acquired at once

	id	**Day**	Which activities influenced your consumption?	How would you change your activities?
LH18-1	11	1	we werken thuis dus is ons verbruik meer en de gro...	-
		2	We hadden een groep die in de kerk teambuilde, van...	-
		3	we hebben de hele dag gewerkt en kind heeft vrij	-
		4	-	-
JD04-1	4	1	stijken,drogen	willen maar niet kunnen,je moet tenslotte de diverse activiteiten blijven doen.
		2	Geen droger,wasmachine of andere energieslurpers gebruikt.	-
		3	niet gewassen of gestreken, de kinderen hebben een.	er is denk ik alleen het hoognodige gebruik gemaak.
		4	wassen en drogen wordt bij voorkeur in het weekend.	Ik zie daar weinig mogelijkheden meer toe,anders dan helemaal niet.
IZ04-1	5	1	extra keer vaatwasser gebruikt	bewuster omgaan met verlichting
		2	extra keer vaatwasser gebruikt, vandaag niet gekookt...	bewuster omgaan met verlichting, vandaag licht eerder uit doen...
		3	extra keer vaatwasser gebruikt, vandaag niet gekookt...	bewuster omgaan met verlichting, vandaag licht eerder uit doen...
		4	extra keer vaatwasser gebruikt, vandaag niet gekookt...	bewuster omgaan met verlichting, vandaag licht eerder uit doen...
CS09-2	7	1	de lampen ‘s avonds verbruiken veel	nog niet
		2	de lampen ‘s avonds verbruiken veel en de kerstve...	minder lichten aan
		3	de lampen ‘s avonds verbruiken veel en de kerstve...	minder lichten aan
		4	zuinig met de lampen	minder lampen aan doen
NP11-2	9	1	niet extra of anders dan normaal	misschien minder multimedia apparaten gebruiken
		2	avond weg geweest	-
		3	-	-
		4	iris thuis werken	-
CM11-2	8	1	-	-
		2	Huishouden	Nee
		3	-	
		4	-	-

APPENDIX V

	LH18-1				JD04-1				IZ04-1				CS09-2				NP11-2				CM11-2			
Participant id	11				4				5				7				9				8			
Day	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
total	64 kWh				50 kWh				47 kWh				6 kWh				17 kWh				~42 kWh			
kWh	11	18	18	17	13	8	7	22	20	6	8	13	1	1	2	2	4	3	5	5	~	9	~	~
Mood (E)xcited (H)appy (C)alm (R)elaxed (W)orried (A)ngry (C)alm (S)ad	A	W	A	C	W	C	C	C	W	W	CW	CW	H	HR	HR	E	-	-	-	-	-	C	-	-
Negatively Surprised /-2 <> +2/ Positively Surprised	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	-	2	-	-
Disappointed /-2 <> +2/ Satisfied	-1	0	-1	0	0	0	0	1	0	1	1	1	0	1	1	2	0	0	0	0	-	2	-	-
Worried /-2 <> +2/ Relieved	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	-	0	-	-
Confused /-2 <> +2/ Enlightened	0	0	0	0	2	0	0	0	0	0	0	0	1	-1	0	2	0	0	0	0	-	1	-	-

APPENDIX VI - DM1315



tv	wassen	thee/koffie	koken
antwoord	antwoord	antwoord	antwoord
[illegible]		[illegible]	[illegible]

tv	wassen	thee/koffie	koken
begrip	begrip	begrip	begrip
goed te begrijpen	goed te begrijpen	goed te begrijpen	goed te begrijpen
3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3
moeilijk te begrijpen	moeilijk te begrijpen	moeilijk te begrijpen	moeilijk te begrijpen

tv	wassen	thee/koffie	koken
nut	nut	nut	nut
zeer nuttig	zeer nuttig	zeer nuttig	zeer nuttig
3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3
niet nuttig	niet nuttig	niet nuttig	niet nuttig

tv	wassen	thee/koffie	koken
gevoel	gevoel	gevoel	gevoel
voldaan gevoel	voldaan gevoel	voldaan gevoel	voldaan gevoel
3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3	3 2 1 0 -1 -2 -3
leeg gevoel	leeg gevoel	leeg gevoel	leeg gevoel

antwoorden 1

Zou je de antwoorden op de vragen kunnen toelichten? Zijn er aspecten die je nu wel begrijpt of nog steeds niet?

Eerst dacht ik dat de panelen 1000-en kwh opwekten per dag, maar er worden 3 cijfers achter de komma weergegeven

begrip 2

Zou je kunnen aangeven welke aspecten van Niko er aan bijdroegen dat je alles goed begreep of welke er juist voor zorgden dat het moeilijk te begrijpen was?

Ik weet nog steeds niet of het kan: vergelijken naar het totaalverbruik van een bepaald tijdstip in het verleden...

nut 3

Zou je kunnen aangeven welke aspecten van Niko erg nuttig of handig waren of welke dat juist niet waren?

De functie "live" is super, met de grafiek. Ik zou wel het graag [illegible] willen kunnen schakelen: lukte me niet. De App is een inzicht en gebruik vanuit erg handig

gevoel 4

Zou je kunnen aangeven welke aspecten van Niko er aan bijdroegen dat goed of voldaan gevoel beleefde of welke aspecten juist tot een leeg gevoel of teleurstelling leidden?

Als het opwekken meer oplevert dan het verbruik: top

evaluatie van Niko

Plaats de kaartjes die je gedurende de afgelopen dagen hebt ingevuld op de aangegeven plaats en licht ze toe. Begin op de linker pagina.

beleving 5

Zou je kunnen aangeven hoe je het gebruik van Niko in zijn algemeenheid hebt ervaren?

positief verrast	tevreden	opgelucht	verlicht/geïnformeerd
3	3	3	3
2	2	2	2
1	1	1	1
0	0	0	0
-1	-1	-1	-1
-2	-2	-2	-2
-3	-3	-3	-3
negatief verrast	teleurgesteld	bezorgd	verward

Licht bovenstaande vragen toe. Welke aspecten van Niko waren goed en welke zou je veranderen?

Ik zou ook water-inzicht willen. En kunnen terugkijken (*tussen 4 en 5 gewassen, nu is het 7 uur) Lichtknopjes reageren traag, hierdoor je dubbel gaan drukken. Lichtsensor is heel vervelend voor [illegible] lampen te fel. Badkamer en wc [illegible] zou ik zelf uit willen kunnen doen. Of een functionaliteit in de App: "Alles uit". Is of kunnen instellen hoe lang

elektriciteit opwekken 6

Is je perspectief op het opwekken van je eigen elektriciteit door middel van zonnepanelen veranderd na het gebruik van Niko?

Ja, prettig om te zien, de directe koppeling tussen verbruik en opwekking. Zo is me inzichtelijk dat koken (relatief) meer verbruikt dan ik dacht, en wassen minder.

APPENDIX VI - DM1315

DM1315

Deelnemerskaart

De volgende vragenlijst zal je vragen om je persoonlijke gegevens in te vullen voor deelname aan deze studie. Deze informatie zal niet door ons worden gebruikt voor iets anders dan het interpreteren van de resultaten van de vragenlijst, het zal anoniem zijn en niet worden gekoppeld aan je naam.

Vul hier je leeftijd in:

38

Wat is je opleidingsniveau:

- [ ] Lager dan Middelbare School
- [ ] Middelbare School
- [ ] MBO of HBO voor een gedeelte
- [ ] HBO of Bachelors (Universiteits) Diploma
- [x] Master's Diploma
- [ ] Doctorstitel

Uit hoeveel personen bestaat je eigen huishouden?

7 personen

Woon je in een huurwoning of een koopwoning?

Koopwoning

Zou je kunnen inschatten hoeveel elektriciteit er in je gehele woning met alle apparaten wordt gebruikt op jaarbasis in kWh (kiloWattuur)?

- [ ] Nee, ik heb geen idee
- [x] Ja, het is: 3350

Hoe denk je dat je elektriciteitsverbruik is in vergelijking met andere huishoudens?

- [ ] Gemiddeld
- [x] Onder het gemiddelde
- [ ] Hoger dan het gemiddelde
- [ ] Ik weet het niet

Kan je het vorige antwoord toelichten?

Voor een gezin met 7 personen verbruiken we weinig (gemiddeld nog minder gas): we hebben een PV-systeem en windmolen.

Maak je gebruik van een apparaat of dienst om het energie gebruik in je eigen woning in beeld te brengen danwel te beheren?

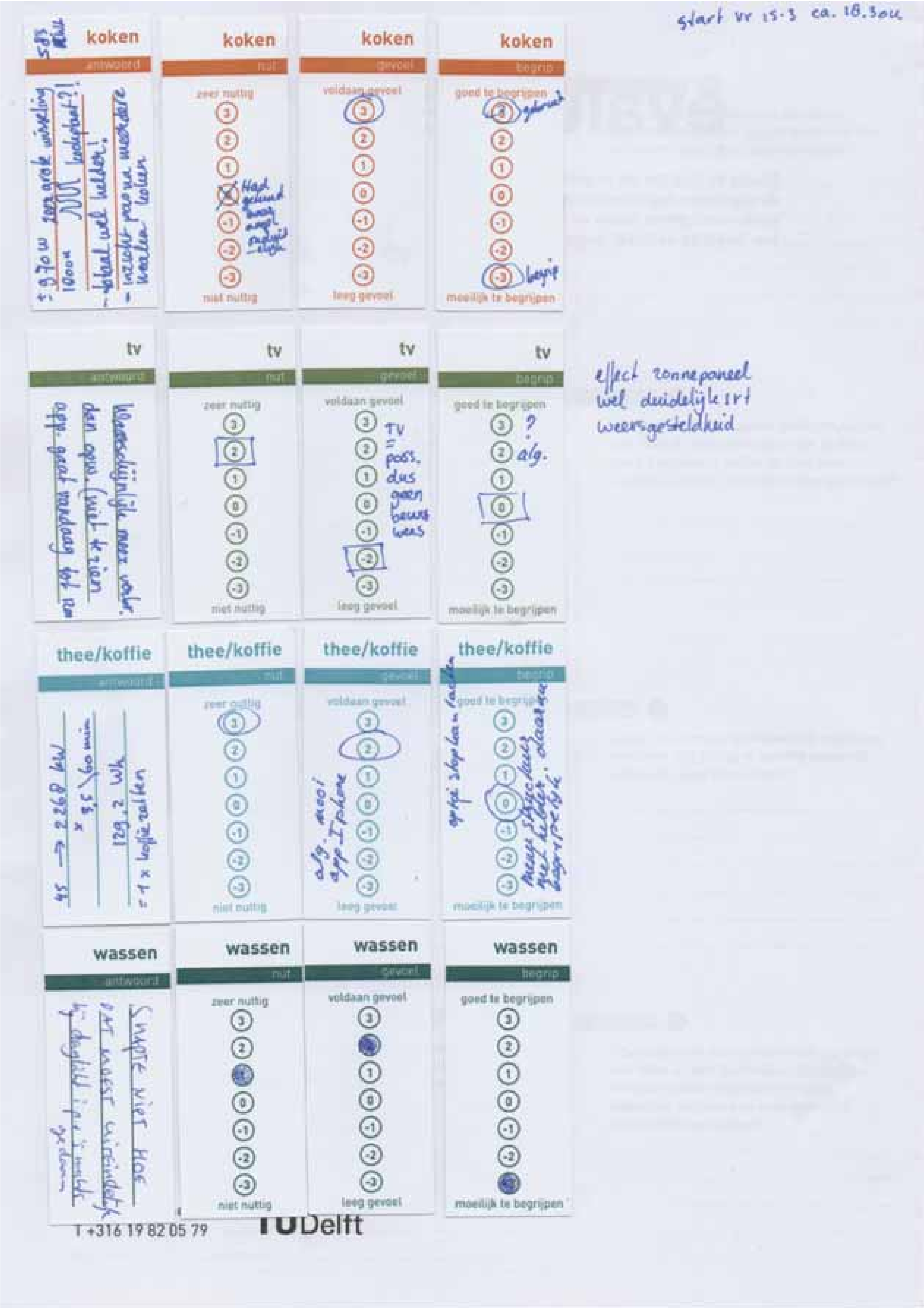
- [x] Slimme meter
- [ ] Slimme thermostaat
- [ ] Energie Monitor
- [ ] Computer programma, zoals excel of een website
- [ ] Smartphone applicatie
- [ ] anders ..

Wordt er elektriciteit geproduceerd in je huishouden? Zo ja, waarmee?

- [ ] Nee
- [x] Ja, door middel van PV (14 x 110 wattpiek) + 1000 kwh windmolen

Hartelijk dank voor het invullen van deze vragenlijst. Je bent nu klaar om te beginnen als deelnemer van het onderzoek.

APPENDIX VI CM1517



Deelnemerskaart

De volgende vragenlijst zal je vragen om je persoonlijke gegevens in te vullen voor deelname aan deze studie. Deze informatie zal niet door ons worden gebruikt voor iets anders dan het interpreteren van de resultaten van de vragenlijst, het zal anoniem zijn en niet worden gekoppeld aan je naam.

Vul hier je leeftijd in:

36

Wat is je opleidingsniveau:

- ☐ Lager dan Middelbare School
- ☐ Middelbare School
- ☐ MBO of HBO voor een gedeelte
- ☐ HBO of Bachelors (Universiteits) Diploma
- ☒ Master's Diploma
- ☐ Doctorstitel

Uit hoeveel personen bestaat je eigen huishouden?

4/6 personen

Woon je in een ~~huurwoning of~~ een koopwoning?

CM157

Zou je kunnen inschatten hoeveel elektriciteit er in je gehele woning met alle apparaten wordt gebruikt op jaarbasis in kWh (kiloWattuur)?

- ☐ Nee, ik heb geen idee
- ☐ Ja, het is:

Hoe denk je dat je elektriciteitsverbruik is in vergelijking met andere huishoudens?

- ☐ Gemiddeld
- ☒ Onder het gemiddelde
- ☐ Hoger dan het gemiddelde
- ☐ Ik weet het niet

Kan je het vorige antwoord toelichten?

10% zuiniger bij vergelijkbare groep qua gezinssamenstelling en woning

Maak je gebruik van een apparaat of dienst om het energie gebruik in je eigen woning in beeld te brengen danwel te beheren?

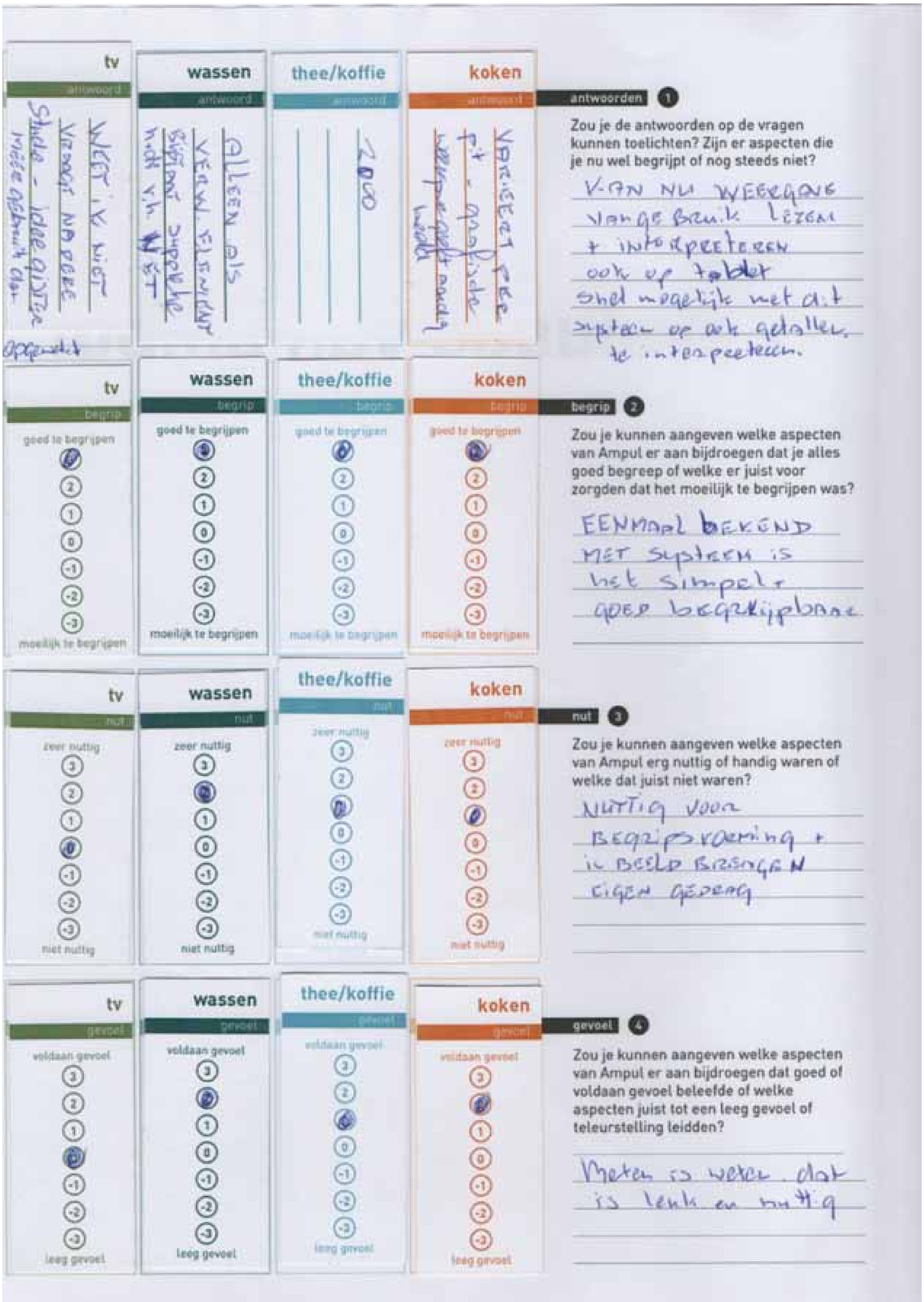
- ☐ Slimme meter
- ☐ Slimme thermostaat
- ☒ Energie Monitor
- ☐ Computer programma, zoals excel of een website
- ☐ Smartphone applicatie
- ☐ anders ..

Wordt er elektriciteit geproduceerd in je huishouden? Zo ja, waarmee?

- ☒ Nee
- ☐ Ja, door middel van ...

Hartelijk dank voor het invullen van deze vragenlijst. Je bent nu klaar om te beginnen als deelnemer van het onderzoek.

APPENDIX VI - NP1820



	tv	wassen	thee/koffie	koken
antwoord	WEET IK NIET / VRAAGT NADERE / Studie - idee gisteren meer gebruikt dan opgewekt	ALLEEN ALS / VERVL. ELEMENT / BIJ DOET DUBBELE / HOEV. V.H. WEET	2000	VARIEERT PER / tijd - periode / verbruik afhankelijk van activiteit
begrip (goed te begrijpen 3 … -3 moeilijk te begrijpen)	3	3	3	3
nut (zeer nuttig 3 … -3 niet nuttig)	0	2	1	1
gevoel (voldaan gevoel 3 … -3 leeg gevoel)	0	2	1	2

antwoorden 1

Zou je de antwoorden op de vragen kunnen toelichten? Zijn er aspecten die je nu wel begrijpt of nog steeds niet?

VAN NU WEERGAVE VAN GEBRUIK LEZEN + INTERPRETEREN ook op tablet. Snel mogelijk met dit systeem op ook getallen te interpreteren.

begrip 2

Zou je kunnen aangeven welke aspecten van Ampul er aan bijdroegen dat je alles goed begreep of welke er juist voor zorgden dat het moeilijk te begrijpen was?

EENMAAL BEKEND MET SYSTEEM IS het simpel + goed begrijpbaar

nut 3

Zou je kunnen aangeven welke aspecten van Ampul erg nuttig of handig waren of welke dat juist niet waren?

NUTTIG VOOR BEGRIPSVORMING + IN BEELD BRENGEN EIGEN GEDRAG

gevoel 4

Zou je kunnen aangeven welke aspecten van Ampul er aan bijdroegen dat goed of voldaan gevoel beleefde of welke aspecten juist tot een leeg gevoel of teleurstelling leidden?

Meten is weten dat is leuk en nuttig

evaluatie van ampul

Plaats de kaartjes die je gedurende de afgelopen dagen hebt ingevuld op de aangegeven plaats en licht ze toe. Begin op de linker pagina.

beleving 5

Zou je kunnen aangeven hoe je het gebruik van Ampul in zijn algemeenheid hebt ervaren?

positief verrast	tevreden	opgelucht	verlicht/geïnformeerd
3	3	3	3
2	2	2	2
1	1	1	1
0	0	0	0
-1	-1	-1	-1
-2	-2	-2	-2
-3	-3	-3	-3
negatief verrast	teleurgesteld	bezorgt	verward

Licht bovenstaande vragen toe. Welke aspecten van Ampul waren goed en welke zou je veranderen?

Ampul informeert + meter is verder is simpel + eenvoudig te lezen. opgelucht omdat ik zelf zonder Ampul weet wat ik aan energie gebruik[illegible] heb maar blij informatie te hebben over beschikbare techniek

elektriciteit opwekken 6

Is je perspectief op het opwekken van je eigen elektriciteit door middel van zonnepanelen veranderd na het gebruik van Ampul?

NEE, maar dat ligt aan investering verhuizen enz.
Mocht ik ooit nieuw bouwen, is dat zeker een optie

APPENDIX VI - NP1820

Deelnemerskaart

De volgende vragenlijst zal je vragen om je persoonlijke gegevens in te vullen voor deelname aan deze studie. Deze informatie zal niet door ons worden gebruikt voor iets anders dan het interpreteren van de resultaten van de vragenlijst, het zal anoniem zijn en niet worden gekoppeld aan je naam.

Vul hier je leeftijd in:

57

Wat is je opleidingsniveau:

- [ ] Lager dan Middelbare School
- [ ] Middelbare School
- [x] MBO of HBO voor een gedeelte
- [ ] HBO of Bachelors (Universiteits) Diploma
- [ ] Master's Diploma
- [ ] Doctorstitel

Uit hoeveel personen bestaat je eigen huishouden?

2 personen

Woon je in een huurwoning of een koopwoning?

huur

Zou je kunnen inschatten hoeveel elektriciteit er in je gehele woning met alle apparaten wordt gebruikt op jaarbasis in kWh (kiloWattuur)?

- [x] Nee, ik heb geen idee
- [ ] Ja, het is:

Hoe denk je dat je elektriciteitsverbruik is in vergelijking met andere huishoudens?

- [ ] Gemiddeld
- [ ] Onder het gemiddelde
- [x] Hoger dan het gemiddelde
- [ ] Ik weet het niet

Kan je het vorige antwoord toelichten?

Electrische verwarming

Maak je gebruik van een apparaat of dienst om het energie gebruik in je eigen woning in beeld te brengen danwel te beheren?

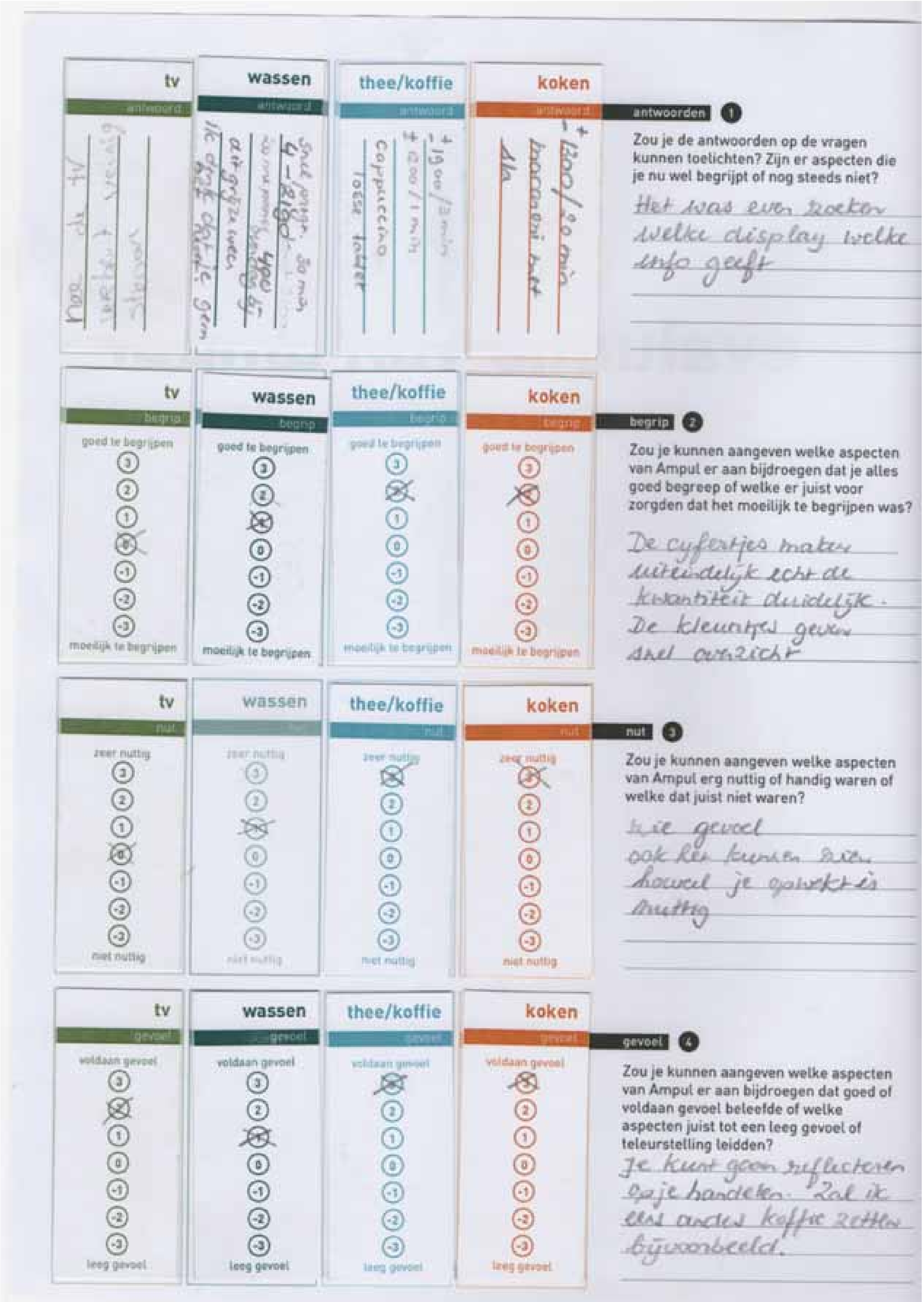
- [ ] Slimme meter
- [ ] Slimme thermostaat
- [ ] Energie Monitor
- [ ] Computer programma, zoals excel of een website
- [ ] Smartphone applicatie
- [x] anders ..

Wordt er elektriciteit geproduceerd in je huishouden? Zo ja, waarmee?

- [x] Nee
- [ ] Ja, door middel van

Hartelijk dank voor het invullen van deze vragenlijst. Je bent nu klaar om te beginnen als deelnemer van het onderzoek.

APPENDIX VI - KL2224



evaluatie van ampul

Plaats de kaartjes die je gedurende de afgelopen dagen hebt ingevuld op de aangegeven plaats en licht ze toe. Begin op de linker pagina.

beleving 5

Zou je kunnen aangeven hoe je het gebruik van Ampul in zijn algemeenheid hebt ervaren?

positief verrast	tevreden	opgelucht	verlicht/geïnformeerd
3	~~3~~	3	3
~~2~~	2	2	~~2~~
1	1	1	1
0	0	~~0~~	0
-1	-1	-1	-1
-2	-2	-2	-2
-3	-3	-3	-3
negatief verrast	teleurgesteld	bezorgt	verward

Licht bovenstaande vragen toe. Welke aspecten van Ampul waren goed en welke zou je veranderen?

Ik vond gebruik van de tablet het duidelijkst en de algemene display. De centrale bediening bij het naar buitengaan is heel handig

elektriciteit opwekken 6

Is je perspectief op het opwekken van je eigen elektriciteit door middel van zonnepanelen veranderd na het gebruik van Ampul?

Ja, ik dacht dat het meer opleverde. Het is wel heel grijs en koud deze dagen.

Deelnemerskaart

De volgende vragenlijst zal je vragen om je persoonlijke gegevens in te vullen voor deelname aan deze studie. Deze informatie zal niet door ons worden gebruikt voor iets anders dan het interpreteren van de resultaten van de vragenlijst, het zal anoniem zijn en niet worden gekoppeld aan je naam.

Vul hier je leeftijd in:

55

Wat is je opleidingsniveau:

- ▫ Lager dan Middelbare School
- ▫ Middelbare School
- ▫ MBO of HBO voor een gedeelte
- ▫ HBO of Bachelors (Universiteits) Diploma
- ✓ Master's Diploma
- ▫ Doctorstitel

Uit hoeveel personen bestaat je eigen huishouden?

6 personen

Woon je in een huurwoning of een koopwoning?

koop

Zou je kunnen inschatten hoeveel elektriciteit er in je gehele woning met alle apparaten wordt gebruikt op jaarbasis in kWh (kiloWattuur)?

- ✓ Nee, ik heb geen idee
- ▫ Ja, het is:

Hoe denk je dat je elektriciteitsverbruik is in vergelijking met andere huishoudens?

- ✓ Gemiddeld
- ▫ Onder het gemiddelde
- ▫ Hoger dan het gemiddelde
- ▫ Ik weet het niet

Kan je het vorige antwoord toelichten?

We hebben geen buitengewone levensstijl en letten er op niet onnodig stroom te gebruiken

Maak je gebruik van een apparaat of dienst om het energie gebruik in je eigen woning in beeld te brengen danwel te beheren?

- ▫ Slimme meter
- ▫ Slimme thermostaat
- ▫ Energie Monitor
- ▫ Computer programma, zoals excel of een website
- ▫ Smartphone applicatie
- ▫ anders ..

Wordt er elektriciteit geproduceerd in je huishouden? Zo ja, waarmee?

- ✓ Nee
- ▫ Ja, door middel van ...

Hartelijk dank voor het invullen van deze vragenlijst. Je bent nu klaar om te beginnen als deelnemer van het onderzoek.

APPENDIX VI - MA2426

tv	wassen	thee/koffie	koken
Ja, dat lijkt zo.	Dit is niet gelukt.	Ja. Door een grote uitslag lijkt het veel energie te verbruiken.	Wisselende uitslagen. Moeilijk om de hoeveelheid aan te geven.

antwoorden 1

Zou je de antwoorden op de vragen kunnen toelichten? Zijn er aspecten die je nu wel begrijpt of nog steeds niet?

Het meten van bv. het koken was lastig omdat het roze vlak gelijktijdig veranderde met het witte vlak.

	tv	wassen	thee/koffie	koken
goed te begrijpen				
3	3	3	3	3
2	2	2	X	X
1	X	X	1	1
0	0	0	0	0
-1	-1	-1	-1	-1
-2	-2	-2	-2	-2
-3	-3	-3	-3	-3
moeilijk te begrijpen				

begrip 2

Zou je kunnen aangeven welke aspecten van Ampul er aan bijdroegen dat je alles goed begreep of welke er juist voor zorgden dat het moeilijk te begrijpen was?

De wisselende uitslagen van het roze vlak waren verwarrend

	tv	wassen	thee/koffie	koken
zeer nuttig				
3	3	3	3	3
2	2	2	X	X
1	1	X	1	1
0	X	0	0	0
-1	-1	-1	-1	-1
-2	-2	-2	-2	-2
-3	-3	-3	-3	-3
niet nuttig				

nut 3

Zou je kunnen aangeven welke aspecten van Ampul erg nuttig of handig waren of welke dat juist niet waren?

Het inzicht krijgen in verbruik door de witte uitslag is nuttig. Het roze vlak geeft verwarring door het gelijklopen met het witte, en soms een grote stijging of daling

	tv	wassen	thee/koffie	koken
voldaan gevoel				
3	3	3	3	3
2	X	X	X	X
1	1	1	1	1
0	0	0	0	0
-1	-1	-1	-1	-1
-2	-2	-2	-2	-2
-3	-3	-3	-3	-3
leeg gevoel				

gevoel 4

Zou je kunnen aangeven welke aspecten van Ampul er aan bijdroegen dat goed of voldaan gevoel beleefde of welke aspecten juist tot een leeg gevoel of teleurstelling leidden?

Door het niet hebben van een referentie is het moeilijk om aan te geven of het goed of niet goed voelt

evaluatie van ampul

Plaats de kaartjes die je gedurende de afgelopen dagen hebt ingevuld op de aangegeven plaats en licht ze toe. Begin op de linker pagina.

beleving 5

Zou je kunnen aangeven hoe je het gebruik van Ampul in zijn algemeenheid hebt ervaren?

positief verrast	tevreden	opgelucht	verlicht/geïnformeerd
3	3	3	3
2 X	2	2	2
1	1	1	1
0	0 X	0 X	0
-1	-1	-1	-1 X
-2	-2	-2	-2
-3	-3	-3	-3
negatief verrast	teleurgesteld	bezorgd	verward

Licht bovenstaande vragen toe. Welke aspecten van Ampul waren goed en welke zou je veranderen?

Verhoudingsgewijs kunnen zien wat je verbruikt op dat moment is goed.
Een vaste indicatie van voorraad en verbruik per dag geeft duidelijkheid en is een verbeterpunt

Door de registratie van de energie opslag die paralel loopt met het weer krijg je wel een goed gevoel.

elektriciteit opwekken 6

Is je perspectief op het opwekken van je eigen elektriciteit door middel van zonnepanelen veranderd na het gebruik van Ampul?

Nee, wel word je bewuster van het verbruik van energie.

Deelnemerskaart

De volgende vragenlijst zal je vragen om je persoonlijke gegevens in te vullen voor deelname aan deze studie. Deze informatie zal niet door ons worden gebruikt voor iets anders dan het interpreteren van de resultaten van de vragenlijst, het zal anoniem zijn en niet worden gekoppeld aan je naam.

Vul hier je leeftijd in:

56 jaar

Wat is je opleidingsniveau:
- ☐ Lager dan Middelbare School
- ☐ Middelbare School
- ☐ MBO of HBO voor een gedeelte
- ☑ HBO of Bachelors (Universiteits) Diploma
- ☐ Master's Diploma
- ☐ Doctorstitel

Uit hoeveel personen bestaat je eigen huishouden?

1 personen

Woon je in een huurwoning of een koopwoning?

koopwoning

Zou je kunnen inschatten hoeveel elektriciteit er in je gehele woning met alle apparaten wordt gebruikt op jaarbasis in kWh (kiloWattuur)?
- ☑ Nee, ik heb geen idee
- ☐ Ja, het is:

Hoe denk je dat je elektriciteitsverbruik is in vergelijking met andere huishoudens?
- ☑ Gemiddeld
- ☑ Onder het gemiddelde
- ☐ Hoger dan het gemiddelde
- ☐ Ik weet het niet

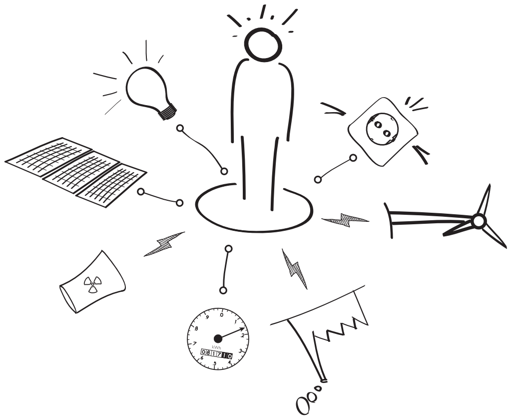
Kan je het vorige antwoord toelichten?

Energie gebruik ik heel bewust daardoor gemiddeld/onder gemiddeld.

Maak je gebruik van een apparaat of dienst om het energie gebruik in je eigen woning in beeld te brengen danwel te beheren?
- ☐ Slimme meter
- ☐ Slimme thermostaat
- ☐ Energie Monitor
- ☐ Computer programma, zoals excel of een website
- ☐ Smartphone applicatie
- ☑ anders de standaard met apparatuur

Wordt er elektriciteit geproduceerd in je huishouden? Zo ja, waarmee?
- ☑ Nee
- ☐ Ja, door middel van ……

Hartelijk dank voor het invullen van deze vragenlijst. Je bent nu klaar om te beginnen als deelnemer van het onderzoek.



DESIGNING AMPUL

EXPLORING FUTURE PROSUMER INTERACTIONS

IN THIS PROJECT AN EXPLORATION IS DONE OF THE CURRENT PLACE OF THE USER IN THE ENERGY MARKET AND LEADS TO THE CONCEPTUALISATION OF A NEW PRODUCT WHICH I NAME AMPUL. IT AIMS TO CONNECT PERSONAL OR SMALL-SCALE ENERGY PRODUCTION SUCH AS SOLAR CELL TECHNOLOGY WITH PEOPLE'S DOMESTIC ENVIRONMENT AND THEIR DAILY LIFE ACTIVITIES IN A MEANINGFUL AND NATURAL MANNER.

A MASTER GRADUATION WORK BY JAAP RUTTEN

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