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Final Bachelor Project



EASTON

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DFP003 - DESIGNING FOR GROWING SYSTEMS IN THE
HOME

Executive summary

This report provides an overview of the design process that led to the final design of Easton. It has been designed in the context of the theme “Energy” and in context of the smart home.

The product helps people to balance their energy supply and demand. Furthermore, it aims to support existing or emerging energy cooperatives in trading electrical energy generated by solar panels. One of the underlying reasons for balancing supply and demand, is the problem of the *duck curve*, contributing to climate change. The duck curve describes the energy usage of households as peaking during the morning and evening, times at which their self-generated energy is least available. Hence, people rely on existing energy suppliers taking energy from coal and nuclear plants. This problem diminishes the benefits of energy cooperatives, sharing electricity generated by solar panels. Methods of analysis used during the design process, include a *trend analysis* and a *thematic analysis*. *Storyboarding* was applied for further framing of the design challenge itself. Hereafter, different concepts were created during a brainstorming

session. Out of these concepts, one concept was chosen, focusing on the purchase and disposal of appliances. One of the concepts features, finding a balance between supply and demand, later led to the final concept of Easton. In between these two concepts, other concepts were formed and validated. A phase included the evaluation of different concepts and interaction styles for balancing supply and demand. Moreover, a deployment was executed, validating the main question:

Can the designed system influence users to use more energy when it is available (from themselves and the community)?

The deployment itself included the placement of an early prototype of Easton in a real house during the course of a week. After feedback was generated by means of an interview, a final prototype was created, focusing on the scenario of working at home. This prototype consists out of a physical product and an application. The physical product displays which kind of energy is being used: from the user itself, from the community or from an existing energy supplier. The application shows a more detailed overview of both spending and

earnings related to the energy trade. From the deployment, it appeared that the presence of both a physical and digital product are necessary for creating the intended behavior change. Finally, Eaton’s trading aspect and stimulation of the use of renewable energy were both found to positively influence this change. Recommended future steps for design include:

- Exploring the use scenario of not being at home
- Conducting in depth research related to the relationship and interaction with members of the cooperative
- Improving the existing prototype and detailing the existing business proposal

Vision

When looking at users, it is important to create personalized products, which therefore have a greater emotional value to the individual. This may lead to less consumption of meaningless items, which contributes to a sustainable future. By focusing less on consuming and more on living, people increasingly value positive experiences in life.

Apart from the personalization of single products, designed environments contribute to the wellbeing and positive experiences of individuals or an entire group. It is important to design these environments by providing shared products, services and ambiances that also offer personal experiences. Finally, technology plays a major role in achieving these personalized products and living environments. Self-learning systems can be valuable tools, as they can constantly monitor and adapt to the user's needs. Moreover, the creation of new materials and 3D printing can contribute to personal and innovative aesthetics.

Prologue

The report presented to you is called “Easton: finding a balance between supply and demand”. In this report, I, as a student of the Industrial Design Department of the Technical University of Eindhoven, will guide you through my project which involves the design of Easton. During the execution of this project, I was part of the DIGSIM squad, which stands for Designing for Growing Systems in the Home. I consciously chose to join this squad, as it focusses on connectedness and the smart home, which I consider to be a designed environment referred to in my vision. To me, the aspect of connectedness is important as different products can work together to create this personalized, yet shared experience.

The principles of the DIGSIM squad have influenced many aspects of my design process. For instance, Easton was designed in relation to a broader family of connected products, which have been designed by other students. Moreover, it was designed in the context of the smart home of the future, practically represented by a scale model.

Just as my process was influenced by the principles of the squad, it was equally influenced by my own vision. This particularly influenced my decision to choose the theme “Energy” as a starting point for my design. I chose this because of the role of renewable energy in creating a sustainable future, which is one of my vision's core pillars.

During the process, I was coached by Lenneke Kuijter, a leading expert in practice-oriented design, who provided me with useful advice and insights regarding design and energy consumption and production. I would like to thank her and other people who have helped me during this process. These people particularly include my friend Lisa Laugs, who advised me on design decisions, Rob van de Walle and Marcel Huijben. Lastly, I would like to thank other fellow students, family members and staff members from the TU/e.

I hope you enjoy your reading.

Doortje van den Bergen

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1. Introduction

Nowadays, there is a growing demand for electrical energy. In the Netherlands alone, the demand increased from 99TWh in 2000 to 109TWh in 2017 (Global Energy Statistical Yearbook, 2019).

Although this growth has been partly stabilized in Europe, there is still a growth in other countries such as China and Africa, where growing markets and increases in population create new demand. This growing demand is accompanied by the need for renewable energy sources. One of the causes of this need is rapid climate change. Well-known problems that arise are the sea-level rise and rising temperatures which endanger both humans and animals. To illustrate, National Geographic states that "sea levels are expected to rise between 10 and 32 inches (26 and 82 centimeters) or higher by the end of the century" (Global Warming Effects, 2019).

The general aim of my project is to stimulate the increased use of renewable energy sources and therefore to contribute to the prevention of growing climate change. To be more precise, I aim to help people to find a balance between energy supply and demand. In this

case, supply is energy generated by their own solar panels and demand is their actual consumption. This balance is important, as most people relatively use most electricity during the evening and morning. This is however not in line with solar panels' production, that produce most energy around noon. Due to this imbalance, people use most energy from existing energy suppliers, who take their energy from coal and nuclear plants (Roberts, 2018). This again negatively affects our climate.

In the following chapters, I will explain my design process which eventually led to the design of Easton. With this product, I strive to contribute to the beforementioned energy balance and therefore also to the increasing use of renewable energy sources.



2. Framing the design challenge

The Donaldson-Dvorak Family

Before diving into research and brainstorming, I tried to get a better understanding of my target group, for everyone in the DIGSIM squad designs for the fictional Donaldson-Dvorak family. This family lives in the house of the DIGSIM squad (a scale model of a smart home, see Figure 19, p. 19). Members of the family include parents David and Emily, children Gregory and Mimi and grandfather Bernie. To retrieve an improved comprehension of their way of living, I created a storyboard, outlining the

course of a typical day through the eyes of Emily. What I found, is that the family itself has a very busy day, with many moments of interaction (e.g. dinner and reading before bed). This information could come in handy when designing for a multi-user scenario.

STORYBOARD

6:30 Waking up
6:45 Showering
6:50 Dressing up
7:00 Getting children out of bed

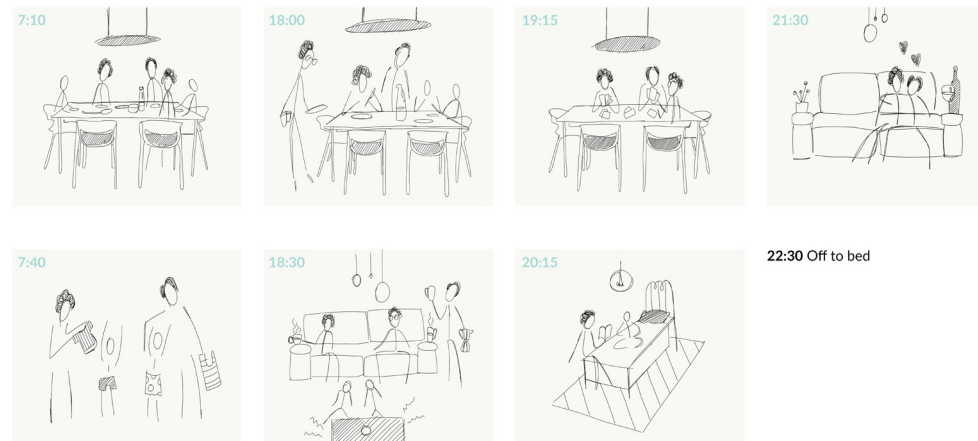


Figure 1. A typical day in the life of the Donaldson-Dvorak family

Trend analysis

To find interesting problems in the context of Energy that I could design for, I applied a trend analysis (van Boeijen, Daalhuizen, van der Schoor, & Zijlstra, 2014, pp. 58–59).

For this analysis, I identified several trends and classified them as being micro, midi, maxi or mega. The interesting design directions I found included urban farming, energy in transportation, energy storage, and geothermal energy. Moreover, I saw opportunities in making control systems more tangible, the social aspect of sustainability (e.g. co-responsibility related to sustainability) and connecting energy production to energy use.

Apart from sorting interesting directions, I made some observations related to products already on the market:

1. There exist many intangible control systems. An example may be Google Nest (Nest Labs, n.d.), a brand from Google, of which the portfolio consists of several connected products that help

- users create their smart home.
- 2. Most products that can be connected are offered by the same brand and when they are not, they seem expensive and primarily affordable by rich people.
- 3. A substantial amount of products related to energy management are focused on individual households, instead of on entire communities. However, co-responsibility in relation to energy could possibly stimulate the use of renewable energy at a larger scale.
- 4. Most products related to energy management focus on the house itself and not on its surroundings (e.g. energy consumption while gardening).
- 5. Products helping with monitoring personal energy use and production are often separated.
- 6. Privacy concerns may arise when proposing connected systems in general (Duffy, 2018).

Identifying different trends and observing existing products inspired early concept designs.

My first concept was based on the idea of urban farming (see Figure 2). It proposes a system which helps people in sharing their grown vegetables. An app shows people when someone's vegetables are ready and where they can pick it up. This concept is both beneficial to the community and the individual user itself. However, I highly doubted its link to energy, as there is merely an indirect link which includes saving energy for transportation of vegetables.

A second concept focused on managing the balance between supply and demand with the interference of energy storage (see Figure 3). This concept means showing users the amount of energy that is left and what amount is being stored. When using a product of the smart home, such as a dishwasher, a block should be filled with energy. In this way, only the available energy can be used. An advantage of this approach would be that people gain more insight into the consumption of each device they own in relation to their production. However, a disadvantage would be that its main focus is awareness instead of it having a more practical functionality.

Lastly, I made a few smaller concepts which firstly comprises a system which creates personal consumption profiles for all family members (see Figure 4). Members get a so-called "energy budget", which they can use for whatever device they would like to turn on. Another concept consists of an app which lets people order packages together to save transportation energy. The final concept is a system which shows the performance of the entire neighborhood in relation to the usage of renewable energy.



Figure 2. Concept based on urban farming

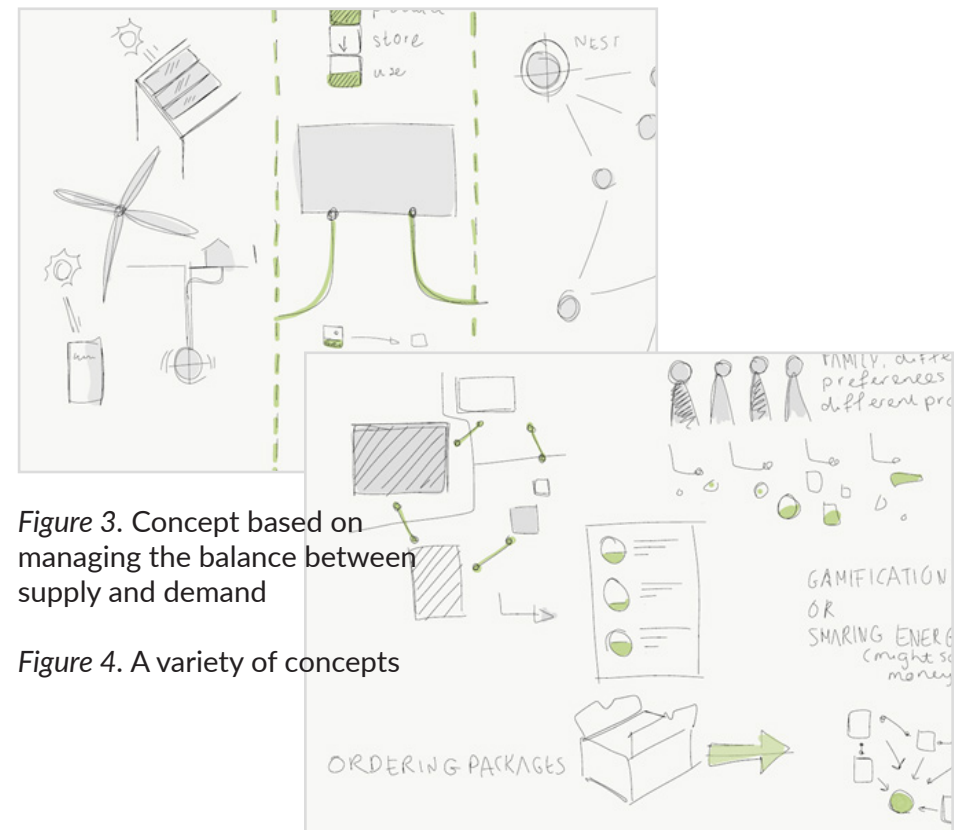


Figure 3. Concept based on managing the balance between supply and demand

Figure 4. A variety of concepts

3. Concept 1 – purchasing and disposing appliances

After evaluation of the aforementioned concepts, I decided to come up with several others. A concept I chose, which was partly based on the second concept (see Figure 3), was that of a device which helps the user to make choices related to purchasing and disposing of energy consuming appliances. On a bigger scale, it helps to decrease a household's energy use and the community's general one.

The weighbeam

The first concept I created, is that of a weigh-beam which shows the balance between the energy consumption and production of all devices or generators in the house. All devices and generators are represented by a token. This token can have two different shapes, depending on whether it represents an energy consuming device or a generator. To see the energy consumption and production of all devices and generators, you simply add all tokens to the weighbeam. When a user prefers to add a product, such as a second TV, one can just place a new token on the beam. The balance will then be recalculated and the device

will suggest some other alternatives. This would, for instance, be not to buy a new TV but to buy one from a neighbor. With this suggestion, the device also calculates the amount of money and energy one would save.

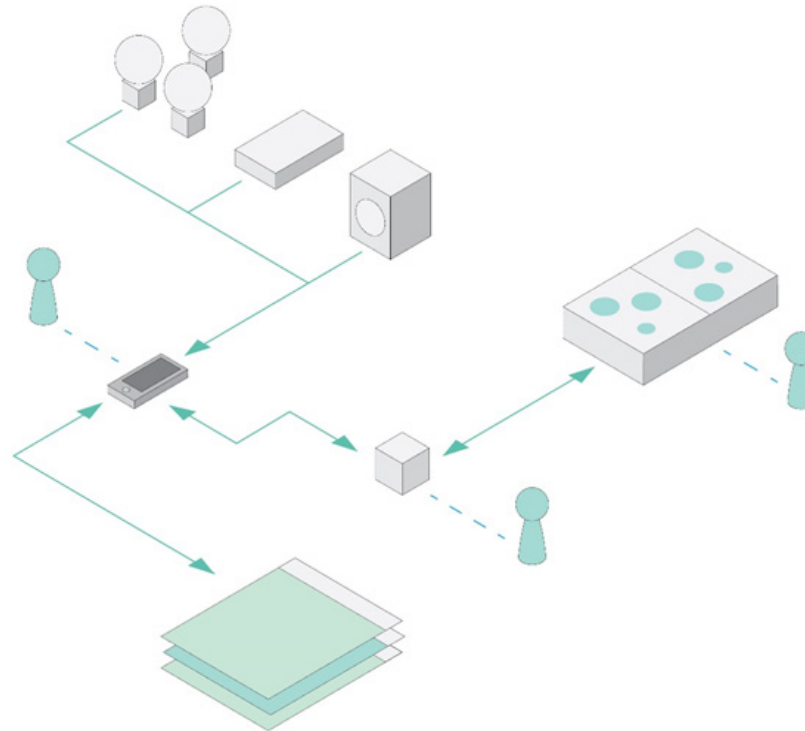


Figure 5. The weigh-beam as a part of a connected system

A connected system

In Figure 5 one can see a graphical representation of the concept and its connections to other concepts. I made a distinction between other physical devices, users and digital concepts. Users are represented in blue and see where and when they are involved helps to get an overview of which design aspects need validation. The green arrows represent data, flowing from one concept to the other. To illustrate, one can see that there is a green arrow between the phone and a washing machine. This means that data from the device is captured by the phone. In the first concept, this data would be related to the energy consumption and specifications of the washing machine. One can represent this washing machine by connecting the token to the phone, which contains this data. The data from this token is then again processed by the weigh-beam. In short, data from devices flows to the weighbeam by passing a phone and a token. The reason why there is a phone involved is that people often already own apps that contain consumption and specification data from there devices and generators. By combining this data with data from the web, an

algorithm could recommend the best alternatives related to purchasing and disposal.

on whether it is sustainable or not. Therefore, it would be very hard to influence people's buying behavior.

Evaluation

To evaluate my first concept, I asked several questions (see Appendix A). It appeared that the concept would be too complex when focusing both on a balance of energy and on the purchase of appliances. Motives for buying a device are not solely based

4. Concept 2 – Managing the energy balance

After receiving more feedback on the previous concept, I decided to proceed with the concept of managing the energy balance. One of the things that were mentioned during a feedback moment, was that going for a weighbeam would exclude the exploration of other concepts that could be more suitable. Therefore, I also sketched other ideas related to balancing energy. Out of these ideas, I chose the five most promising concepts.

1. The seesaw

The first concept is quite similar to the concept of the weighbeam. However, the concept of the weighbeam might cause some conflicting interaction styles. A question that was raised was how people would interpret the going down of one of the platforms after the placement of a new device. Some might interpret the going down of a platform with consuming devices as them being more energy consuming, while this might be different for the platform with producing devices.

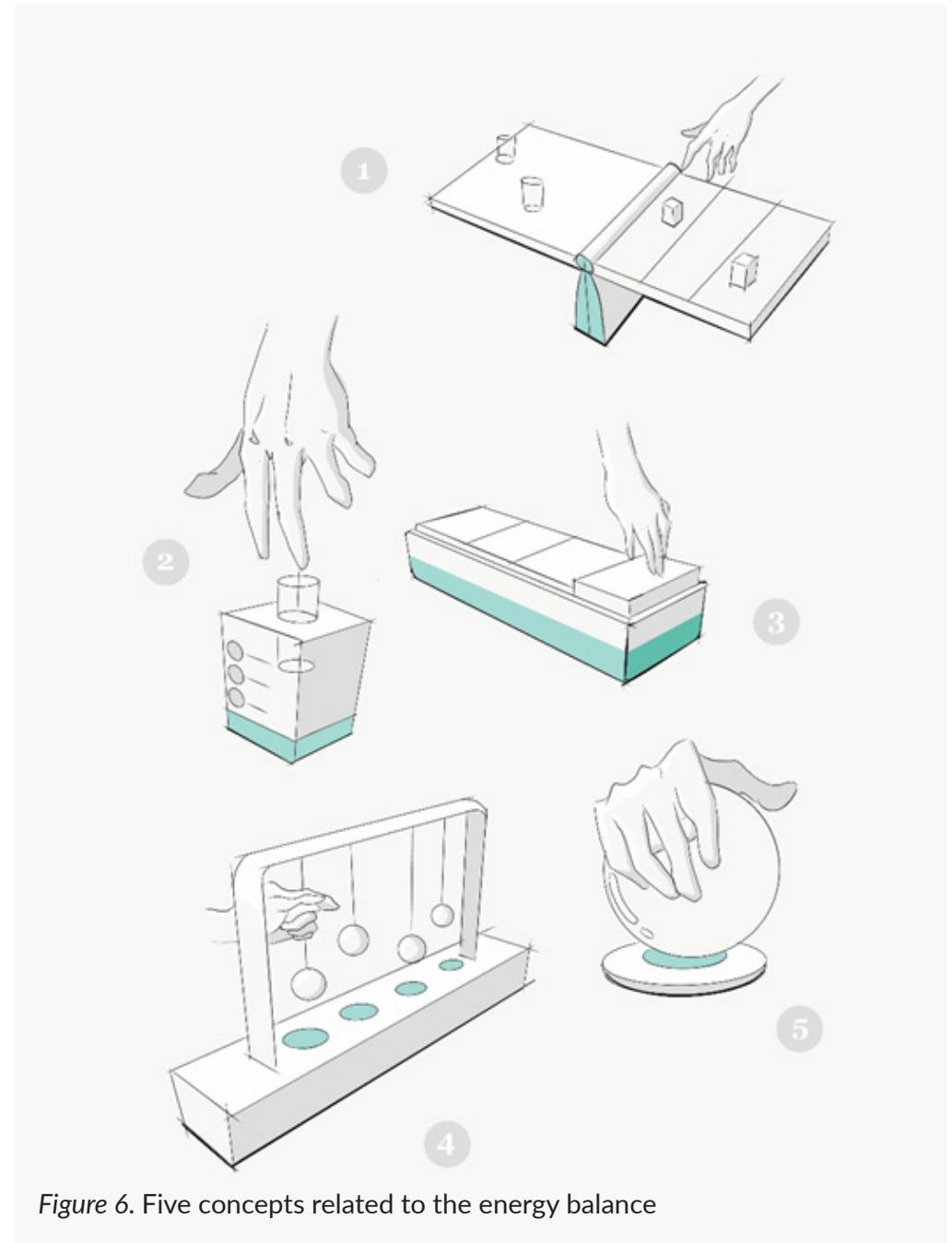


Figure 6. Five concepts related to the energy balance

The seesaw concept does not cause a conflict, as the movement of the platform means the same for both consuming and producing devices. Namely, the going down of the platform for energy consuming devices means that there is more energy consumption than energy production. For the platform for energy producing devices, this means that there is more produced than used.

On the platform of energy producing devices, there exist different zones. One of the zones is defined as the 'off-zone' where devices are placed which are turned off. The middle zone is defined as the zone for devices which are on the hold, meaning that they will be turned on at a later moment of the day. The outer zone is meant for devices that are turned on, and therefore cause the biggest perceived difference in energy consumption. The platform for energy producing devices does not include zones, as these devices are always turned on.

2. The energy sharpener

Based on the idea of a pencil sharpener, I came up with an 'energy sharpener'. In this case, energy is represented by a rod. When using more energy, this rod will go down

into a cube. The sides of this cube are screens, which display this amount of energy used.

3. The energy dock

This idea was based on the concept of a bowl of water. When wanting to turn on a device, one places one of the cubes (representing an energy consuming device) into the container. The energy level is visualized on the sides of the container and drops as a new device is added. When energy levels are low, the container will get smaller. This happens through platforms filling up the empty spaces of the container. When one wants to insert a new device, one has to simultaneously push down the platform. This creates more of a barrier for turning on devices that consume too much energy. When wanting to turn on the device at a later time, one places the device on the platform. When the time is right, the platform will come down and the device will turn on.

4. The energy strings

Different tokens represent different energy consuming devices. One can simply add a device to the system by hanging a new device onto the beam. In rest, a device will be attached to the beam. However, when turning on a device, you pull the token down.

The token will then slowly come down, as its heaviness is linked to its energy consumption. Simultaneously the energy levels represented on the sides of the supporting beams will drop. When energy levels are low, it will be harder to pull down a string and therefore to turn on a new device.

5. The energy ball

For this concept, a ball represents a device. When a device is turned on, the ball will start to shake. After a while, this ball will stop shaking and starts shaking when a new device is turned on. When wanting to turn on a new device which uses too much energy, the ball will start to give an alarming signal (by making sounds or emitting light). One then actively has to decide whether he or she wants to turn on the device. This can be done by shaking the ball for turning it on or by pinching for maintaining its turned-off state. The interface, on which the ball rests shows how many energy is lefts and which devices are turned on.

Evaluation

By making these ideas physical, I intended to gather opinions related to their desirability and interaction styles. This would be easier if people could actually interact with them and discuss them in a real environment. To make these ideas physical, I created five prototypes from foam core, which can be seen in Figure 7.

Feedback

I asked a total of seven people about their opinion and preferences regarding the five concepts (see Appendix B). For this interview, I explained each concept individually and informally asked what they thought about:

- The clarity and intuitiveness of interaction.
- The desirability (whether they would want to put the effort into interacting).
- The different restrictions of each concept. For instance, some concepts show the energy use of individual products, while others do not.
- What they would like to see regarding the balance of energy (numbers or more abstract measures).

Balance

Most people said that they would not want to see their energy balance in actual numbers but in a more abstract way. Some mentioned percentages, others said that they liked the concept of an energy bar that becomes smaller or bigger.

Threshold for interaction

People might not want to replace tokens themselves each time they want to turn a device on. Therefore it might be hard to use physical tokens when having many devices. However, some participants said they would not mind if you need to do this once for all devices (for turning on or off a device). For many devices, it would be better to automatize the planning and on and off states.

Turning the device on at one place might not be that much of a problem as one is often walking around anyway. So putting it in the hallway could be working (depending on the layout of the house).

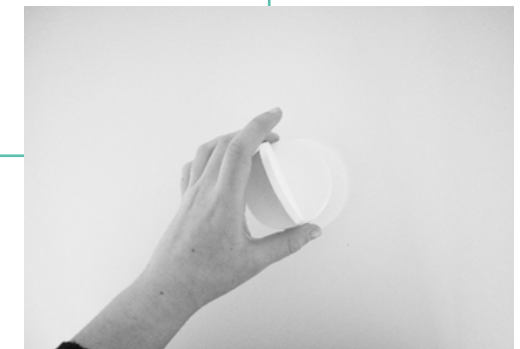
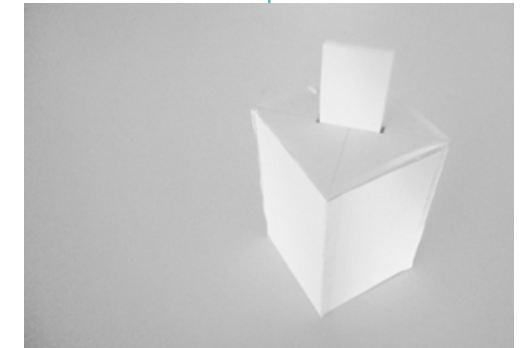
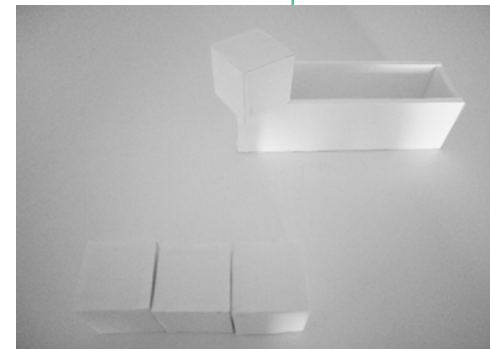
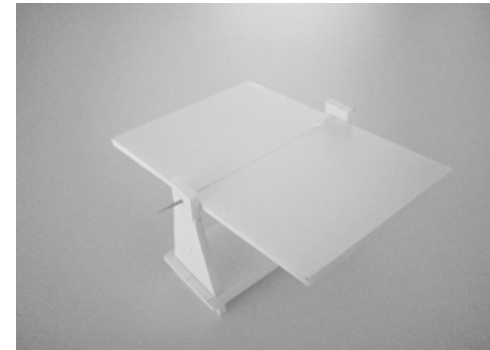


Figure 7. Foam core models of the five concepts

5. Concept 3 - Energy sharing through neighborhoods

A critical note regarding the planning of devices made me rethink my design approach. Moreover, I shifted towards designing for the community instead of for just the individual.

In the first place, this was due to the fact that this would make my product more distinct from other products already on the market and because of an interesting business opportunity.

Profitable energy sharing

The opportunity I found was to have people share the energy they have produced by means of solar panels. This way, people without solar panels can still use renewable energy sources and people with an oversupply can easily share their energy at a price that is beneficial for both parties (See Appendix C). Currently, this business strategy was based on the Dutch market. To illustrate, one can sell one kWh for €0,16 and pay €0,02 for transportation (“Tarieven voor transport energie stijgen met 1,5 euro per jaar”, 2018). This way, the neighbor saves €0,23 (average pricing)-€0,16=€0,07/kWh. The seller could earn €0,16 - €0,02 = €0,14/kWh . People can approximately trade a maximum of 70% (Schoenmakers, n.d.) of their energy, which is $2,11 \cdot 102$ kWh/month with 8 solar panels. This would mean that they earn €29,54/month. Takers can save €14,77.

Energy cooperatives

After the creation of a business plan, I discovered the existence of so-called ‘energy-cooperatives’. The American MJM Electric cooperative describes such

an organization as being “operated by and for people of the community. Its goal is to provide reliable power, not make a profit” (“What is a Cooperative? | MJM Electric Cooperative,” n.d.). In the Netherlands itself, the number of cooperatives has increased from 85 to 484 in 2018 (Hier Opgewekt, 2018). This number is expected to increase even further.

Although money is one of the motivations to join an energy cooperative, there are two others involved. One of these includes taking part in the energy transition by using renewable energy sources. Moreover, there is the wish of becoming independent from existing energy suppliers.

The duck curve

However, one problem I noticed and which is by science referred to as the duck curve (PredictEnergy Marketing, 2018), might become a problem for cooperatives relying on energy generated by solar panels. The duck curve describes the consumption of energy throughout the day. In the morning and evening this consumption peaks, whereas it is lowest around noon when most energy is generated. Therefore, people with solar panels rely on energy from energy suppliers. They retrieve this energy from power plants, which again threatens the energy transition and the principles of the energy cooperative. Creating a balance between supply and demand throughout could help solve the problem of the duck curve.

Another aspect threatening the principles of the cooperative is the abolishment of the supply-side price arrangement by the government. This means that people will not receive or receive less money when giving back energy to the supplier in case of a personal oversupply.

Concept 3.1 – Energy cubes

Originally, I was inspired by solving the problem of the duck curve and my idea of energy sharing.

Therefore I came up with a first concept, consisting of different boxes and an application. I thought of different boxes visualizing the energy balance from different houses connected to the cooperative or neighborhood. When having an oversupply, one could press on top of one of the blocks and consequently give an equal amount of energy to all houses with an energy deficiency (see Figure 8).

I choose to equally distribute energy, as this would diminish the chance of conflicts between neighbors.

Apart from the boxes, I designed an app which displayed data related to paying and the network itself. My main motivations for this type of design were first of all the modularity: there was a quick overview of all houses in the community and houses could easily be added. Moreover, there was a social aspect involved in giving energy and sharing blocks with each other. This could

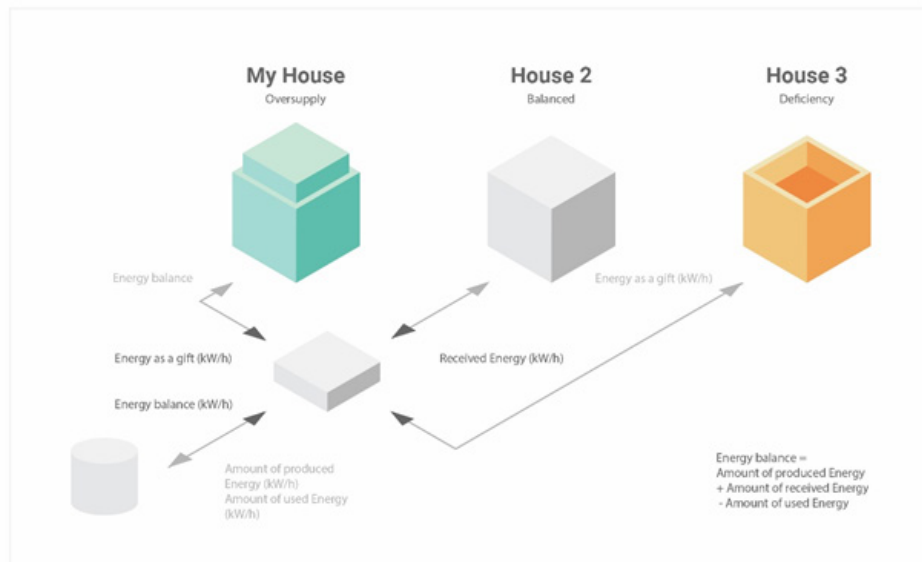


Figure 8. Explanation energy blocks

possibly enhance the feeling of co-responsibility and cause people to live up to the cooperatives principles. Finally, an app would make it easier for people to get a detailed overview of their spending and create a platform for joining the cooperative.

Evaluation

After creating this first design, I had some doubts related to the concept. First of all, I thought of privacy concerns, which I already mentioned in Chapter 3 as a possible burden for using connected systems. What is evident, is that this concept shows the energy balances of different

houses, which may cause rivalry and slander. In the end, I received other feedback, pointing out problems related to the interaction and purpose of the design (see Appendix D). Important considerations included:

1. *Whether or not to fully automatize the process.* The concept proposes interaction with energy, however, as notices earlier in Chapter 4 people do not prefer to interact with a device throughout the entire day. Therefore, frequent interaction could decrease the product's usability.
2. *The value of a physical interface.* The physical interface that

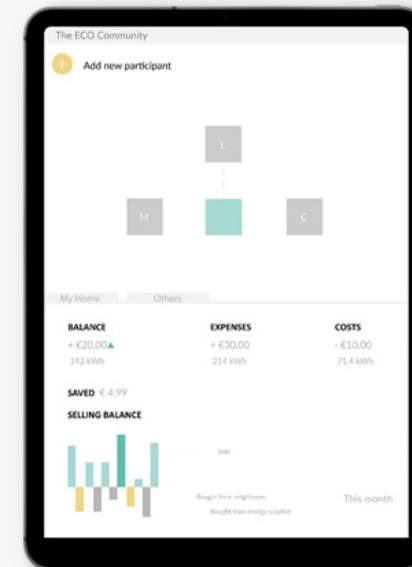


Figure 9. App displaying data about paying and the network

I proposed is not adding functionality that could not be reached with a digital interface. On the one hand, however, this interface does increase the presence of rich interaction, as proposed by Joep Frens in his paper "Designing for rich interaction: integrating form, interaction, and function" (Frens, 2006). On the other hand, there is a risk that this type of interaction does not outweigh the costs and non-functionality of a physical prototype.

3. *How to involve neighbors.* I thought of involving neighbors by asking them in person and by exchanging energy blocks. However, the complexity of this interaction had not been fully explored yet and was not yet integrated into the concept. In addition, the interaction does not merely include one-to-one communication. It does also include other neighbors that have to agree upon taking new members and representations of new houses.

Concept 3.2 - The arrow

The previous evaluation lead me towards a new concept, namely that of the arrow.

Aspects that I tried to improve were the usability of the physical product, the interaction with neighbors and the automatization of the energy exchange. In conclusion, I looked into the differences in interaction between working at home and working elsewhere. To communicate the concept of the arrow, I created a storyboard which highlights important aspects of the arrow's use. Simultaneously, I created a name for my product, Easton, and I created a logo fitting the brand identity I already applied.

Prototyping

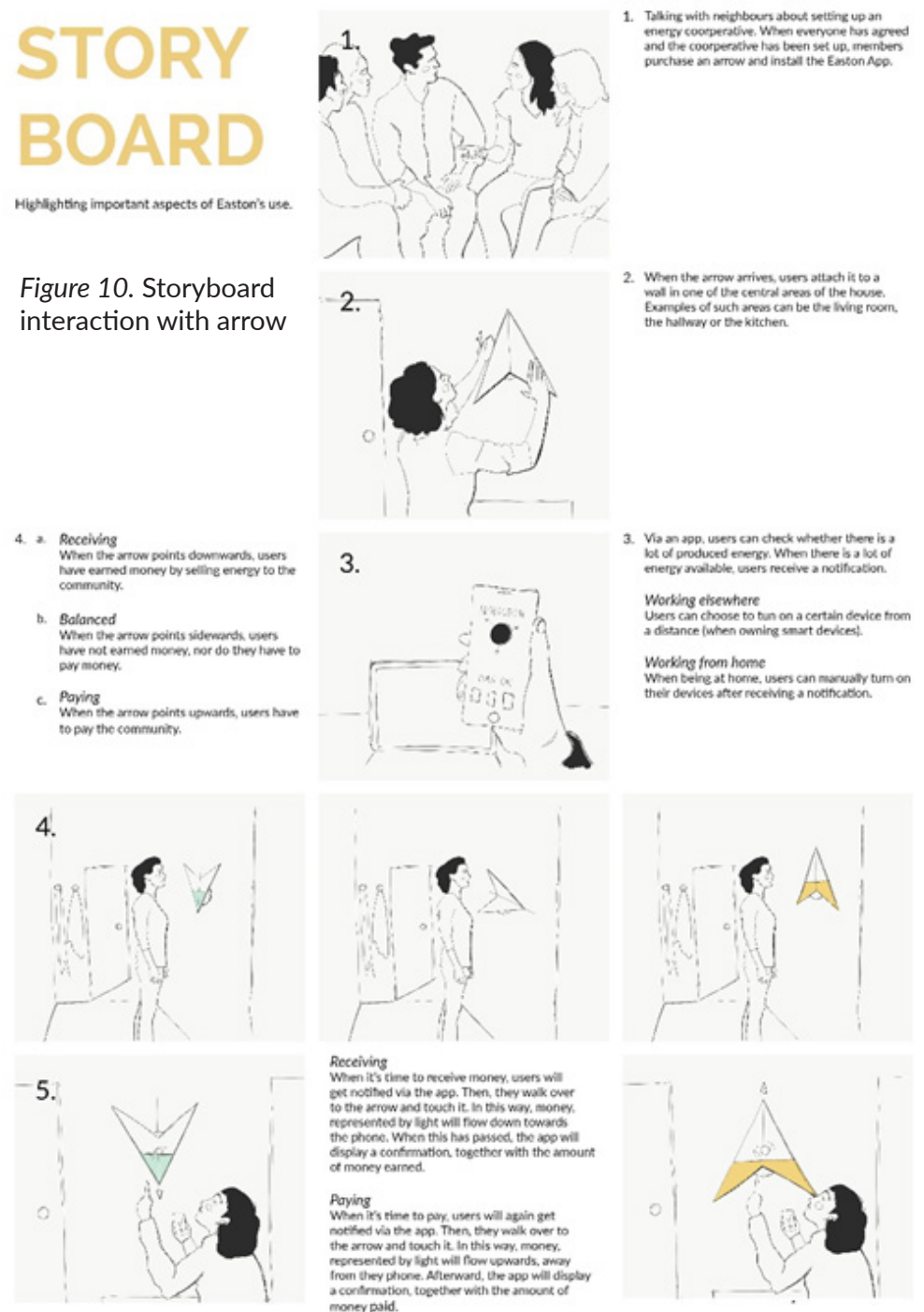
Focus

To prototype my concept, I focused on the scenario of working at home. This was due to the fact that I would deploy my prototype in a real-life setting during the period of one week. During this deployment, my prototype would be connected to Flow, a product designed by fellow student Lisa Laugs. This was due to the fact that she could provide me with data about energy consumption, whereas I could provide her with data about production. Flow, however, lets people turn on devices by providing it with a limited amount of energy made physical by marbles. As this would conflict with turning on devices at a distance, it would be better to test the working at home scenario first.

STORY BOARD

Highlighting important aspects of Easton's use.

Figure 10. Storyboard interaction with arrow



Creating

The prototype that I created for the deployment was that of the arrow and of an application. The application provided people with a more detailed overview of energy consumption and production, whereas the arrow provided them with information about the type of energy that was being used (from the net, the community or from

the user itself). Simultaneously, it served as a means for communicating with the neighbors. This is different from the interaction described in the storyboard, that focusses on payment. I changed this interaction, for I thought that enhancing the aspect of co-responsibility would be a bigger motivation than the aspect of awareness through paying for energy.



Figure 11. Prototypes energy blocks



Figure 12. 3D-printed servo attachments



Figure 13. Deployment of the arrow in hallway

A servo turned the arrow around and set it into three different states: 0, 90 and 180 degrees, representing taking energy from the net, the community and the user itself.

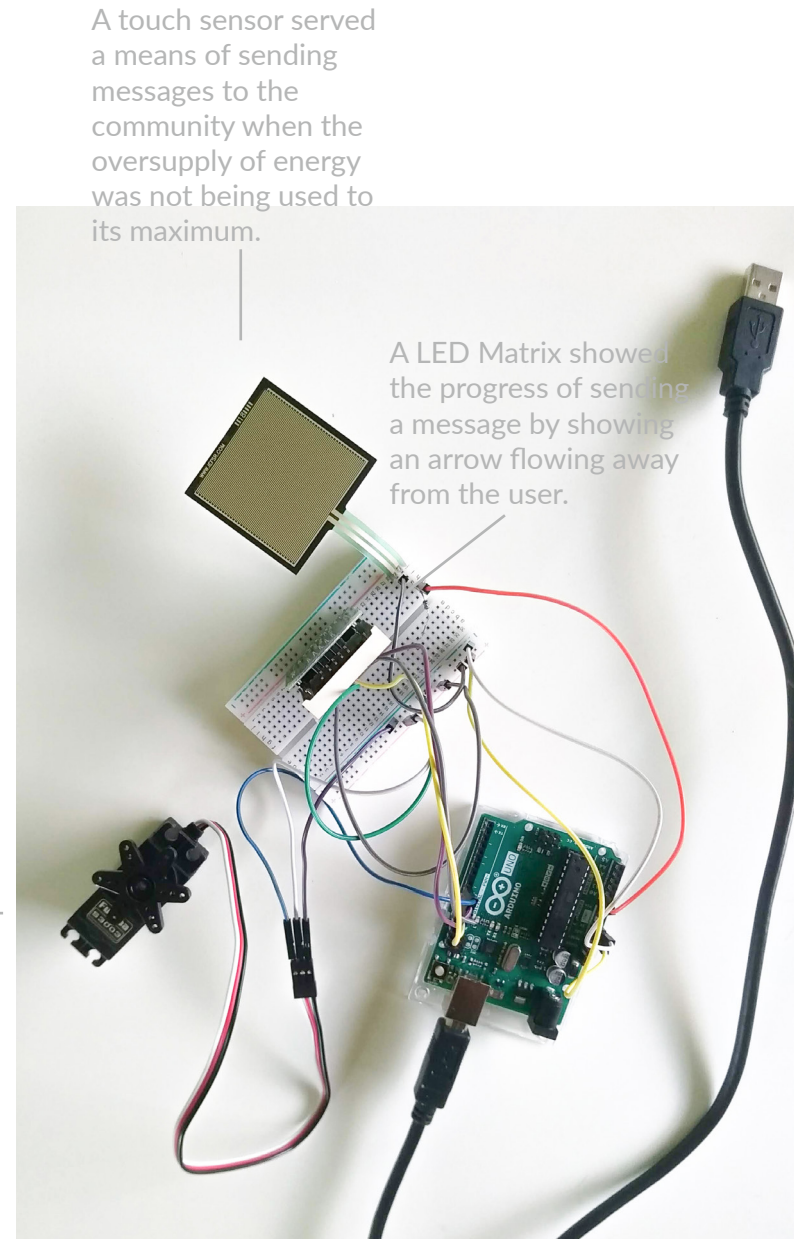


Figure 14. Electronics of the arrow

Deployment

As mentioned before, Flow and Easton were both placed in a house during the period of a week. Easton was placed in the hallway, as this is one of the central places of the house. For the deployment, my main question included:

Can the designed system influence users to use more energy when it is available (from themselves and the community)?

This question refers back to solving the problem of the duck curve (mentioned in Chapter 5) by creating an energy balance through stimulation of using energy when it's available. My sub-questions included:

- Does a shared responsibility with the community influence the times at which users turn on devices? Does seeing the community's results contribute to this feeling?
- Does money influence the user's willingness to turn on devices at the time energy is available?

These questions were meant to validate my assumptions that money and co-responsibility could influence people's behavior of turning on devices at times when energy is most available.

Results

To retrieve answers to my questions, I conducted a small interview beforehand and a bigger one afterward. After the translation of these interviews, I performed a thematic analysis (The University of Auckland, n.d.), leading to several findings (see Appendix E). Some of these findings supported the design decisions I made, while others were somewhat contradicting. An example of a finding which was contradicting would be that users think they are doing great when having an energy surplus every day. However, they do not realize this is not great if they do not use it at the right times. A rather supporting finding might be that the physical presence of the arrow is indeed necessary because people tend to look at the app only one to three times a day. They do however check the arrow multiple times when passing by, which also confirms the placement in the hallway. A final finding would be that there are indeed people that plan the turning on of their devices by setting a timer. This supports the idea of turning on devices around noon.

Concept 3.3 - Easton

Based on the results from the deployment, I refined my concept. Due to a tight time schedule, I decided to focus on mainly improving the physical product. However, the application itself also needed some adaptations (see Figure 17, 18,19, p. 18), that will be described in Chapter 7.

A new prototype

One of the aspects of the deployment prototype that proved to be most unsuitable would be the arrow. Since it has only three states but is able to point towards angles in between, it is not clear what is meant by the states in between. Nor is it clear what its scale implies. Therefore, I thought of making this clearer by creating three separate hexagons, that each represents the available and used energy from both users, the community and the energy supplier.

A visual hierarchy should show the user that the energy of the energy supplier, which is located lowest, is also the lowest type of energy.

Moreover, the brightness of the lights is easier to interpret than the changing angle. For users, it would also be easier to identify an unused surplus of energy. Now they can notice a high brightness of the lights corresponding to their module.

A final adaptation I made, was to create certain modularity, giving users more control over energy sharing and using. This includes two separate modules and one attached one (see Figure 16), which lets users decide whether they want to use the energy from the supplier and the community or not. In this way, users can choose to have extra sustainable settings, implying that they can only use the energy from the modules they inserted. However, after evaluation of my prototype, I think that the module of the community should better also be attached, as there are no disadvantages to being connected to the community.

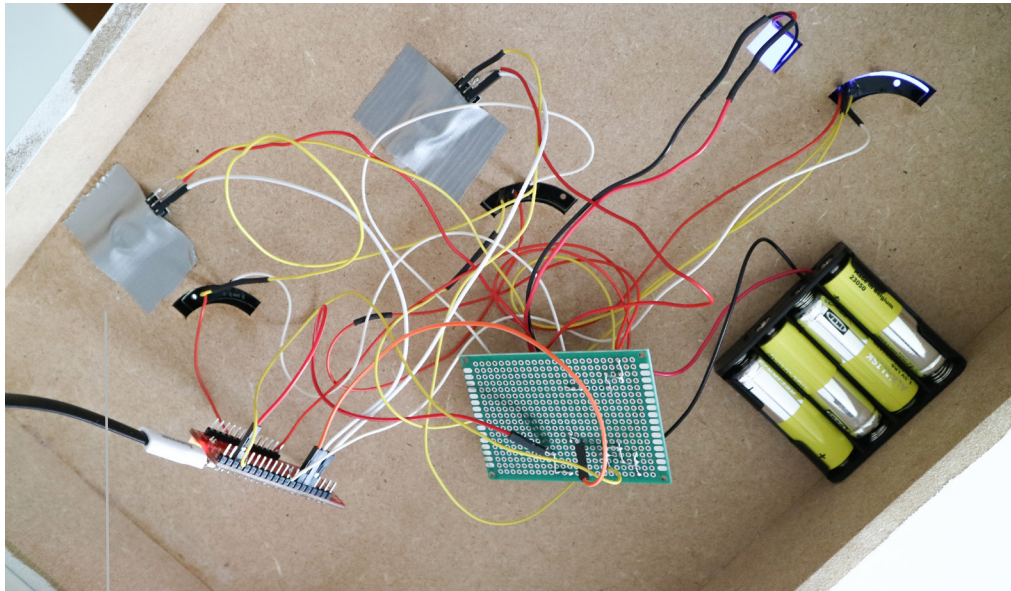


Figure 15. Electronics of final prototype

Brightness of LED ring shows the amount of energy left from a certain category

Figure 16. Final prototype of Easton



Infrared sensors detect the presence of modules

Pressure sensor acts as a button for sending messages to the community when there is an unused oversupply



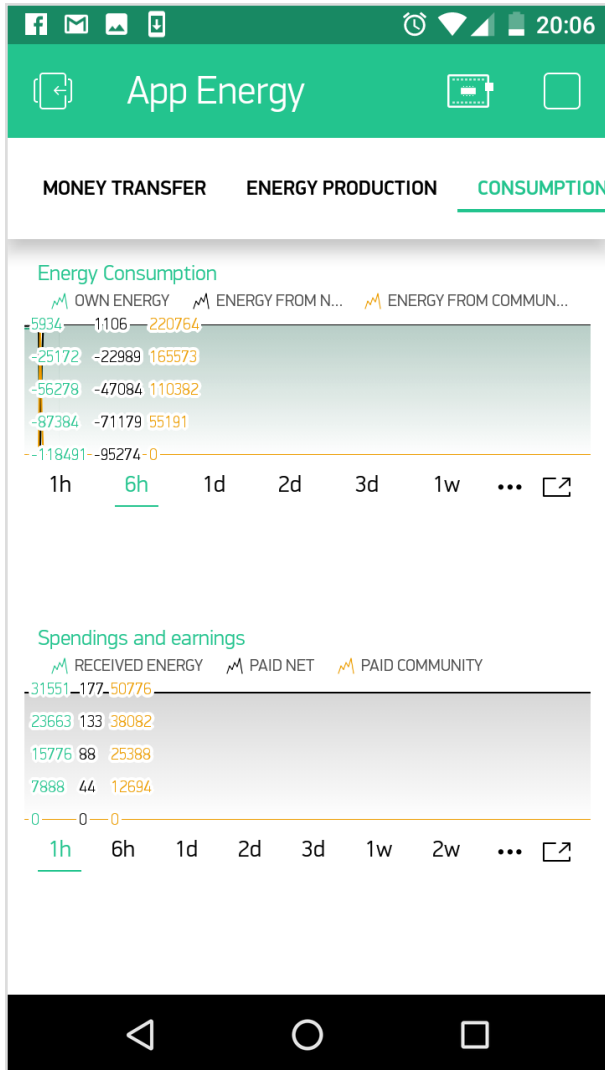


Figure 17. Initial overview of the spendings and consumption in the arrow app

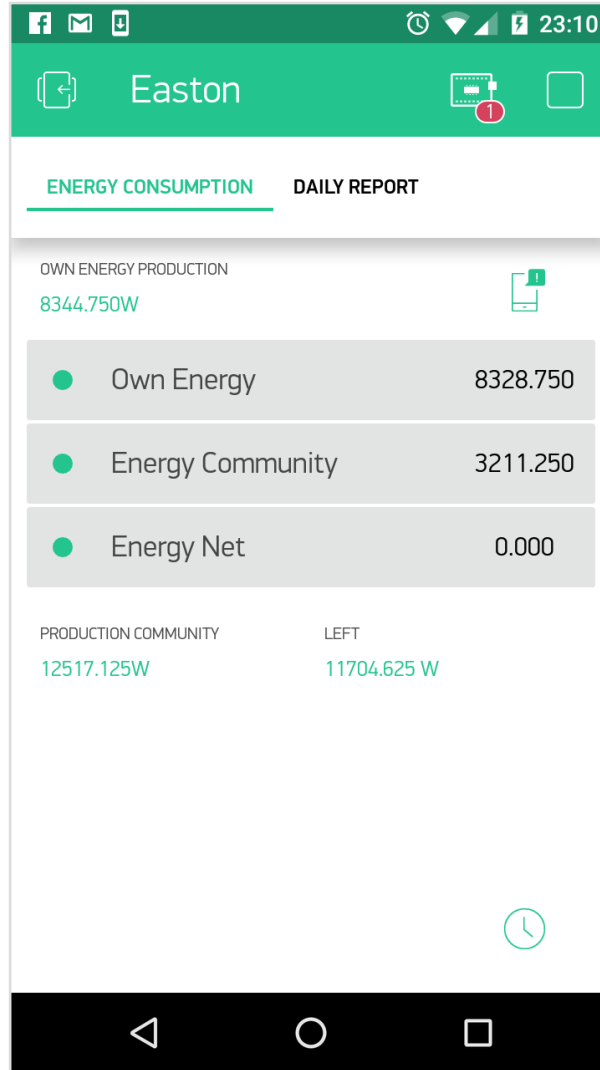


Figure 18. Overview of daily consumption in the final app

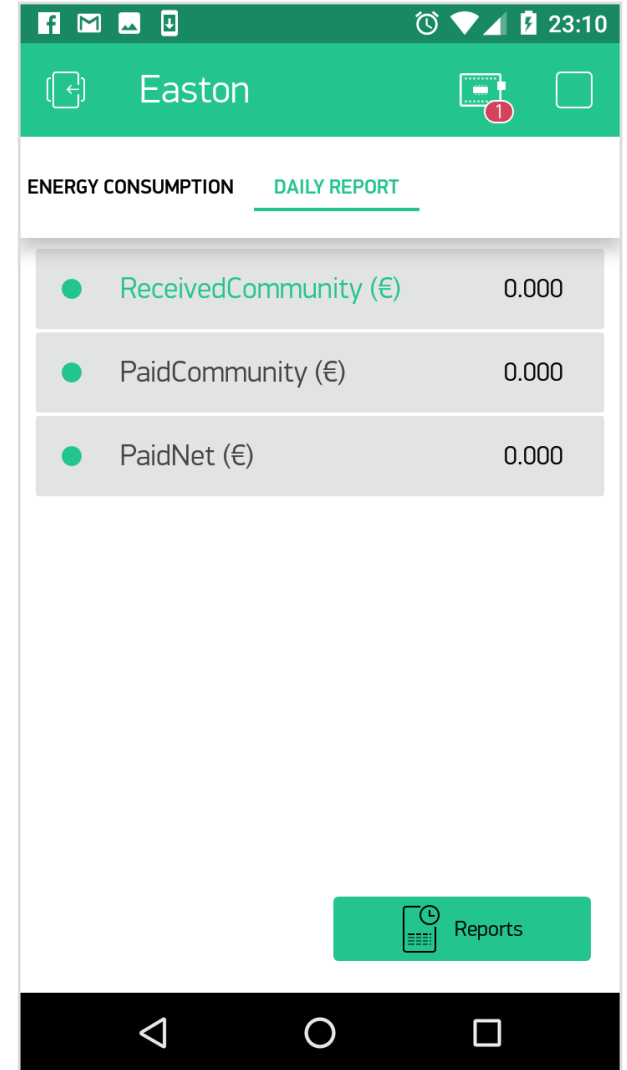


Figure 19. Overview of daily spendings in the final app

Connection to the DIGSIM house

As one can see, users are, via the physical product and application of Easton, connected to other people in the cooperative. Easton itself is again connected to several appliances of the smart home. To illustrate, the scale model of the DIGSIM house was used. Inside the house, several appliances were connected to Easton and showed an increase in energy use when they are turned on. Simultaneously the brightness of the module representing the user's own energy was represented by a red light, placed at the location where Easton would normally be placed: namely in the kitchen, a place where people often pass by. The implementation in the DIGSIM house showed that Easton can work well with other connected products of the future, but that network problems can make the current system quite vulnerable. Without WIFI, energy balances are inaccurate, and so are money calculations. The implications will be further discussed in the next chapter.



Figure 19. DIGSIM house displaying state of connected products (Boxtel, 2019)



Figure 20. Devices (e.g. cookingplate) that can be turned on by swiches (Dijken, 2019)

Easton

Easton's aim is to help people to balance their energy supply and demand. This supply can be retrieved from self-generated, renewable energy sources, such as wind and solar energy. To motivate people, Easton offers them the opportunity to share their energy with neighbors. Because of co-responsibility, neighbors can motivate each other to use energy at the right moments. Moreover, taking part in such a neighborhood decreases dependence from big energy suppliers. Finally, sharing energy with neighbors has the advantage of saving and earning money.

Easton supports the notion of co-responsibility by offering a way of interacting with neighbors. By touching one of the hexagons, they can notify all neighbors when they have an oversupply. They can also send messages to each other via the Easton app.

To create more awareness about the energy balance, the physical product shows how much energy is left and used from the owner, the neighborhood and the net. Moreover, a more detailed overview can be accessed via the app. The app also provides an overview of the money that has been received or that has to be paid.

6. Discussion

Design process

The previous chapters have taken you through the design process, leading to Easton. It developed from a concept focused at purchasing appliances to one focusing on balancing energy supply and demand.

Throughout the process, I evaluated all concepts and created new ones accordingly. One of the key moments of evaluation included the deployment, during which the prototype of the arrow was presented. The interview, meant to evaluate my main question, subsequently led to the final design of Easton.

Implications

The main aim of Easton is to help people to balance their energy supply and demand. Currently, the prototype consists of the application and the physical product. After evaluating my concept, I found that the presence of a physical product is key to remind people of their energy supply and demand. Moreover, I found that both money and using renewable energy sources were indeed motivations to use Easton.

Another aspect supporting my design decisions was that messaging neighbors was found to be a convenient and contemporary way of communicating with neighbors.

One of the biggest implications of my design would be the behavior change people should experience. Only this way the underlying target, diminishing the problem of the duck curve, will be reached. I do think that Easton could reach this target when being fully realized, but one should keep in mind that not all people will be able to change their behavior. This is due to the fact that use of Easton already requires some effort from the user itself and a willingness to do well for the environment. Nevertheless, I do think more people will fit this target group when the consequences of climate change will be increasingly observable. Moreover, increasing energy prices could stimulate the need for being independent of existing energy suppliers.

Limitations

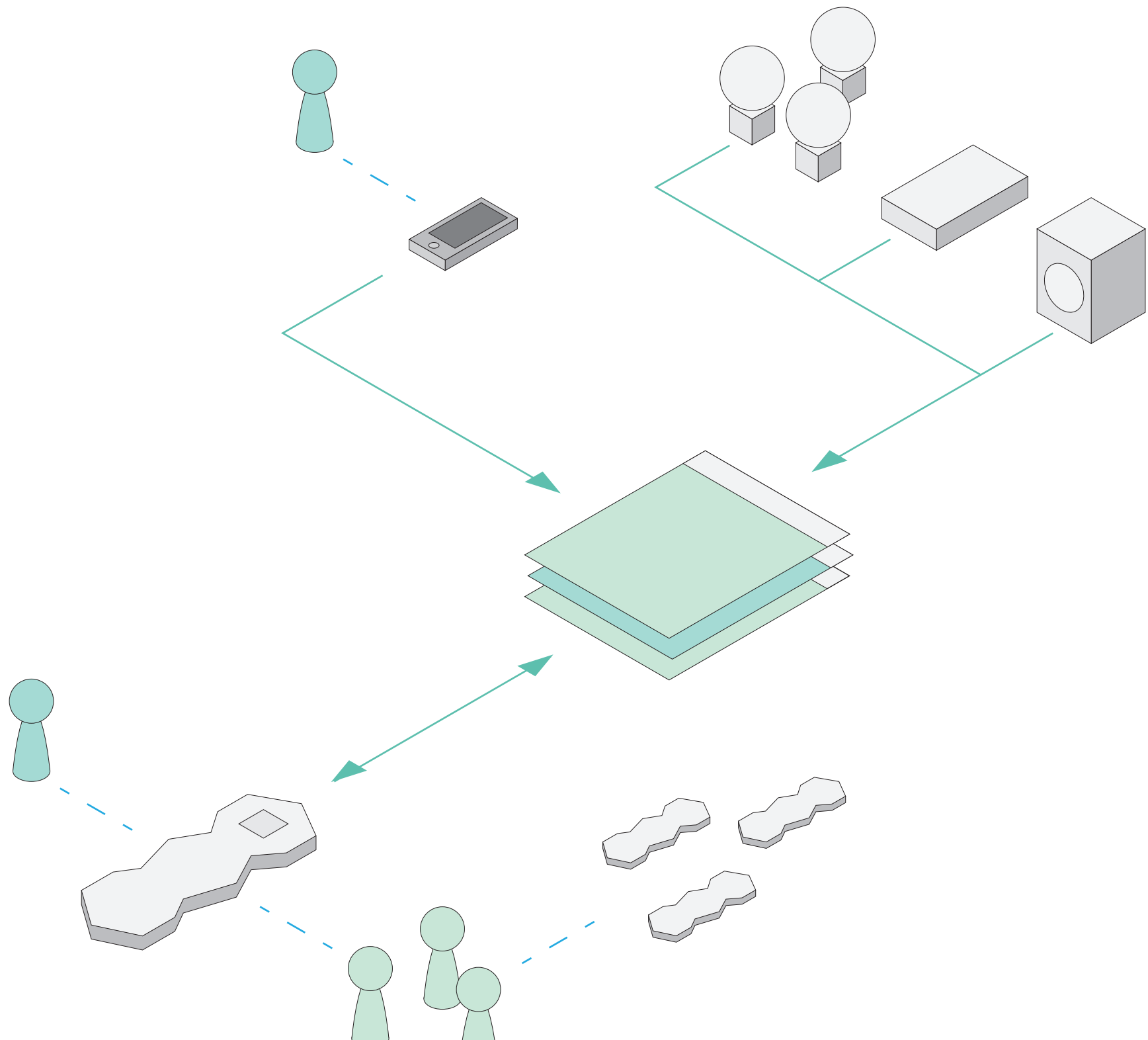
Concept

Things that have proven to be limitations of my design, is first of all that I designed for a spliced

scenario. As explained in Chapter 5, I only designed for the scenario of people working at home, and not for the people that have a full-time job. Another limitation of the design would be that some devices are hard to turn on at any preferable moment. An example might be the cooking plate. It is highly unlikely that people will shift their behavior to cooking warm meals around noon instead of in the evening. However, this limitation may not be disastrous for the implementation of the design. There are ample of other appliances that could be planned or turned on at a preferred time. Examples include the dishwashers, washing machines, all automated devices (e.g. automated vacuum cleaners and grass mowers) and finally the act of charging devices. With the rise of automated devices in relation to the smart home, the planning of devices will become even more applicable.

Realization

One of the limitations of my prototype is that it is not possible to plan devices when not being at home. As mentioned in Chapter 6, there is also unnecessary modularity of the tile representing the energy of the community. Another limitation may be that the current prototype is only



suitable for people that are producers themselves. People that merely take energy from the community, will not need a tile representing the energy they produced themselves. Finally, there is a limitation related to the connectedness of the system Easton partakes in. In Chapter 6, it was explained that WIFI connections could disturb the connectivity of Easton.

Future Steps

Both implications and limitations have consequences for the future steps that need to be taken in order to make Easton a product which is market-ready.

Prototyping

For the prototype, a future step would be to research the scenario in which people are not at home. One idea that I already visualized for this scenario is to have an app feature focusing on the planning on devices. When being away, people could set a timer for all their devices. However, it is not clear whether this feature will equally influence the behavior of people turning on devices around noon. Moreover, I earlier observed that people only look at the app once or twice a day. Without the physical

product, people are not always aware of the right moment for turning on devices. Hence, I would recommend developing a tool to catch the awareness of people without further interrupting their workflow. A possible design direction could be to test a smaller version of the physical prototype which can be placed on a desk.

Another step which could be taken is to improve the physical product itself. At the moment, it consists of a box with a hive structure attached to it. As a final product, I imagine it to be a magnet board, to which modules could be attached. After attaching, a light in the module itself would light up. This way, the LEDs are invisible and redundant properties are reduced (such as the structure). Currently, the light from the LEDs is also excessively blocked, which could be reduced by having modules that are more translucent. An example of a product closely related to the product after the execution of the proposed changes might be Helios Touch (Trailblaze Media, n.d.).

Lastly, a limitation mentioned before was related to connectedness. I would recommend improving this by using Bluetooth as a backup when WIFI fails. Moreover, one could consider using a cable to connect the physical product to the net.

Business plan

For now, the business plan mainly consists of the concept of trading energy with neighbors. I have considered interaction with neighbors (see Figure 10), but this could be researched to a greater extent. Directions to look into are already existing platforms for creating and joining cooperative, via which cooperatives using Easton could possibly be established. By collaboration with these platforms, Easton could also be offered to already existing cooperatives. Finally, one could further look into the different channels that come in play when bringing Easton to the market. Furthermore, one could think about a branding strategy and way of efficiently producing Easton.

7. Conclusion

This report outlined the several steps that have been taken to arrive at the final design of Easton. During one of the most important validation phases, the deployment, I aimed to validate my main question:

Can the designed system influence users to use more energy when it is available (from themselves and the community)?

When fully developed, Easton will have the potential to indeed influence users to use more energy when it is available. Findings supporting this statement, include the positive reactions related to the physical product itself and underlying motivations, namely the earning of money and the use of renewable energy. Moreover, Easton's target group, people timing the use of their devices, is quite realistic, as illustrated by the deployment. Although Easton could indeed influence users to use more energy when it's available, future steps should be taken to create a product fitting all scenarios. These steps may include paying more attention to a business plan and to the prototype itself.

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Appendix

A. Evaluation Concept 1

System design

1. Which aspects of the system are necessary to prototype and which are less important?
 - It might be too hard to prototype everything.
2. Does using a token improve the concept (rich interaction) or does it create a threshold for interaction?
 - It might overcomplicate the concept or make it very expensive.
3. Should a phone be involved or could the data from appliances and the web be directly sent to the weigh-beam?

Alternatives

1. What motivates people to purchase a new electronic device?
2. Would people be motivated to use the device?
 - Do money and sustainability prove to be enough of a motivation?
3. Should alternatives be tailored to the person (by a learning algorithm or set profile) or should it give a basic set of options?
4. What are those options?
5. How does the learning algorithm abstract data from the internet and what data should it extract?

Weigh-beam

1. What data does the user want to see?
2. How does the user want to interact with the weight beam?
3. Is the weight-beam the optimal solution and does it have an optimal form?
4. What data does the weighbeam send to the phone?

B. Evaluation of the five concepts

<i>Concept</i>	<i>Interaction</i>	<i>Desirability</i>	<i>Restrictions</i>
<i>The seesaw</i>	Futuristic to say all devices turned on via energy balance	Less desirable to walk over to balance to turn things on Concept itself is desirable because it provides a general overview when shortly looking Can provide more details when looking closer	Physical tokens might not be convenient for energy producing systems (no state change) Only representing consuming devices may be confusing The weight of the devices is not physical when making digital representations.
<i>The energy sharpener</i>	Interaction is clear: pencil metaphor understood	Same as previous concept	No overview of individual appliances Little physical interaction Devices need to be turned on via the device Balance is less present
<i>The energy dock</i>	Interaction is understood	All devices can be controlled individually	What devices are relevant?

		More persuasive	Only big appliances
		Shape change	Less idea of balance
		Can put things to a later time slot	
The energy strings	Interaction is clear after explanation, but it is not immediately clear. (pulling harder etc.)	Less overview of balance at first glance. Do not want to see use of all devices immediately.	Mapping energy not directly linked to energy use Putting things to a later timeslot
The energy ball	Interaction not very clear, needs explanation. Maybe too vague.	Not very desirable, as it is not clear.	One object representing multiple devices. Hard to check on and off state of each device. Need to turn on devices through concept.

C. Price calculations

Buying from energy supplier

Bare	€ 0,085 (Hage, 2019)
Energy taxes	€ 0,11934 (Pricewise, n.d.)

Energy storage (sustainable energy) €0,02287 (Pricewise, n.d.)

Total price (€/kWh) 22,721 cents ≈ €0,23

Selling to energy supplier (Energieleveranciers.nl, n.d.)

Eneco € 0,092

Energiedirect € 0,06

Essent € 0,07

Greenchoice € 0,11

Nuon € 0,07

Qurrent € 0,10

Average (€/kWh) € 0,08

Earning Model

Selling to neighbor for €0,16

Paying €0,02 for usage of the grid (Autoriteit Consument en Markt, n.d.)

Neighbor saves €0,07/ kWh

Seller earns €0,16 - €0,02 = €0,14/kWh

Example

(Volta Solar, n.d.)

East/West of the Netherlands	125kWh/m ² /year ≈
10,4kWh/m ² /month	

South of the Netherlands 150kWh/m²/year ≈ 12,5 kWh/
m²/month

Average production 275kWh/m²/year ≈ 22,9 kWh/
m²/month

Measurements one solar panel 1,65 x 1 m = 1,65 m²

So, a household with 8 solar panels has an average energy production of 1,65 X 8 X 22,9= 302,28 kWh/month.

The average is 30 use and 70 goes to the net. This means that people can approximately trade 70 percent of their produced energy (de Vlugt, 2017), which is 0,70*302,28 =2,11*10² kWh/month. This means a family can earn up to 2,11*10² x 0,14 = €29,54. This also saves buyers €2,11*10² x 0,07=€14,77. When having more solar panels, this will be even more.

D. Feedback energy blocks

Feedback by one of the DIGSIM coaches

- You may want to think about the details regarding the selling and buying of energy. What about the numbers?
- What feedback do you receive as a user?
- Why would you interact this much with your energy, why would you not automate this process?
- Giving energy is nice, you save money and there is no imbalance.
- You might make it nicer to give energy to the neighbours than to give it back to an energy company. You could also do something with the neighbourhood being in balance. What if the neighbourhood buys a new solar panel together?
- The business model is there, but you might need to think more about the interface itself. What is the value of having a physical interface?

E. Results deployment

Beforehand

The answers to the following questions have been written down and have been translated.

1. *Are you aware of your daily energy production?*
Not exactly (although there are some things). Nevertheless, I do kind of see it when I get my annual bill. Moreover, I can read the meter.
2. *Do you already take special measures to save energy (e.g. scheduling, rules)?*
Yes, I try using the washing machine after 9 p.m. This way, I can use energy for an off-peak tariff. I set a timer to achieve this.
3. *Would they like to save more energy? And why would they do that?*
Yes, we could like to do that for both the environment and money.
4. *Do you keep the time of the day in mind when turning on devices?*
See question 2 (only for the washing machine).
5. *How is the relationship with neighbors? Do they like to talk to them?*
I think we are not that close to our neighbors, as we do not talk to them every day. However, I would like to share my energy with them.

During test

- Did you ask the neighbors for energy? If so, how often?
- Did you look at the arrow today? Did it influence the timing of turning on devices?
- Did you look at the app today? If so, how often?

After test

The answers to the following questions have been audio recorded and have been analyzed by means of a thematic analysis.

1. Did you experience many difficulties when interacting with the arrow of app?
2. Were you aware of pressing the arrow at the moment that you produced more energy than you actually used?
3. In general, did you change the timing of turning on device and was this the same for all devices?
 - Did the community aspect influence this?
 - Did the money aspect influence this?
 - Or intrinsic motivation to do better for the environment?
4. Did you talk about the app or arrow with the other user or members of the house? If so, in what context?
Did you talk about the messages from the neighbors?
5. Were you aware of using the app and arrow at specific times (not in the evening for example)?
If so, how could this be caused?
6. Would you like to share some other things that haven't been mentioned yet?

Because of confidentiality, the original interview and thematic analysis are not included.

Conclusions

1. Testing

- When deploying again: users should be contacted more frequently, big appliances should be involved, product should access real data about production.

- The product should clearly communicate its state (on/off, connected/not connected).
- People think they are doing great when having an energy surplus every day, but they do not realize this is not great if they do not use it.
- Products Easton and Flow could more clearly communicate their connectivity.

2. Overall concept

- Idea is being thought of as contemporary. It's questioned whether people will still be motivated to use it after a longer period has passed.

3. App Usage

- As people tend to look at the app at the end of the day, the arrow should be there to inform them during the day itself.

4. Planning

- Remotely turning on devices via the app would be convenient for people who aren't at home.
- Programmed appliances could be involved into the equation.

5. Communication

- There should be thought of communication within the family, as people look at their own app and do not share whether they turn on a device and for how long.
- Communication with neighbors stimulates involvement.
- Messaging nice and convenient way of communicating.

6. Saving Energy

- Money and doing well for environment are both motivating.

7. Storing Energy

- Integrating the ability to store energy is something to think about for future projects.

F. Code

The following link provides access to an overview of the codes used during the deployment and the final demo day:

Deployment

<https://create.arduino.cc/editor/doortjemarkovic/f9050bb1-b032-4529-9fb0-86cd9d6f8694/preview>

Demo day

<https://create.arduino.cc/editor/doortjemarkovic/2a5c187f-4741-4fef-a577-0a3dff42e491/preview>

Explanation Code

During the demo day, a code was used for connecting Flow to Easton. Therefore, there is a part included that establishes this connection via OOSI. The values regarding the real-time production of the user has been simulated by having different consumptions as functions of time. The functions have been based on the following diagram:

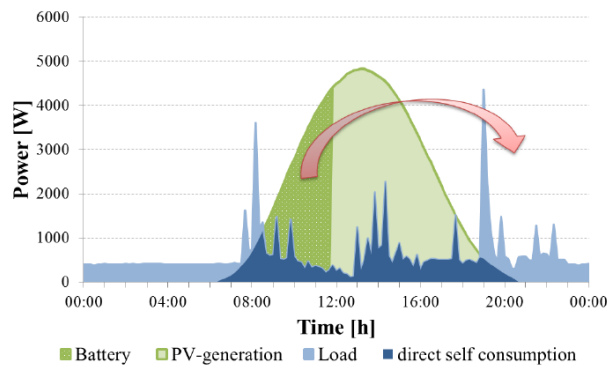


Figure 21. Diagram of energy production and consumption (Struth et al., 2013)

Similarly, the production of the community was taken to be a multiple of the consumption of the user. For the community, the amount of solar panels was taken to be forty-six, corresponding to a total of eight neighbors.

Daily overview

For the daily overview, the surface areas of the functions related to the real-time production and consumption were taken. By taking a surface area, one multiplies the amount of Watts with the amount time, resulting in a total usage in kWh.

Final demo day

During the final demo day, Flow was connected to several devices which could be turned on. These included the oven, washing machine, dryer, cooking plate and dishwasher (see r.130 of the code). when they were turned on, the value of energy consumption would increase. The values for the consumption of the separate devices were retrieved from SwitchCo (SwitchCo, n.d.).

G. Trend analysis

Energy Production	Kind of trend (micro, midi, maxi, mega)	Website
Developing Biorefineries (allow the substitution of non-renewable resources by renewable ones)	Mega	https://reader.elsevier.com/reader/sd/pii/S1876610216317118
Energy storage systems are vital to maximize the production and utilization of energy production from existing and /or future RES (renewable energy systems)	Mega	
Reduce use of energy in transportation	Mega	
Assessing sustainability of renewable energy systems	Mega	
Emissions control and abandonment	Mega	
Renewable share falls with increasing income before reaching a turning point where it begins to rise again.	Mega	https://ourworldindata.org/renewable-energy#renewable-ener
Own energy production (solar panels, wind turbines, hydro power, solar water heating, solar air conditioning, tesla power wall, geothermal)	Midi/mega	https://www.popularmechanics.com/science/energy/g28257/ https://www.energievergelijk.nl/onderwerpen/warmtepomp
Apps for keeping an overview of energyproduction	Micro	https://enphase.com/nl-nl/producten-en-services/enlighten-en