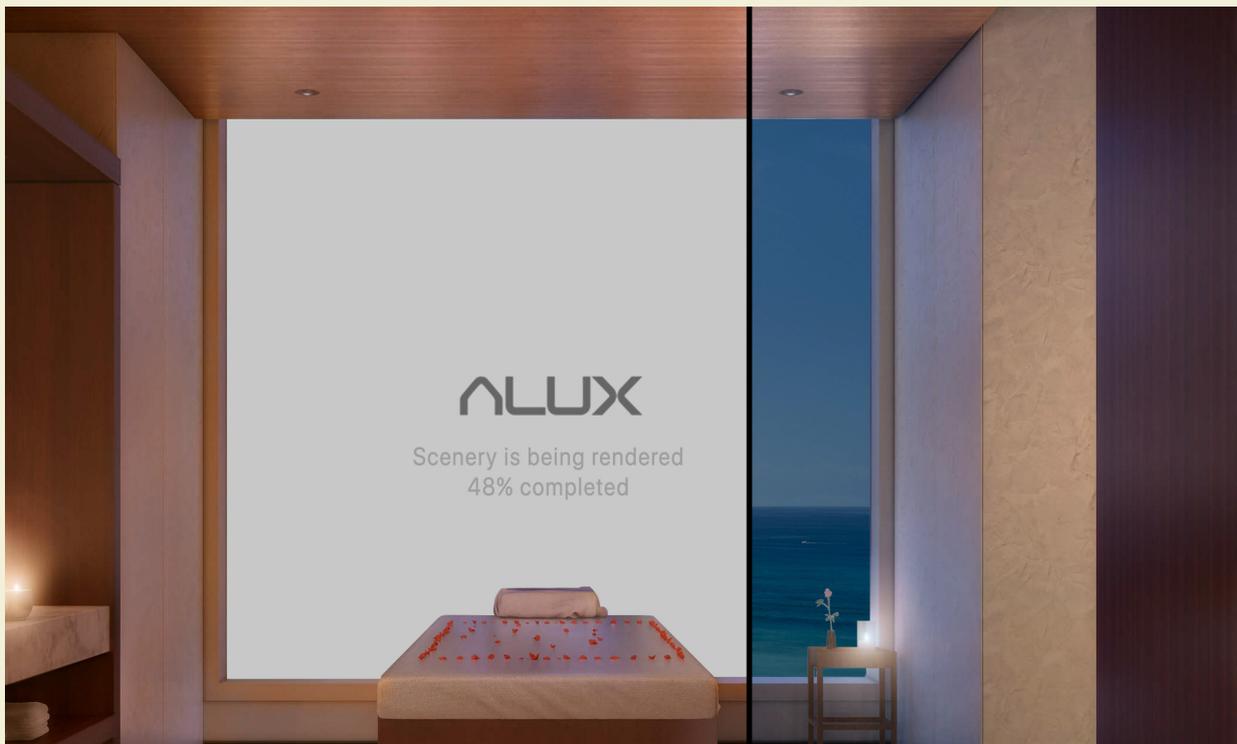


# ALUX



Eindhoven University of Technology  
Bachelor College Major Industrial Design  
DPB100 Project 1 Design  
Smart Cities  
2017/2018, Semester B

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# Introduction + Project Goals

## Introduction

In the 21st century modern cities have problems with housing. Underground housing is one of the solutions to this problem. Yet this solution has one major problem. The lack of sunlight and air for the citizens. Everyone wants to have a window for sunlight and fresh air. This lack of essential components can result in depression. This can occur in underground housing but also in public spaces.

Our goal is to make sure that your inside environment mimics the outside one so there won't be a disconnect with your reality. That's why we came up with ALUX. ALUX is the best artificial lighting underground experience. It is an artificial window that mimics the current sunlight and air. It provides you the feeling that you still live above ground. With adjusted colours ALUX provides you the actual weather of your outside environment. This way you won't even notice it being artificial. We provided a scenery to give you the feeling it is an actual window. The depth of the box makes sure there is motion. These components give the user the feeling they have an actual window and that they still live above ground.

## Personal Goals

Emma van Amersfoort	<ul style="list-style-type: none"><li>- Poster work: learn how to work with Adobe software</li><li>- Prototype work</li><li>- CAD design</li></ul>
Nijs Bouman	<ul style="list-style-type: none"><li>- CAD design</li><li>- Prototype work</li></ul>
Rachel Feldman	<ul style="list-style-type: none"><li>- Report work: learn how to make reports cleaner</li><li>- CAD work</li><li>- Conduct user interviews</li></ul>
Wouter Stevens	<ul style="list-style-type: none"><li>- Pitch work</li><li>- Sketch work</li><li>- lo-fi prototype work</li><li>- Conduct user interviews</li></ul>

## Project Goals

We want to solve the problem of lack of housing in the big cities, this is why we researched alternative housing solutions. One of these was living underground. It has been tested a lot, but one of the biggest problems that occurred with the people that lived underground, was depression. This is caused by the lack of sunlight and airflow. This is why we wanted to create something new, an artificial window with the two important aspects as described before. Another reason people don't want to live underground is the view, they want to have a window so they feel connected with their environment. We want to solve the problem of underground housing with a design that gives the user the feeling they still live above ground. We want to get more information about the interaction that people have with their windows. We want to be able to look at windows differently. That's why we hope to be able to do enough user testing to learn how to create a realistic artificial window.

# Process

## Pressure Cooker

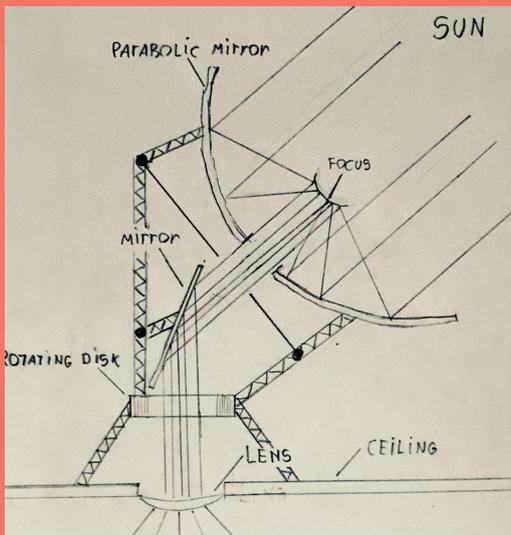


Figure 1:  
Sketch from  
the pressure  
cooker.

We started the process with brainstorming. Then we moved into researching the main problems of cities, writing down our ideas and discussing them. We highlighted the ideas that we saw the most potential in as a group. After that we ranked them based on how interesting we thought the ideas were. Each of us then drew sketches about the ideas, so we could compare them in the next meeting. This way we could define different approaches for the same idea. We voted for every idea and eventually, we all saw the most potential in the mirror which would reflect sunlight into a lens. This would replace a modern lamp.



Figure 2:  
Lo-fi  
prototype  
from  
pressure  
cooker.

Next, we decided which concept we wanted to develop for the pressure cooker and we started to think about our target group. We each wrote a text about what our target group would look like. We combined the most important values and created personas. (Personas in appendix) The next step was making the prototype for the pressure cooker.

## Realizing our Concept

After the pressure cooker we evaluated the idea we presented, based on the comments we received. We came to the conclusion we were not totally satisfied with our concept. We took a look at our other concepts again and couldn't make a decision. Then, the coaches gave us the advice to look back at the problems of cities and not only the concepts. The problem we were looking at, was the lack in housings in bigger cities. We thought of living underground, but a big issue was the depression that followed. This depression is caused by the lack of natural lighting and fresh airflow. This brought us back to lighting. We all liked the idea of solving the underground lighting problem, so we decided to go further with this. We thought about a new concept, ALUX our artificial "window". To improve not only living underground, but also for places where real windows are not an option. Next, we created a SWOT analysis to address the problems with our concept, which can be found in the appendix. This helped us to see what possible steps user could take. Although this wasn't as accurate as real user testing. (SWOT analysis in appendix).

After reaching this point in our concept we went on to validate and continue with our realization process. This included a survey, feedback at the midterm demo day, and a new prototype. We discuss the survey and midterm demo day on page 7, and the first prototype on page 11.

# Where We Were

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Brainstorming

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Sketching

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Creating Personas

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Pressue Cooker

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SWOT analysis

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Logo/name Ideation

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CAD Design

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Material research

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User Testing

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Reflect on User Testing

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Building Prototype

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Arduinio/Teensy Research

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Electronics Prototype

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Preparing Pitch/Poster

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Demo Day

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Refelection on Demoday

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New Planning for Quartile 4

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The past quarter we started with a lot of ideation and conceptualization activities such as brainstorming and sketching and finding user problems through personas (see appendix A). We were mainly focused on finding a problem and trying to communicate different ideas and solutions. Once we focused on the idea of underground housing and the lighting and venting issues we moved to validate our idea further with a questionnaire. This helped us to get some preliminary user feedback about light needs within the home before we started to realize our design (see appendix C for the questionnaire and results). From that we were able to interpret responses to be able to continue in the design process. After extensive material research and other research to find how to start building our prototype we were able to move to a realization phase of our design where we started to build the prototype in figure 3. This prototype was a light box that displayed diffused light in different color temperatures similar to outdoor conditions. We hoped to use demo day at another user test to get feedback on our design so after the realization phase we focused on preparing for demo day to help us validate our idea further.

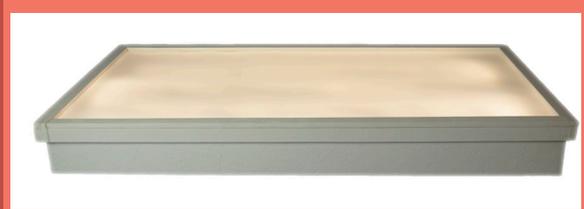


Figure 3: Prototype one from the mid-term demo day.

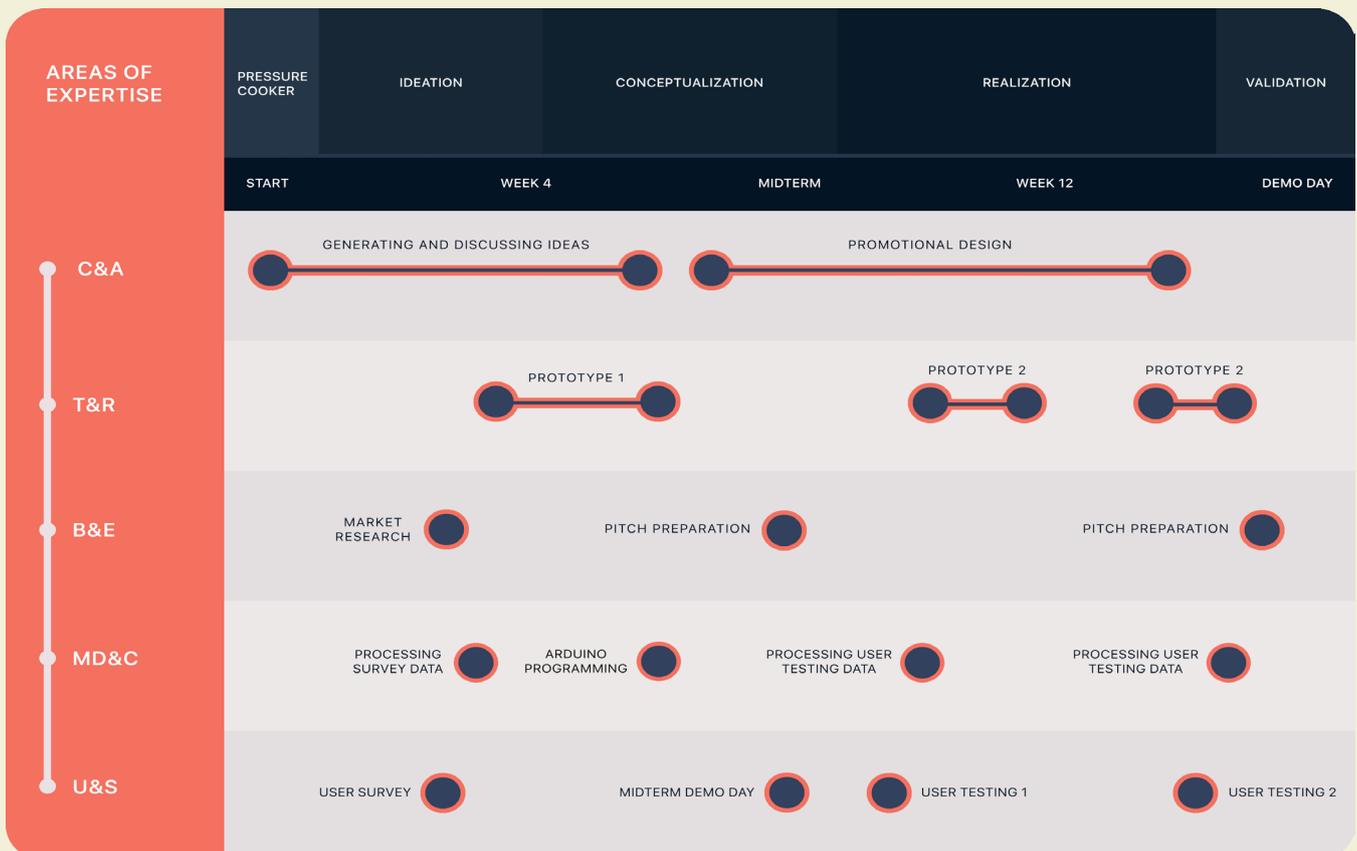
# How we Proceeded

During demo day we got a lot of initial feedback on our design. Some of it was conflicting as we heard opinions on which color temperatures were preferred and uncertainty about if we should always show an accurate display of outdoor conditions. We also had some feedback on size and lack of an image. We then chose to continue our validation phase of our process and reached out to an expert and started to conduct more user tests. Once we had done that we came away with a few overall conclusions about size, type of image, and type of movement needed for our next prototype. This allowed us to start working on our next prototype and realization phase which included an image, seen in figures 4 and 5. After this prototype was built we went on to do further user testing for validation of the previous realization phase. After this user testing was done we came to some conclusions, one of which was that we needed to implement a fan system. This helped us develop another small iteration of the prototype seen in figure 4 and 5. After this was build we started with another phase of our process, we started to prepare for demo day. This included starting to make a video, posters, and other promotional material.



Figure 4: Prototype two with a cooler color temperature, mimicking a cloudy day.

Figure 5: Prototype two with a warmer color temperature, mimicking a sunny day.

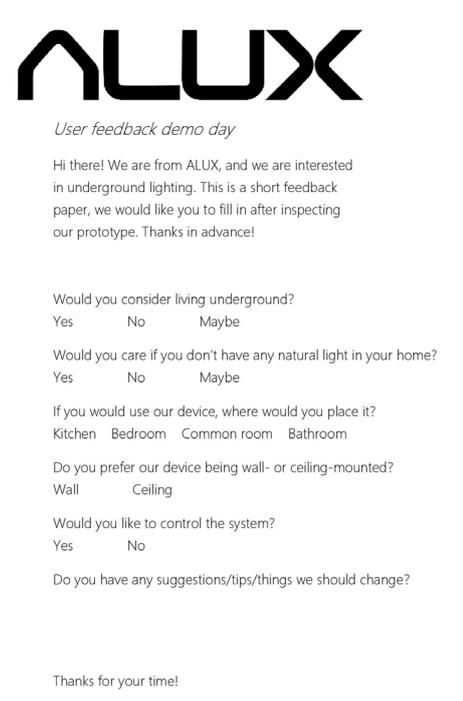


# User Testing + Expert Interview

## Questionnaire

Before the midterm demo-day we wanted very direct closed question feedback on our device. We figured a questionnaire would be the best way to tackle this. Based on these questions we wanted to get feedback on our very first working prototype. A lot of the basic questions were covered in that questionnaire, although there still was no real conclusion to the issue whether we would go for a wall- or ceiling mounted device. The main conclusion was about the actual size people liked this device to be, how they would like to control it, how bright they want their rooms to be, whether they would prefer natural light and if they would like it to be connected to the real-time weather conditions. We ended up with approximately 100 responses, which lead us to an accurate view about the needs of our possible users. (The questions and responses of this questionnaire are in the appendix C)

Figure 6:  
User  
feedback  
demo



The image shows a printed questionnaire for 'ALUX'. The header features the 'ALUX' logo in a bold, black, sans-serif font. Below the logo, the text reads 'User feedback demo day'. The main body of the questionnaire consists of several short paragraphs of introductory text, followed by a series of multiple-choice questions. Each question is followed by three options: 'Yes', 'No', and 'Maybe'. The questions cover topics such as living underground, natural light preferences, device placement (Kitchen, Bedroom, Common room, Bathroom), mounting preferences (Wall, Ceiling), and control system preferences. The questionnaire concludes with a 'Thanks for your time!' message.

## Midterm Demo Day

The demo-day was for us the first interaction between other designers / possible users and our prototype. During the designing phase we followed all the conclusions we came up with from the questionnaire to create our current best solution. We invited a couple of the questionnaire respondents to see if their opinion had changed with our adjustments. We wanted people to see our device in real life, to see whether their opinions were different than the ones that just saw pictures. To make sure we could get as much feedback as possible, we prepared a very short questionnaire for visitors (see appendix E for answers) to fill in after our pitch-talk.

A very remarkable result was that most of the people during the demo-day preferred a wall mounted version of our device, while the people from the questionnaire preferred a ceiling mounted. This was mainly because we focussed on ceiling in our pep-talk in the questionnaire, and during the demo-day we supplied the people with pros of both versions.

Because of the futurism of our concept, user testing is quite hard to do. The focus of our product is to design for underground living people. As this is not the case in our society as of today, we felt it would be good to still gain new insights from our colleagues.

During the demo-day we asked our visitors for possible new features or adjustments. This turned out to give us a lot of new inspirations. For more interaction with our device, we asked the visitors how they would like to control our device. One of the new ideas we got was to control our device with gestures that replicate the actions you would do with a real window. This led us to a lot of new ideas.

# Expert Introduction

We wanted to know more about the exact specifications that our light sources would need to have, to give the users a feeling of natural light. This is why we asked Prof. dr. ir. Yvonne A. W. de Kort (TU/e, Human-Technology Interaction) for an interview with us, to learn more about this subject and the projects she did. The core of her expertise is in the effects of light on human functioning and how interactive, intelligent solutions can add value to public, professional and care environments<sup>1</sup>.

## Interview Summary

During the interview we learned a lot about the perfect specifications of natural light that have influence on a person's interpretation of real light. Both the light and fuse have effect on people's wellbeing. Windows give you a lot of information about the weather, your surroundings, and much more. For a human's wellbeing, daylight is the most important exposure to light. With a good intensity at the right time of the day. With darkness in the evening, your biological clock stays right. Light has a very broad spectrum, with a lot of blue colors. Blue is the most important color for your biological clock. The buildup of the light is also important. RGB for instance doesn't work, because of the low amount of colors in the light itself. Therefore it would be better to have multiple different LEDs, than to have a set of RGB LEDs.

Daylight also provides a lot of information about the nature and time of the day. The natural light restores stress, and makes emotions more positive. Light and nice nature often have a connection. If there is a lot of light, you'll probably also find a nice looking natural scenery. Light is important for everyone, but nature just for specific people. Directional and diffused components of sunlight are important when you are recreating it. These aspects of light are really dependent on the people you're aiming it for, you should find yourself a target group. Just normal light in working spaces won't be enough for the mornings, natural light is mostly important in the early morning, during breakfast for instance. It would be important to have an information display of what happens above ground. People are mostly interested in the weather above ground instead of a different artificial location, however no real experiments were done for this answer. They would want a realistic feeling of the outside weather, however you should try to keep it positive. If the weather for instance is really rainy and grey, you should recreate it, but minimize the grey colors.

Simulations of nature will work, and static pictures could also work with an addition of a small movement. The psychological effect works best if you think that it is real. She did tests with the parallax movement and found out that parallax is really important. She had a virtual window that had a sensor that made the image move like as if it was a real window. Parallax creates depth. The feeling of space that parallax creates gives you a sense of reality.

Vitamin-D is very important, although we're never getting enough inside. The best way for people living underground to receive this without the risk of skin cancer, is by taking supplements. Although, with supplements you can take too much or too little vitamin-D, with sunlight you can't.

Artificial windows with a display, are mostly used in stressful situations like dentists or hospitals (or a submarine / in outer space). For improvement of the biological clocks, and training good sleeping patterns. The most important aspects of a real window, "everything has a value for creating a more realistic feeling." Possible priorities could be, parallax, depth, light quality, and imagery. For doing user tests you could do short exposures, with stress induction, or follow people in real life. The fact that it is not real is not so important, because the movement is more important than the quality of the scenery. Behavioural > pictorial. Try to find out what the biggest issue is within a group. Don't make the group too broad. A good focus group for instance is nurses; radiology nurses. Do experiments with some kind of physical or mental stressing situations. As for the light source, LEDs are the best way to go for now. (For the whole conversation, see appendix for a Soundcloud link).

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1: <https://www.tue.nl/universiteit/faculteiten/industrial-engineering-innovation-sciences/de-faculteit/medewerkers/details/ep/e/d/ep-uid/19960199/>

## User Testing 1.0

Before this user testing, we had the expert interview. During this interview we learned a lot and already had a new focus on how we should approach the next prototype. A lot of the questions we were planning on asking the users were covered in this talk. After doing a couple of user tests we already figured that we won't be learning new information and that the conclusion was already known. This is why we decided to cancel the user tests we planned ahead and first focussed on improving our prototype. The questions we asked are in the appendix. (For video footage and questions of our first User testing, see the link in appendix G)

## User Testing 2.0

After the improvement of our device, we had a much better feeling about it. We thought about a good way to replicate a situation where people would use our device. We wanted to make sure that our device had a clear improvement in mental stability compared to a ordinary light bulb. The idea for the user test was to create a situation where the users could adjust to the atmosphere in the room and had to wait for a few minutes. We did this by faking a waiting time for the last member of our group. After approximately five minutes the last member would enter the room and tell the user that the main part of the user test is finished. After this waiting time, we wanted the user to do an online stress test (<https://www.bemindfulonline.com/test-your-stress/>) and see the results. Then ask them general questions about the device (seen to the right.) The point of the stress test was so we could compare the results we got with those of people we had waiting in a room without our prototype.

However, after a while we found out that the information we gathered from the stress test wasn't worthwhile since it was hard to gauge the effect the room had. We decided to only run tests with our prototype present because of this.

We asked the users questions about the improvements we made because of the information we got from the expert.

## Questions 2.0

Q1; How did you perceive this waiting? Was the waiting relaxing or intense?

Q2; Do you feel like our product is effective as an artificial window?

Q3; Would you want to change the weather conditions with a remote if the weather seems bad?

Q4; How do you like our device compared to a normal light screen / light box?

Q5; Do you think that this device helps you to connect to your outside environment if you would live underground?

Q6; Can you compare and contrast our device with a real window?

Q7; Can you compare and contrast our device with a normal light bulb?

Q8; Can you describe how you feel looking at the product?

Q9; Do you feel like it has depth?

Q10; Would you like to change the scenery?

Q11; Any final thoughts?

(The overall answers and scores are in the appendix H)

## Summary of Question Answers

Some of the participants experienced the waiting time as a relaxing time, while others thought this was annoying. A few of our participants thought our design was quite childish, others liked the design very much, they do think it needs to be more realistic to really mimic a real window. By adding sound for instance, this could be improved. They did think this was a lot better than having no windows at all. They would like to be able to change the weather condition that is automatically updated to personal preferences, but with the awareness of being changed. They like our device better than normal lights or a light box, because of the feeling of having a real scenery to look at. This could take away the claustrophobic feeling, but that also depends on how it is implemented in the living space. They agree that the different weather conditions helps you to see what is going on outside without having to grab your phone and see the current temperatures, this makes it more natural. They would want to be able to change the scenery to their own preferences, and movement could also really improve the feeling of reality. They think a real window is more dynamic, has air ventilation (fans weren't implemented yet at that moment), has more sound, and more realistic light. The feelings they have while looking at our device are: Calmness, pleasant, relaxing, fascinating, soothing, childish. However the transparency does confuse the actual depth. They would like to be able to change the scenery to their own preferences and like to see something like curtains in the future.

# Final Demo Day

The moment we've all been working to. We started off early with a meeting to talk everything through. We decided to not make a questionnaire again like before during the midterm Demo-Day. This was because we figured this would create less interaction with the users/visitors, and by asking questions, we could make them elaborate their opinions even more. And provide the necessary explanation to help them understand everything.

Unfortunately we started off with one of the LED strips not working, so we couldn't provide the first visitors with an optimal presentation of the different weather conditions. However this was fixed in a few minutes, and we could continue with the whole presentation.

Our coaches gave us very helpful feedback concerning the final looks of our prototype. The fans for instance, that we added afterwards, will eventually need to be implemented in the squared device for a better look and window like design. This is something we will have to work on for the future design of our project.

The mimicking of the weather conditions went really well. We got a lot of positive feedback about the different feelings people got while staring at our device, while the colors changed. How the happy summer day changed to a depressing rainy day, was especially a clear noticeable change in reaction and mood.

The thickness of our product was also something that confused a lot of people. It was really hard for us to find a perfect balance between the realism of the prototype and the thickness. We wanted to make sure that the aspects we learned from our expert were as best as possible to make it look real. The lights needed to be diffused, and the depth had to be created. We did some experiments on how close this could be to have the best of both, and unfortunately this couldn't be smaller than 20 centimeters. For future development, we will need to experiment with different options to tackle these aspects and at the same time, keep the thickness as small as possible.



# Iterations

## Iteration One

The first iteration of our prototype was the one that we ended quarter one with, seen in figure 8. This had oscillating LED strips in it which displayed different color temperatures. This was a rather large prototype, as we wanted to mimic how much light was currently present in above ground housing from windows. We had an diffuser panel on top as we felt that this was the best way to display the light. As can be seen in figure 8, the first prototype is made out of wood and plasterboard. Also, inexpensive LED strips (see 22), a breadboard with components including a microcontroller (see figure 22) and a diffuser panel are used in order to keep costs low in this earlier stage of development.



Figure 8: Casing of the first prototype



Figure 9: Prototype two being put together

## Iteration Two

The second prototype was made of foamcore and has scenery, since the first using tests showed that people would like to see scenery. Also, this is what an expert on this topic had argued in an interview. The second iteration we made a little bit smaller but still window size. It included the same LED panel but also included an image on it with 3 layers cut out of a transparent plastic to create a parallax when looking at the prototype as suggested by the expert. In order to mimic depth, multiple layers of transparent plastic have been designed. This way, a parallax effect occurs. This is caused by the difference in distance between the perceiver and given layers. Additionally, these layers are interchangeable, so a desired scenery can be established. The layer designs are seen in figure 10, 11, and 13. There was a fourth layer, seen in figure 12, but when building it we determined that it looked better without it.



Figure 10: The first layer of the new design



Figure 11: The second layer of the new design

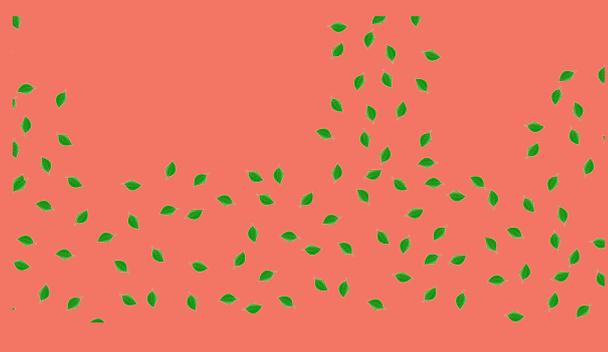


Figure 12: The fourth layer of the new design which was not used



Figure 13: The third layer of the new design



Figure 14: two different LED strips are used in both prototypes



Figure 15: Prototype two being put together

## Iteration Three

The last iteration was the implementation of an air circulation system. This system mimics natural air flow. The RPMs for these fans can be changed. The final iteration we included a fan system and we secured the previous iteration on all the sides to make it more stable. This is seen in figure 17. We also started to work on video and photo work to help us be able to communicate our idea for demo day and the ideas that we haven't been able to realize yet.



Figure 16: Final prototype in context.



Figure 17: Final prototype with cool weather tones and fans.



Figure 18: Final prototype with cool weather tones and fans.



Figure 19: Final prototype on wall in photo-shopped context



Figure 20: Final prototype with mixed weather tones and fans.



Figure 21: Final prototype in context

## Lighting

The white-toned LED strip is five meters long and the blue-toned LED strip is ten meters in dimension. The LEDs have been taken off to be used for the second prototype, since they still functioned well. Figure 22 shows that the circuit includes two field-effect transistor, two 5V mono color LED strips which have different color temperatures, an Arduino Uno microcontroller and two resistors to limit current flow. The circuit has been resoldered for the second prototype.

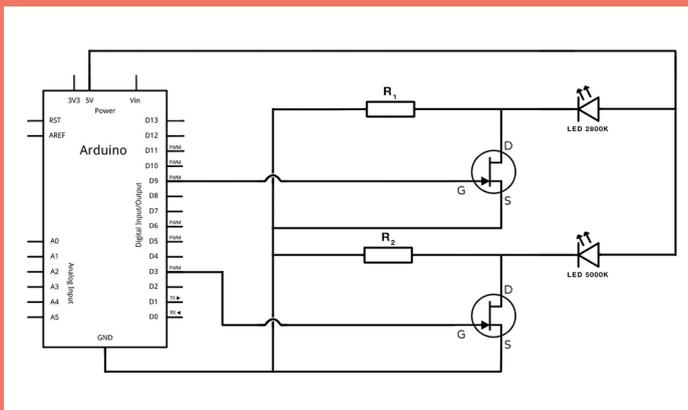


Figure 22: Schematics of the electronic circuit

The powerflow for the two LED strips is provided by the 5V power output pin of the Arduino and controlled by two output pins that support pulse-width modulation. Pulse-width modulation (PWM) is a method that enables digital output to be observed analogically. The FET's enable the PWM outputs of the Arduino to be transferred to the LED strips while operating at the proper voltages.

The two 5V LED strips have different color temperatures. By altering the average voltages across the individual LED strips, the two tones are blended and the output color can be controlled this way (see figure 20).

We have chosen the Arduino microcontroller over the Teensy microcontroller because Arduino is able to provide 5 volts and is overall more reliable.

# Results + Future Plans

## Final Results

During user testing, some feedback occurred multiple times. People generally responded positively to the device. Getting acclimated to the light helped setting a positive, more relaxed mood for the participants. The device was present in a pleasant way. Participants have generally indicated that they want more realism. Some didn't agree with that however. They preferred more abstract imagery (art-like). Overall, a desire for more senses have been observed, such as air circulation, sounds etc. The depth effect (parallax) in the scenery was sufficiently noticeable according to the majority. Conflicting opinions about changing the screens were present. Most thought that they wouldn't, because it's too much work. They would consider it if it was digital however. Consensus has been reached with regard to the changing color temperature. Everyone liked it a lot. Some preferred the warm color over the cold, and some vice versa however. Other remarks include: try to incorporate more movement, work on the aesthetics, and design scenes that fit in with interior aesthetics.

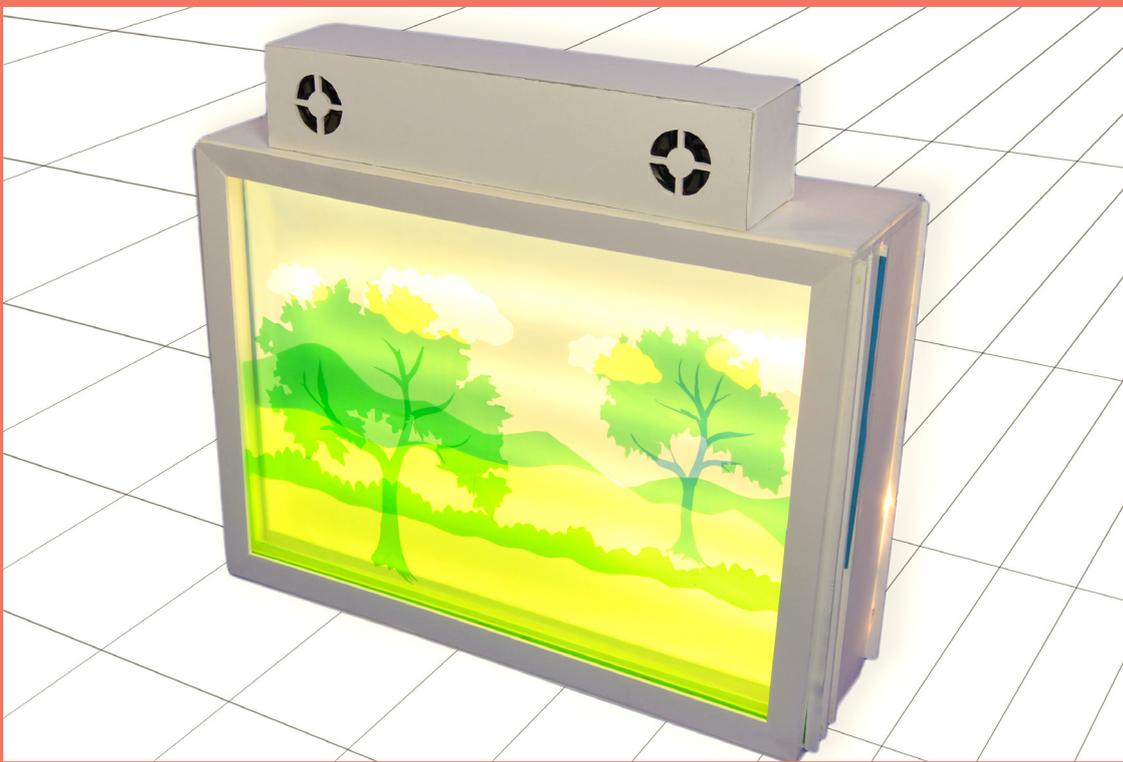


Figure 23: Prototype as demonstrated while doing user tests.

## Logo

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A variety of names have been discussed (see Appendix I Potential names). Eventually, the name "ALUX" was chosen. ALUX is a semi-acronym for Artificial Lighting and Underground Experience.

## Business

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Our target group contains people who want to live underground, so probably people in large cities. Also people owning the building that is used for living or working. They will provide a better environment so the building will be more popular on the housing market.

We figured that our key partners will be building landlords, architects and doctors. The landlords and architects want to expand their target group. Once they find out the issues with underground housing they will be happy with a solution that might help. Doctors and therapists are interested because ALUX can also be effective in closed working spaces and it will reduce the amount of people with depression. When we work together with the landlords and architects we can already integrate ALUX in the underground houses, this way it will provide the lowest price for the dweller. It will be an extra benefit for living underground. People will also be able to buy it themselves, this way they can place it in every house they will ever live in. Another benefit is that they can choose themselves where they place it in the house or have multiple devices.

To keep it a low cost design the extra screens will be optional. People can choose themselves if they want extra screens. This way you don't obligate people to buy the advanced option.

Right now mostly our target group are people with low income, so we want to expand to people with a higher income. We will develop the casing and screens further so it will be a luxury for that target group.

We want to promote ALUX via health campaigns. We want to create awareness about seasonal affective disorders and depression in spaces without windows. We want to show that you can create a healthy environment with our product.

# Future

Participants of the user test have indicated that they would like to see more realistic scenery, and that optionally would fit in with interior aesthetics. Using more advanced printing techniques would result in more realistic scenery. Figure 25 shows alternative scenery.

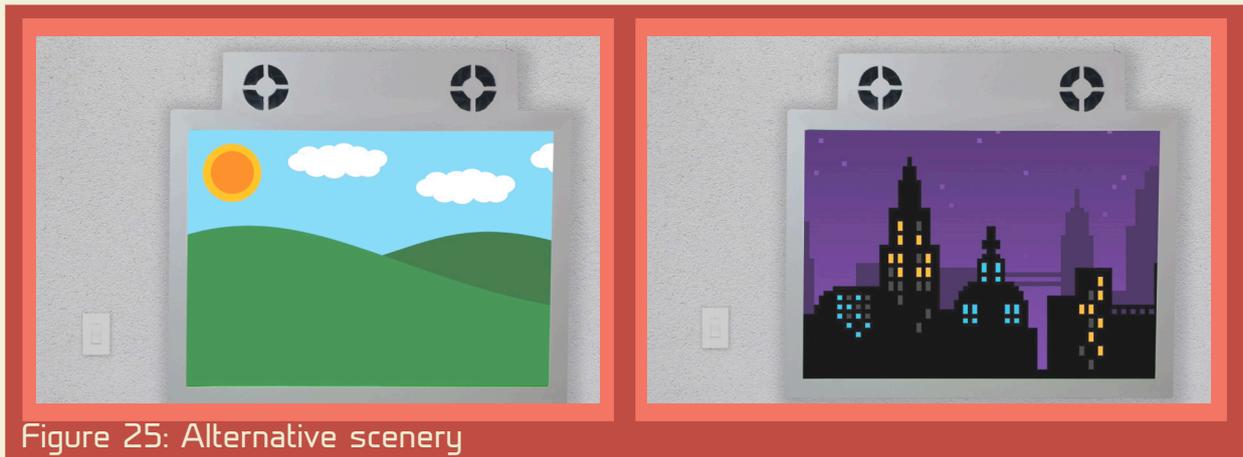


Figure 25: Alternative scenery

Currently, two means of interaction are incorporated: users are able to control the fans, and lighting. In the future, fans could also be programmed to fluctuate in accordance with a real air breeze. Also, the lighting could be connected to current weather conditions. This means changing the light intensity and color in order to mimic weather conditions. Also, gesture could be used to control the window. For example, gestures to dim the light or turn off the device at all.

In addition to light and air, other senses could be included as well. For example, smell and sound. Sound could mimic the outside world or something that improves the state of mind. Participants have indicated that they like the smell of the after-rain outside world and the smell of summer nights. These kinds of smells could be implemented.

Depending on the target group, 'nicer' materials could be used for the casing, in order to give the product a more finished look and feel. For example, thermoplastic polymers such as acrylonitrile butadiene styrene, which would meet demands (temperature resistance, durability, toughness<sup>2</sup>) or more expensive aluminium alloys such as the 8006 series<sup>3</sup>.

The following images are artist impressions of a potential future product. The envisioned technology blends in with interior aesthetics. Figure 26 shows the room without scenery. Figure 27 shows how scenery adds a new feeling to the room.

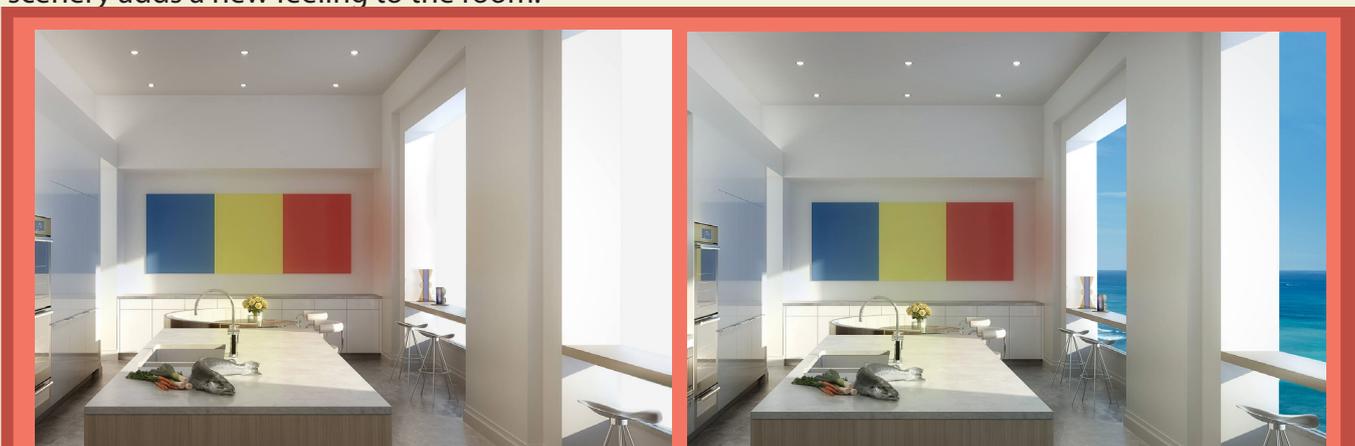


Figure 26 (Left): Artist Impression of a living space without scenery using ALUX technology  
Figure 27 (Right): Artist Impression of a living space with scenery using ALUX technology

2: The Wikimedia Foundation. (n.d.). Acrylonitrile butadiene styrene. Retrieved June 7, 2018, from [https://en.wikipedia.org/wiki/Acrylonitrile\\_butadiene\\_styrene](https://en.wikipedia.org/wiki/Acrylonitrile_butadiene_styrene)  
3: The Wikimedia Foundation. (n.d.). Aluminium alloy 8000 series. Retrieved June 7, 2018, from [https://en.wikipedia.org/wiki/Aluminium\\_alloy#8000\\_series](https://en.wikipedia.org/wiki/Aluminium_alloy#8000_series)



Figure 28 (Left): Artist Impression of a bathroom without scenery using ALUX technology  
 Figure 29 (Right): Artist Impression of a bathroom with scenery using ALUX technology

Light adds life to a room, but it's not all about lighting up a room. It is also about providing a hue to the room. See how the color of the interior affects the interior (Figure 28 and 29 above). This is, among other reasons, why scenery should be adaptive to outside weather conditions.

A use case for ALUX is adding an experience to a room. Some experience are just not possible with regular windows. For example, this relaxing area is located in the city. Using ALUX, a new atmosphere is established by introducing a new scenery.



Figure 30 (Left): Artist Impression of a relaxing area with scenery using ALUX technology  
 Figure 31 (Right): Artist Impression of a relaxing area using ALUX technology, imagery being rendered

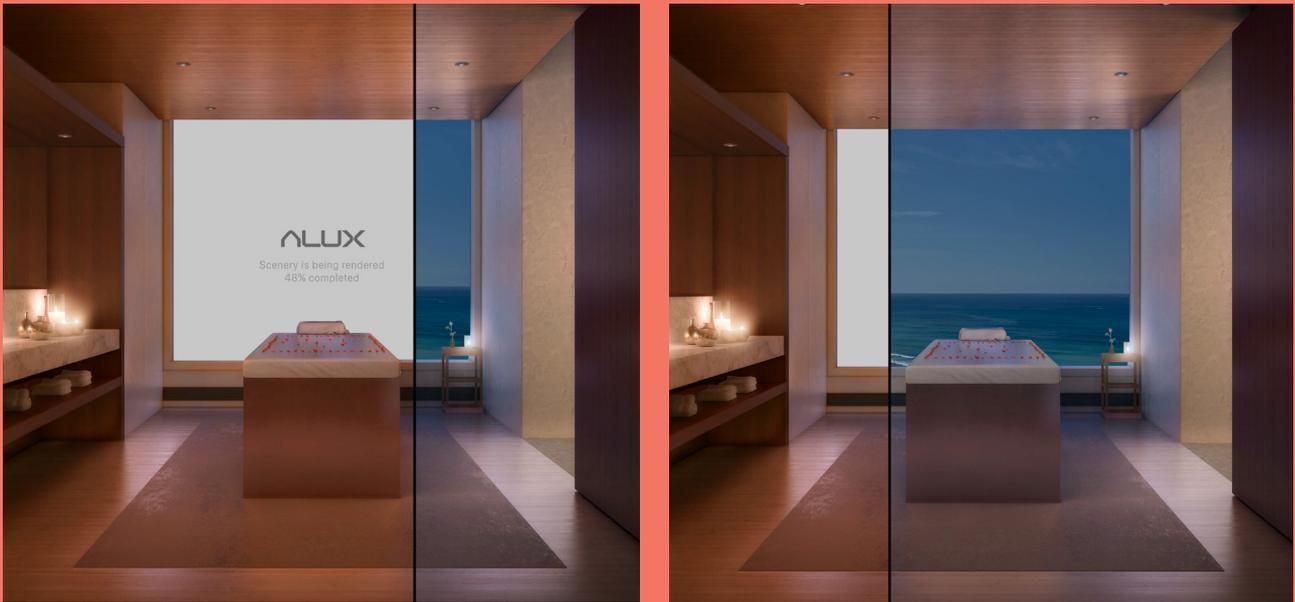


Figure 32 and 33: Artist Impression of a relaxing area using ALUX technology, imagery being rendered (difference in surroundings' lighting indicated by black line)



Figure 34: Artist Impression of a relaxing area using ALUX technology

Fans are incorporated into the foot of the device, in order to blend in with interior aesthetics. These fans provide a light, fluctuating breeze. Movement of the sailboat is being generated to provide a feeling of depth and change.

This theoretical product would idealistically also include a smell module, as well as speakers to mimic the sounds of the outside world.

The envisioned product would include all four senses that are relevant for such a device: light, air, smell, and sound. This way, the effects a window has on your brain are mimicked, rather than the window itself.

Source of imagery: DBOX<sup>4</sup>

4: DBOX. (n.d.). 432 Park Avenue. Retrieved June 12, 2018, from <http://www.dbox.com/work/432-park-avenue/>

# Conclusions

Our first prototype was very basic, we mainly worked with light and dimensions. For our users this was still hard to identify as a real window. While learning more about the important aspects of a window, by user testing and talking to an expert, we noticed the need for certain features. Light, air, imagery, movement, sound and smell are very important for creating an artificial window. We started to focus on the first three aspects, since those were the most valuable for us. By adding those features to our previous idea, we could see the improvement in the reactions of the users.

We learned a lot from the expert interview, since it was her expertise and passion to work with lighting. The need for blue light for instance, is something we could not learn from user testing only.

Although we did manage to cover most of the questions we had with this interview, we still planned a few user tests afterwards. However, within a few minutes we found out that we were not learning anything new from these talks. This is something we have to consider in future user testing. To wait for asking the possible end user for their opinions, until we've got most of the basics and specific technological aspects covered by talking to an expert.

In the end we managed to include the three aspects we wanted in our prototype. This was a huge improvement compared to what we had before. The users reacted a lot better on this design than our previous design and they would now even consider living underground with this device. At the first questionnaire we learned that most of our users wouldn't consider living underground. We are happy to say that we could change a lot of opinions about living underground with our concept design, and hope to help smart cities grow even bigger.

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# Reflections

## Emma van Amersfoorth

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When I look back at the past five months I am glad I choose Smart and the City. This project helped me with developing my identity and vision. It became clear for me which parts of the design process I am good at and which I have to develop further. I also now know that projects focussed on sustainability peaked my interest and I would like to develop myself more in this sector. This project started out to be something sustainable in the brainstorm sessions. Eventually when we developed the concept more, that part was not the main topic, but that didn't matter in this case.

In this project I mainly focussed on prototyping, together with Wouter I explored different ways to make our second and third prototype. I also made the pressure cooker prototype. Focussing on prototyping this semester was a good decision. It gave me a lot of knowledge on what is the most efficient and clean way to make a prototype. We made mistakes, we fixed it and learnt from it. I can be confident that when I need to make other prototypes next year, I will be able to make good quality ones.

I learnt also a lot about time management, how to plan your process. Mainly Rachel focussed on this, but I learnt from her how to plan in a way you have spare time for mistakes. You put a deadline on every task there is and that's how your process will go fluent. Of course something can go wrong, but if you have a good planning you will be able to manage that. That's why we were not stressed about our demo days.

Another PDP goal was developing my skills with the Adobe software. In this project I made the last posters for the demo day. I made a clean poster, and showed it to my team members. I got a lot of feedback and they helped me with visualising my idea of how it should look like. I now am able to make a clean poster but in the future I will have to practise more to develop my skill from basic to expert. I will do this with projects within my study program but also outside.

Another PDP goal was developing my English skills. I was able to do this because first of all Rachel speaks English, so we had to communicate in English. I also made the survey for the user test. It was not that challenging because it were short sentences, but it was a beginning. We all made a part of the report so this way I could practice that too. I highlighted the words/sentences I thought could be written better and the others did then some suggestions. It's not that I am bad at English I just think I should be able to express myself better and that's what I focussed on.

Overall I am happy with the results of our project. I could develop my skills a lot. This project was for me a test if this study was the right choice, because I will be doing a lot of projects in the future so I am happy I liked it. The teamwork went well and we learnt a lot from each other. I think I developed myself within every expertise area. Because even when someone else has the lead to perform a task, you discuss how he did it and why. I am very happy with my team and project and I look forward to learn more next year.

# Nijs Bouman

During the project, I have been able to work on all areas of expertise. For example, I have worked on building the electronics and lighting system (Technology and Realisation), but also on presenting the product (e.g. posters, renders, digital impressions, visuals, and logo). I did not have much experience with electronics, so I decided to dive deeper into this area. I've learned that we should make stronger connections next time, because the device malfunctioned twice.

Meanwhile, Emma and Wouter have worked a lot on building the casing, assembling the product, and carrying out expert evaluation (among other things). Rachel has taken care of the agenda, and has also prepared the user testing. In total, we have carried out three user tests and obtained valuable insights.

My team functioned very well. All team members have contributed equally to the project. Everyone knew what to do. There's a good dynamic within the team. Furthermore, we were all able to work on different areas of expertise, and obtained new skills and knowledge this way. I am satisfied with the function I had within my team. It fits my interests and my learning goals. My goals for this project were obtaining experience with more ways of prototyping, visualizing ideas, and working on the final stage of product development. All goals have been reached, although the last one not physically. We have made a proposal for future improvements however.

Making sketches of our idea did not go very well at first. It was hard to get the idea on paper. After the first prototype, much more became clear about what we wanted for our product. I have invested much time in visualizing the ideas digitally, and some visuals turned out quite well. Visualizing a concept was one of my smart-goals. Project 1 helped me reach this goal.



Figure 34:  
Visual I have  
made for  
explaining the  
future of our  
project

The current prototype, which is our third, is not suitable as an end product. Therefore, we have worked on visualizing what a next prototype might look like. We have also indicated what should be improved, e.g. the aesthetics, the light distribution, the depth effect in relation to the thickness, the implementation of the fans, and implementing the product into an interior. Solutions for these problems are presented in this report. For the next prototype, we would also like to add more senses, sound and smell, to our product, because we think it makes the experience more complete.

The product is not yet finished. But for us, it is more about mimicking the effects a window has on our brain, rather than mimicking a window itself and getting all the details right. So overall, I am very satisfied with the results.

# Rachel Feldman

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Overall, I'm really happy with both the project result and the progress I have made personally from it. I've been able to make a lot of progress towards my goals such as learning how to prototype, make reports in InDesign, and do user testing. I am also very proud of how well my team worked together. I've also learned a couple of very valuable lessons about how I should handle projects moving forward.

I handled a lot of the user testing and also lead the expert interview so I am happy to say I've made a lot of progress in the user and society area. It was a really rewarding experience being able to interview and take notes for all of this. I learned how to listen and take notes better and also be able to ask follow up questions that can direct the conversation in a way where I can get the most from my time with experts or users. As an international here this was one of my main struggles in my past projects as I felt uncomfortable talking to users who would prefer to talk in Dutch because they would look to my teammates instead of me and this led to me feeling cut out of the process. Through this experience I feel like I've been able to overcome this. I also feel like I've progressed in the technology and realization area as well as the math, data, and computing area because I was in charge of a lot of the electronics for the lights. It was a good learning experience learning how to code and wire LED strips. I feel like this could help me out a lot going forward with future prototyping.

One of my smart-goals for this quarter was to learn how to use InDesign more, I've learned a lot about this for this project. I ended up watching an entire youtube series to self-educate myself on the subject and I have made leaps and bounds as a result. I am now extremely comfortable working in InDesign and I feel like it shows in my work on this report. I made both the layout for the mid-term report and for this report and I feel like the difference between the two shows how much I've grown in graphic design.

I've also learned a lot about how to handle projects personally. I really gravitate towards the organizational aspects of projects and team management and this has got me in trouble when working previous teams but throughout this project I feel like I have been able to learn how to communicate in a more effective manner but still be organized.

One of the areas that I have started to realize that I need to work on more is being able to let go and be professional in the face of something stressful. I had a difficult time with the preparations for demo day because we had divided tasks in a way I wasn't used to. Emma was in charge of the poster, Wouter and Nijs were working on the video and we were all doing the pitch. I was in charge of organizing everything for the report. This means that most of the responsibility for our deliverables were on my team and it was difficult for me to not worry about it. It was a good division of tasks though because it allowed all of us to accomplish our personal goals. After I realized how this was affecting me I tried to resolve this by communicating with my team more. I felt that this helped but I can still improve this in the future and learn to control less. I also saw that my control issues affected the final demo day itself too and this is another opportunity for growth. We had a minor technical issue in demo day, we found out that a small wire had broken during transport and this was fixed as soon as I was able to replace it. This really stressed me out since I was devastated that all our hard work couldn't be displayed, especially since the issues was really unexpected. I really wanted to be able to troubleshoot the problem immediately but I got overwhelmed and I wasn't able to act very professionally. Looking back I feel like this is a learning point as I need to be able to control my emotions in these situations and still be able to give a good pitch and sell my idea.

My group functioned really well. I enjoyed being able to learn from all of them. Nijs was very good with photoshop and video editing so I was able to learn from that, Wouter was very good at diving straight into the realization process and prototyping, and Emma was very helpful when it came to communicating vision and design which allowed me learn how to approach communication with the team differently. We all had these different skills to bring to the table and I honestly believe that we were each able to grow and learn from each other because of this.

I really enjoyed working on this project and I would like to explore more smart city topics in the future because throughout this course it has really been inspiring to see how many directions this can be taken. It was really fun to follow multiple cycles of the design process here and I'm excited for my next project; I know that I'll be taking valuable lessons away from this one.

# Wouter Stevens

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Smart and the City, a modern project most of the bigger cities are working at. Creating a city where everything is connected with each other to improve the wellbeing of its citizen. My vision is focused on making daily life practises easier, the simplification of life. Smart cities have the same goal, and that is why I decided to choose this subject. Here I could begin my journey to make the 'unthinkable to be thinkable',<sup>5</sup> and create a world where everyone could enjoy today's technology to its fullest potential.

Before starting this project, I had set some goals for my personal development. The main subjects that I had to focus on, were pitching, sketching, prototyping and user testing. With sketching I could improve the visualization of my ideas. Although, this was mainly needed for the first stage of the prototyping, where we didn't had a specific idea or view on things yet. This helped me to convince the others, since sometimes I find it hard to explain my ideas well in English. This is because I tend to describe my ideas a little vaguely, and to translate this to English is even harder. During this project I could really work on this skill and that helped me a lot.

Just like the describing of ideas, was it really hard for me to pitch our project within a few sentences. This would mean that I have to be very concrete about the information I tell. My goal was to improve this skill. During the Midterm Demo Day, I could pitch our project and the feedback I got from a lot of the visitors and our coaches was very positive. In between the midterm and the final demo day, we even got a special lecture about 'Pitching your project'. In this training I learnt a very valuable lesson, something I often struggle with was the text learning. In the training they told me to not memorize the whole piece of text, but just the keywords and try to link them while talking. This helped me with the final Demo Day, where my pitch worked out great.

Next to the paper prototyping, was my goal to improve the prototyping overall. Especially the lo-fi cardboard prototyping was something I wanted to improve, since this was the first step to making your ideas real. Together with Emma we could work on the prototypes. I've learnt a lot about the best way to connect different pieces in the strongest way, and many different techniques. This is absolutely a skill that I plan on using in the nearest future.

My last goal was to learn more about user testing and interviewing. For a designer it is very important to know the needs of your end user. Not everything you might find important is important for the user. During this project I learnt when you should do a user test, and when you should answer the questions by yourself or through a persona. You shouldn't include the end user in every stage, because they might give you a wrong idea about their needs. But not just the timing was something I learnt, also how to ask a question. Some questions might be easier to answer with a closed answer, and for others this might be an opportunity to get more feedback. I also learnt the relevance of an expert interview and how to approach such a conversation.

The teamwork went very well, and we were able to have everyone to focus on their own goals while still having everything covered. We could trade questions to learn the most. This really helped me to learn faster and more precisely focused. Rachel took the lead, and this helped us to get everything done in time, and at the same time, was able to focus on her personal goal to work with electronics, programming and report designing. Nijs was focussing on the CAD and Video designs, and Emma could focus on her goal to work with InDesign and have more experience with prototyping. The communication was good, although not always did things go as planned. This is also something I have to work on, to get more structure in the goals we set and make sure I start early to get everything done in time. In the end this all worked out fine, because the personal deadlines we had set were earlier than needed. This gave us some time to delay if needed and created relaxation and peace within the group.

In the future I want to focus more on digital designing, so the making of posters and reports. This will be my next project's goal, and also making the basic expertises I learnt during this project even better until I master these expertises.

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5: <https://wouterstevens.wixsite.com/website/vision>

# Appendix

## Appendix A - Personas

### Summary

- Young
- Landlords
- Living in a "smart" city
- All live underground in small apartments
- No need for large houses
- All financially independent but not incredibly well off not 1% more upper to middle class
- All have degrees
  - €500-1500

### Persona



#### Bio

Hao-Li was born in 1986 in Hangzhou (China). He started studying Electronic Engineering in 2004. He graduated from The University of Beijing in 2009. After that, he obtained his PhD in 2014 at the Eindhoven University of Technology. He began working as an Assistant Professor in 2017. Hao-Li has a sober lifestyle. As a student, he used to live in an underground apartment with a floor area of 15 m<sup>2</sup>. Most of the money that Hao-Li earns, is saved on his savings account. He plans to purchase an Audi A3. Hao-Li transfers € 1000,- a month to his mother in China.

NAME Hao-Li Rong

SKILLS Programming, Electronics, Scientific Research.

AGE 32

MOTIVATIONS Family, money, curiosity.

STATUS Single

FRUSTRATIONS Bureaucracy, irrationality, the Dutch language, bugs.

CHILDREN n/a

EXTROVERT Medium

LOCATION Beijing (China)

RATIONALITY High

WORK	Assistant Professor at TU/e	IQ	132
CONTRACT	38 hours	LIFESTYLE	Unhealthy, busy, hard working.
INCOME	€ 82.075,- ex. (year)	LIFE EXPECTANCY	75 to 85 years
HOBBIES	Creative Electronics, Programming, Arduino, Measuring, Cars		
BRANDS	Audi, Apple, Huawei		

### Ethan and Nikki Phillips



#### Personal:

Ethan and Nikki are a young couple who have recently moved into the city center for work. They now live in an underground apartment. This is rather strange for them as they used to live in the suburbs where they have access to lots of light and sunshine.

#### Background:

- Ages 24 and 25
- Just started new jobs in the city
- Building a new lifestyle together
- Used to live in the suburbs together
- Grew up together
- Married last year
- Has family and friends in the area

#### Customer Needs:

- Needs more natural light
- Feels a bit stuck in small apartment
- Wants something stylish and clean to fit both of their aesthetic tastes
- Wants better ventilation for stuffy apartment

### Julie



Julie is 18 and just started with studying. She loves to play the piano and to go for a run in the woods. To save some money she rents a studio underground. She is very happy with what she gets for the small price, but she misses the nature around her house. Especially the sun which wakes her up every morning. She desires a concept which gives her the best fake sunlight but it should be easy to apply and has to be affordable for a student.

#### Needs

- Feeling of a window
- Fake sunshine in the room
- An affordable solution

### Ben



Ben is 30 years old. He just finished his study and plans to go to work in a busy city. He just got a job offer, but has some issues with traveling. He wants to move to the city, but can't find a house anywhere. He doesn't really have any requirements for a house, because he won't be home much. He likes to be outside and grabbing a drink after work. He prefers eating in a restaurant over cooking for himself. So his only needs are a spot for a bed, a toilet and a bathroom. He doesn't want to be late for work which is in a skyscraper office. He heard about the housings underneath the building, but he only worries about the daylight not reaching his room. He is very interested in the new concept for replacing windows with artificial ones.

#### Overall, his needs are:

- Separate bedroom
- His own toilet
- A bathroom
- Daylight (artificial is also fine)
- A small little breeze
- A kitchen for the little snacks
- A desk to work on

# Appendix B - SWOT Analysis

## SWOT - Strengths Weaknesses Opportunities Threats

<https://www.thebalance.com/how-to-conduct-a-swot-analysis-2275929>

**Strengths** - Due to the fact that housing is becoming a problem in bigger cities, we will need to think about a solution. One of these solutions is building houses underground. This might seem like a great idea, but healthy-wise this causes a lot of problems. The lack of sunlight creates depression, the feeling of loneliness and gives you the feeling of being locked up. Besides the lack of sunlight, people also experience a lack of fresh cooled air. This is why we wanted to find a solution for the lack of sunlight and fresh air in one system. Our idea is to make a fake window, with sunlight and a small fresh breeze, to make the underground living possible, and solve the problem of housings in bigger cities.

- addresses underground housing issues like lack of sunlight and ventilation
- Helps address SAD and other disorders associated with lack of sun
- inexpensive and effective → targets people who don't have the means to live above ground
- easy to install → user/consumer based no need to address housing complexes or anything architecturally.

**Weaknesses** - The fake light could foul up your day-night rhythms. This could eventually give you the feeling of a jetlag. This wouldn't be practical for a normal working schedule. It is also very hard to replicate the same amount of luminosity as the sun's, and not to be forgotten the same amount of Vitamin-D. This could give a wrong impression about the effectiveness of a fake sun.

**Opportunities** - To make sure your day-night rhythms won't be fouled up, we will implement sun-cycle into the brightness of the window. Not only with a change of brightness, but also a change in color. As for the vitamin-D supplement, we will replace some of the bulbs with special vitamin-D lamps. They do need a timer on them, because of chance of burning, tanning and even a risk of skin cancer. Experts tested this, and it does work.

- increase in underground housing
- increase in awareness about SAD and depression → more research
- create new working hours → helps with jetlag and helps with people with demanding jobs
- inexpensive and easy to install → opens this product to younger generation and people less financially stable

**Threats** - living underground could affect social behaviour, people being stacked underneath each other, and create new working hours that grow considerably in a wrong way. Other companies that try to replicate it, for a lower price, but with less effect / harmful effect.

- CoeLux
- Jetlag
- improved chance of skin cancer → lack of knowledge about the lights
- other technical things

# Appendix C - Questionnaire 1

Title: UNDERGROUND LIVING

Introduction:

Hi there! We are four students Industrial Design from the Eindhoven University of Technology who are interested in underground lighting. We are developing a technology for underground living and would like to know your opinion. This questionnaire should take 10 minutes at most.

Please note: this questionnaire is mainly aimed at adolescents, students, and young adults. Input and information from other age groups is also appreciated however.

Hallo daar! Wij zijn vier studenten Industrial Design van de Technische Universiteit Eindhoven die geïnteresseerd zijn in ondergrondse verlichting. We ontwikkelen technologie voor ondergrondse huisvesting en willen graag uw mening in acht nemen. Deze vragenlijst duurt maximaal 10 minuten.

Nota bene: deze vragenlijst is hoofdzakelijk gericht op adolescenten, studenten en jongvolwassenen. Input en informatie van andere leeftijdsgroepen wordt echter ook gewaardeerd.

Questions part 1:

How old are you?

16-18, 19-21, 22-24, 25-27, 28-30, 31-33, other...

What is your current occupation?

I am a student (full-time)

I am a student (studying + part-time job)

I've (just) started working

Other...

How bright do you want your room?

A scale from 1 up to and including 10 from dimmed to bright.

Would you consider living underground?

Yes, No, Maybe

Why did you choose 'Yes', 'No', 'Maybe'?

\*open answer\*

Would you care if you don't have any natural (day-) light in your home?

Yes, No

Why wouldn't you care?

\*open answer\*

How much natural light vs. artificial light do you have at home (approximately)?

100% natural light vs. 0% artificial

70% natural light vs. 30% artificial

50% natural light vs. 50% artificial

30% natural light vs 70% artificial

0% natural light vs. 100% artificial

How many windows do you have in your main living space and what are their average dimensions approximately?

Amount of windows: 1, 2, 3-4, 5 or more

Average dimensions: Small (0.5 m<sup>2</sup>), medium (3 m<sup>2</sup>), large (6 m<sup>2</sup>), extra large (wall-sized)

Product introduction:

We are developing a technology for artificial underground lighting to improve underground housing. With our technology, it should feel like you are still living above ground.

The system would consist of lamps that imitate sunlight and fans that give you the feeling that there is some wind breezing through your window. The next questions are about our design.

We ontwikkelen een technologie voor kunstmatige ondergrondse verlichting om ondergrondse huisvesting te verbeteren. Met onze technologie zou het moeten lijken alsof u nog steeds boven de grond leeft.

Het systeem zal bestaan uit lampen die zonlicht nabootsen en ventilators die u het gevoel geven dat er wat wind door uw raam waait. De volgende vragen gaan over ons ontwerp.

<< pictures of our device and branding logo, to give people a better understanding of our concept design. >>

Questions part 2:

Where would you place our device?

- In the kitchen
- In a bedroom
- In the common room
- In the bathroom
- Other...

Do you prefer a ceiling-mounted or a wall-mounted system?

- Ceiling-mounted
- Wall-mounted

Would you like to control the system?

- Yes, I would like to control the light
- No, the default settings are fine.

How would you prefer to control the system?

- With an app
- With a remote control
- With a control panel on the wall
- With a switch on the system/connected to the system
- With a timer system
- I would not like to control the light
- Other...

Would you like to have the option to connect the system to a weather app, so the light and fans adapt to current weather conditions?

- Yes, No

Do you have suggestions or other thoughts?

\*open answer\*

Final words:

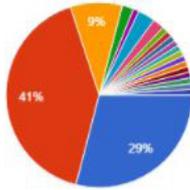
Thank you! | Dank u wel!

Would you be interested in being a part of our user test? If so, please leave your email address behind below. Thank you for your time.

Zou u geïnteresseerd zijn om deel uit te maken van onze gebruikerstest? Zo ja, laat alstublieft hieronder uw e-mailadres achter. Bedankt voor uw tijd.

### How old are you? | Wat is uw leeftijd?

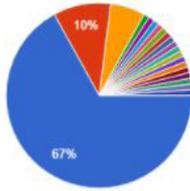
100 reacties



- 16 - 18 years
- 19 - 21 years
- 22 - 24 years
- 25 - 27 years
- 28 - 30 years
- 31 - 33 years
- 36
- 50

### What is your current occupation? | Wat houdt u bezig?

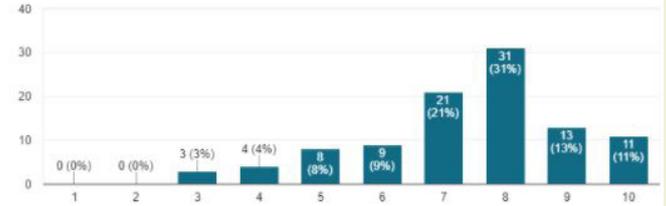
100 reacties



- I am a student (fulltime) | ik ben stu...
- I am a student (studying + part-time...
- I've (just) started working | ik ben (n...
- 30 jaar werkzaam
- Huisvrouw
- Pensioen
- Werk, moeder, huisvrouw
- Al jaren werkzaam

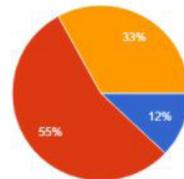
### How bright do you want your room? | Hoe licht wilt u uw kamer?

100 reacties



### Would you consider living underground? | Zou u overwegen om ondergronds te wonen?

100 reacties



- Yes | Ja
- No | Nee
- Maybe | Misschien

How bright do you want your room? | Hoe licht wilt u uw kamer?

How much natural light vs. artificial light do you have at home (approximately)? | Hoeveel natuurlijk li...stmatig licht hebt u thuis (ongeveer)?

Would you care if you don't have any natural (day)light in your home? | Zou het u uitmaken als u geen natuurlijk (dag)licht in uw huis hebt?

Would you consider living underground? | Zou u overwegen om ondergronds te wonen?

What is your current occupation? | Wat houdt u bezig?

How old are you? | Wat is uw leeftijd?

How bright do you want your room? | Hoe licht wilt u uw kamer?

How much natural light vs. artificial light do you have at home (approximately)? | Hoeveel natuurlijk li...stmatig licht hebt u thuis (ongeveer)?

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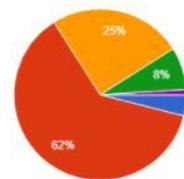
Would you consider living underground? | Zou u overwegen om ondergronds te wonen?

What is your current occupation? | Wat houdt u bezig?

How old are you? | Wat is uw leeftijd?

### How much natural light vs. artificial light do you have at home (approximately)? | Hoeveel natuurlijk li...stmatig licht hebt u thuis (ongeveer)?

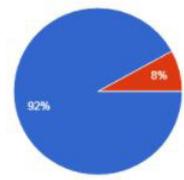
100 reacties



- 100% natural light / 0% artificial | 100% natuurlijk licht / 0% kunstmatig
- 70% natural light / 30% artificial | 70% natuurlijk licht / 30% kunstmatig
- 50% natural light / 50% artificial | 50% natuurlijk licht / 50% kunstmatig
- 30% natural light / 70% artificial | 30% natuurlijk licht / 70% kunstmatig
- 0% natural light / 100% artificial | 0% natuurlijk licht / 100% kunstmatig

### Would you care if you don't have any natural (day)light in your home? | Zou het u uitmaken als u geen natuurlijk (dag)licht in uw huis hebt?

100 reacties



- Yes | Ja
- No | Nee

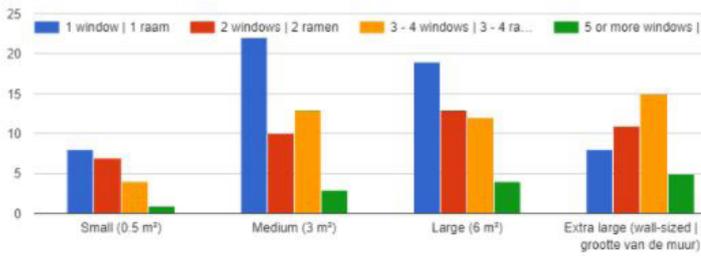
Would you care if you don't have any natural (day)light in your home? | Zou het u uitmaken als u geen natuurlijk (dag)licht in uw huis hebt?

Would you consider living underground? | Zou u overwegen om ondergronds te wonen?

What is your current occupation? | Wat houdt u bezig?

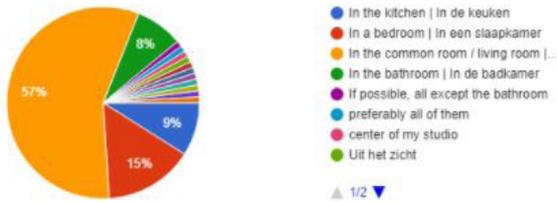
How old are you? | Wat is uw leeftijd?

How many windows do you have in your main living space and what are their average dimensions approximate...middeld ongeveer de afmetingen van?



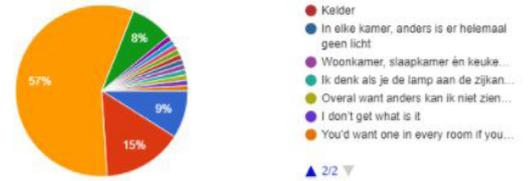
Where would you place it? | Waar zou u het systeem plaatsen?

100 reacties



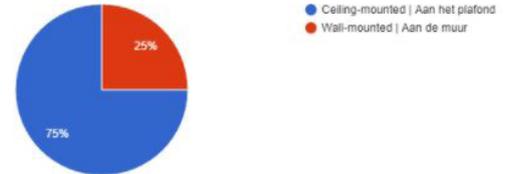
Where would you place it? | Waar zou u het systeem plaatsen?

100 reacties



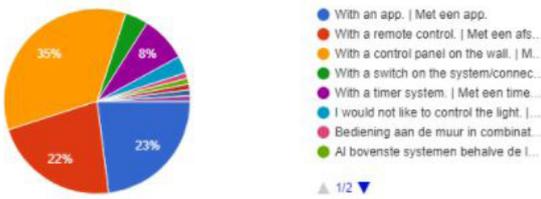
Do you prefer a ceiling-mounted or a wall-mounted system? | Hebt u liever een aan het plafond gemonteerd of een aan de muur bevestigd systeem?

100 reacties



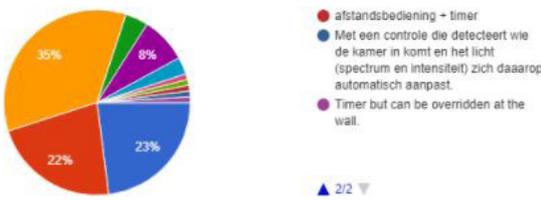
How would you prefer to control the system? | Hoe zou u het systeem het liefst willen regelen?

100 reacties



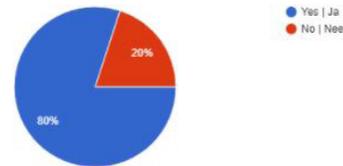
How would you prefer to control the system? | Hoe zou u het systeem het liefst willen regelen?

100 reacties



Would you like to have the option to connect the system to a weather app, so the light and fan adapts to curren...t aan de huidige weersomstandigheden?

100 reacties



Feedback form with multiple sections for user input, including questions about system integration and user preferences.

Feedback form with multiple sections for user input, including questions about system integration and user preferences.

# Appendix D - Consent Form

## Consent Form



### Introduction

You have been invited for a user study about artificial lighting. This study will be conducted by Rachel Feldman, Wouter Stevens, Emma van Amersfoort, and Nijs Bouman from the Department of Industrial Design, Eindhoven University of Technology. You must be older than 18 years to participate in this study.

### Procedure

If you agree to participate in this study, you will be asked to carry out certain tasks regarding user interaction and you will be asked about lighting and windows. Participation of this study will take approximately 20 minutes. Should you have any questions, please let a responsible researcher know.

### Rights

Participation of this study is voluntarily. You may refuse to participate or withdraw at any time.

### Risks

There are no special risks associated with the participation of this study.

### Confidentiality

Your personal data will not be shared outside the research group. It will only be used for further communication if necessary. All data will be kept confidential by the researchers. Published information about the study will be anonymized.

### Agreement to Participate

By signing this form, you indicate that you have read and understood the above information, you have decided to participate, your age is at least 18 years and that a copy of this form has been given to you.

### Additional Permission

Please check the boxes when applicable:

- My voice may be audio recorded for research purposes only.
- My gestures may be video recorded for research and promotional purposes.

---

I agree to participate

Signature:

# Appendix E - Midterm Questionnaire

Q1	Q2	Q3	Q4	Q5	Suggestions/tips/things we should change?
No	Yes	Bedroom	Wall	Yes	Make that gesture-thing!
Maybe	Yes	Everywhere	Wall	Yes	Add something for the night
Maybe	Yes	Common room	Ceiling	Yes	Empty
Maybe	Yes	Kitchen, Bedroom, Kitchen	Ceiling	No	Q4, Because it is just light, no vision. Q5: In order to make it seem more natural. Extra: You mentioned a mural for a wall-mounted solution. Maybe try something like a window to a room designed to look like the outdoors?
Yes	Yes	Kitchen, Bedroom, Kitchen	Wall	Yes	Maybe use sound for rain?
Yes	Yes	Everywhere	Wall	Yes	Connect final prototype to real weather data. For example virtual flight to Italy, to where the sun shines.
Yes	Yes	Common room	Ceiling	Yes	Empty
No	Yes	Kitchen	Wall	Yes	Empty
No	Yes	Everywhere	Ceiling	Yes	Empty
Maybe	Yes	Common room	Both	No	Make it feel real!
No	Yes	Common room	Ceiling	Yes	Empty
No	Yes	Bathroom	Both	Yes	Q4, depends on which room. In a kitchen or living room it would feel more natural on a wall but in the bathroom it would feel like you have a bit less privacy when places on the wall and I would prefer the ceiling. Extra: Not in particular. Maybe pay attention to the color of the wall.
Yes	Maybe	Common room	Ceiling	Yes	Thinner box / mounted in the ceiling (less obvious)
No	Yes	Bathroom	Wall	Yes	Empty
Maybe	Yes	Common room	Wall	No	Empty
No	Yes	Kitchen, Common room	Ceiling	Yes	Q5, Mainly not, but just in case I want to change things.
No	Yes	Common room	Ceiling	Yes	Q5, Mainly not, but just in case I want to change things.
No	Yes	Everywhere	Wall	Yes	Q3, Wherever there isn't a window.
No	Yes	Common room	Ceiling	Yes	Empty

# Appendix F - Expert Interview

<https://soundcloud.com/wouter-stevens-3/expert-interview-prof-dr-ir-yvonne-a-w-de-kort-tue-group-14c-industrial-design/s-CumWI>

The Audio File is on private mode, and can only be accessed through this private link.

Questions we asked our Expert:

What is your experience in the area of creating artificial sunlight?

Thoughts on our product

Helping SAD

How it helps connect users to exterior environment

Thoughts on how to conduct user testing?

How to manipulate lighting to make things seem different for users

Benefits and risks of different lights (which ones help sunlight deprived people, color control, Are there significant differences between warm and cold light?)

What are the main problems with creating a light that mimics sunlight?

How effective is it, compared to the real sun?

How to best diffuse light to look natural

Current lighting situations in housing

If she is aware of how this problem is being solved (how dark rooms are being lit)

Research/websites/products she thinks we might find interesting

# Appendix G - User Testing 1.0

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[https://drive.google.com/drive/folders/14\\_JM23gV-wj\\_SnJk7QKTCqukXpLpYdcB?usp=sharing](https://drive.google.com/drive/folders/14_JM23gV-wj_SnJk7QKTCqukXpLpYdcB?usp=sharing)

This is one of the recorded videos from our first User test, unfortunately this was not useful for further development of our prototype.

Questions we asked during the user test:

Would you like to read and sign our contract before starting our user test?

How do you describe this window? (normal window)

How connected do you feel with your outside environment?

How do you describe this window? (window covered with paper)

How connected do you feel with your outside environment?

Do you still think the window performs its function differently with paper on it or without?

Would you want to live underground?

Here is a short video that we have made describing our product. Which aims to help people who live underground have more natural lighting.

\*Introduction video to our idea and prototype\*

What do you think of our device compared to a real window?

Which of the features do you find the most useful?

What about the color mimicking?

What about the fans?

How would you want to control the window?

How would you attempt to "Shut the curtains" (Make it dimmer/turn off)

How would you attempt to "Close the window" (Turn on/off the fan function)

# Appendix H - User Testing 2.0

Light Group:

Stress test - <https://www.bemindfulonline.com/test-your-stress/>

23

24

17

15

18

17

8

11

10

14

33

23

26

19

25

20

12

14

The average score of the stress test was 18.3

How did you perceive this waiting? Was the waiting relaxing or intense?

Meh, not really one way or the other

Relaxed

Well it was chaotic, wasn't focusing on device, confused,

It was okay people were nice

I thought it was comfortable and relaxed

Wasn't bad waiting because there were friends around

I did notice the lights

Staring at the lights since it was pretty

Discussion about how they change

Like the changing

It was entertaining

Fairly comfortable

Nice, good conversation

Annoying,

It wasn't stressful it was chill

Pretty normal

Relaxed

Didn't perceive it as waiting because of the talking

Dark, I hate fluorescent light, especially the warm light

Questions about the product in general:

Do you feel like this product is effective?

It's not finished

Graphics are a bit childish, realism is missed and snaps out of the effect

Not sure how much scenery would improve it, know that it isn't real

Like to see cars and people pass

Prototype, needs to be more realistic

I think it's quite nice because it doesn't give really light is nice which gives the kind of light

Does add something to the atmosphere

If I would live in a home without windows i think this would give some adds something

Childish

Reminds me of play screen

I would consider using it

I couldn't live inside without windows

It's nice at home during the day I open my curtains and don't have artificial light

I think you need to be careful because it has a large effect on people's mood, shouldn't always be dark

Rain can also be relaxing, don't make it depressing

I like thunder and storms

I like hearing the sounds

My mood can change a lot if it's raining for days on end I would appreciate if it turns sunny every so often

Pretty cool

It needs to be more realistic

Like the atmosphere that it gave to the room

A lot more calming doesn't feel as contained

Yeah it's nice, like between a window and art

Nice to look at

Yes, reduces frustrations

Very human, because of the different colours

It could be if you are in a room with no windows it could be

Better than no windows

I would say it's really cool the way it mimics it is interesting, not a realistic depiction now though, it's just a prototype

I am often really light sensitive, I always look for enough windows in my rooms

Unconsciously it helped me feel more relaxed, especially because of the light change.

Light change makes it realistic

I think it is effective, now it's not that realistic, a little more realistic it might work better the layers help

I think it is, if it was underground I would want a curtain in front of it since I know it isn't real, I don't want

the scenery	whole thing
I would want to choose my own scenery	Missing other senses like sounds and rain, smell, fresh air
Something from my memory	Not as much a a real window but more than nothing
I like to see stuff happening	Movement is lacking
Daydreaming	Doesn't need to be super realistic
Looking down	I like the change with the weather
WOuld you change the weather conditions with a remote?	Really enjoys the shadows and now diffused the light
I would like to control it makybe have a way of adjusting it once you know the real conditions	is
Temperature panel something that doesn't influence mood but give information	I feel like it would be nice to be notified about the weather, can just look out the window
Maybe, yes more control, no you can't change it in real life	Moderately, makes me think of the outside, quite realistic kinda, more if it was against a wall and I knew it was outside on the other side
Yes, lift your spirits up/down, follow your mood weather conditions	real Yes, when it's connected to the outside environment, you don't miss it
I think just mimic what is outside, with a real window you can't either	As of right now probably not since I have a window
I would want to control it, gloomy day is depressing I would want sun	If I didn't have a window then this would help
Compared to a normal light screen	Kind of I guess, First thing I noticed is the levels
Depends on how it was implemented	I'm not sure since it's not real and that's something that you can't see
Concealed in the ceiling or in the wall then prefer without scenery because want own artwork	A little more realistic would help
Light is important but he likes real windows, wants clear panels	I feel like it would, I feel like I would feel happier looking at this opposed to concrete
Likes our prototype more since connection to nature	Not sure how I feel about this
Cool that it changes	I feel like I would want it to mimic exactly what is outside, I would rather want to see the city or a brick wall as long as it is accurate, ugly better than beautiful unrealistic
Gives more of an atmosphere	Can you compare and contrast this with a window?
Can actually look into the light unlike a lamp	Window has dynamic this is a bit too static
Wants more than just the light box. Can look at it longer	Ventilation
	Well a when you have a real window what you see changes more
Do you think that this helps connect you to your outside environment?	This is more of a slide show, always the same video , see bird or other nature
Not sure about connection part of it because unsure how much color temperature changes	This is more of a childish view
Like color temperature to change over course of the day, not as much with weather	Obvious that it's not a real window
Really cloudy is depressing might always want sunny weather	Light makes it more realistic
Yes	Use real screen
Would be nice to mimic the real outside weather so you could check the weather	Movements in the view
Only want it to be really realistic	It's a bit fake and typically wouldn't see a whole tree.
Always want it bright for own happiness	Things are moving outside with a real window
Would consider using the device	Get bored more easily with this
Perhaps a little fake but there is a connection	very quiet
Yes	Real window has noise
Connects to the mood of the environment but not the	Sounds are nice, used to hearing cars
	Not being able to see moving things outside
	Not being able to open it
	Need fresh air
	Outside fans or inside fans?

Want outside air and smell (after it has rained is the best)	Right now I just think it's cool the way it changes, I could imagine it being soothing
Sound needs to be addressed	I really like it, It's a really good idea, I like the transparent Like the transparency since it adds colors and movement
Movement in the image	Serene calming
Movement is the most important	Relaxing
The same with the atmosphere doesn't feel as contained	Do you feel like it has depth
Gives something to look at not as stressful	The transparency is a bit too much
It's shaped like a window	Depth does help
It has the different	Layers creates some kind of depth but still want a little bit of movement
Lighting makes it way more realistic especially the cloudy	Likes the depth
Depth, not same depth but different	I think the depth adds realism
Reminds me more of art	Definitely also most expect movement
Feels like a screen, static, moving leaves/clouds	See depth
Maybe this attracts more attention	Distance is very great and continue with this
Might be more distracting	Could make it more realistic
Get used to it after a while though	I like it.
The scenery doesn't change. As I get used to it it would just me another prop since it's not very natural	Looking at it all the time
The real windows is more of your basics surrounds while this is more of a general depiction	Gives depth
I would rather look at this than a normal window because of the changing lights and cool depth, very interesting to look at. If it goes yellow it really feels like the sun is shining	Like the depth but the transparency is a bit too transparent
I think that the light is changing too frequently	Some of the transparency is conflicting but the depth is necessary
Blue light is a bit too blue	I see what you are doing, pretty effective for a window without making it too thick, flat wouldn't be as nice
I like the tone of the warm light	It's better than not having depth,
Feels like a cloud drifting by	Really like it more like a real window
Can you compare and contrast with with a light?	Kind of because you can make out the distant things from the ones closer
Scenery	Really makes a difference gives more depth
Mimics outside temp and brightness	Yes, composition is good
Ventilation?	Very calm
Can you describe how you feel looking at the product?	The thing is that creating more depth, creace more detail in the front, turn more grey in the background
First reaction graphics are nice for prototype reminds of inside playground for children	I like the color
Main questions is how this fits with aesthetics of own room	Up close more finely detailed
Wants choice	Like to see more depth
I don't know if windows typically invoke an emotion	I like the transparency
Don't feel worse or better	Changing this
Find it soothing	Like the ability to change
Calms me down	Gives different mood
Cooler light is better to look at	Want to see city or park
Calm, peaceful	Depend on situation and mood
Warm: pleasant	Friends parting → city new york studying park
Sunny makes me not more happy but calm vibe	I would like to change the screens but feel like it would be used in the beginning but not very much later Just get used to one
Nice to look at	Want to change
I'm just fascinated	Want the sea
I think it's really cool how you're able to do it	

I would just use the lights, wouldn't really use it for the idea  
scenery  
Pulling it out and putting it back in is too much work  
Different scenery wouldn't impact me as much as the  
lights  
Same display is okay  
Yes but i don't know if I would change it often if I had  
to manually change it  
Takes too much time to change the scenery  
If a remote I would consider it more often  
I would change it for the seasons, I don't know, maybe  
often  
Normal window is the same scene except for the sea-  
son  
If I want to simulate an actual window I would change  
it  
I don't know, depends, for me I think this is fine  
If I would use this I don't think I would change them,  
I don't feel the need to change it since it's in the back-  
ground  
Maybe not panels, screen might be better,  
Looks like it is for a playroom  
Personal bedroom might want to see something else

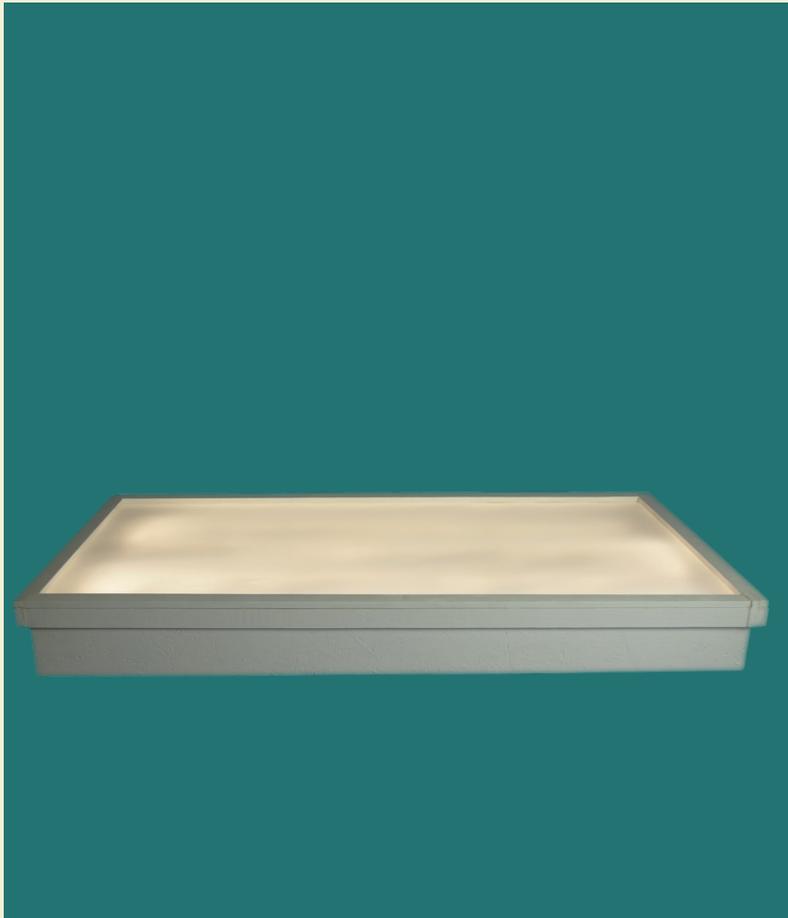
I know there would be people who would like this  
I really like the color changing  
If it had a curtain I would want it.  
Lets light through  
Curtains add depth and and homey

#### Final thoughts

Like the idea think it's a nice product even outside of  
target group might use it as decoration when little he  
had an electronic painting with water which was nice,  
piece of art  
Really likes it and the depth  
Felt like the stress test didn't reflect how chill he was  
right now, since he was reflecting too much on previ-  
ous experiences  
Wasn't based on the  
Leaves move  
Continue really like the idea  
Execution is really good.  
First iteration was weird now with the view it is a large  
improvement  
Might be nice for people in cities  
Multiple panels might be fun to see  
Looked into making the light softer or harder  
I think it's a nice project, really nice prototype  
Prepare for business questions  
Cost and stuff  
Be confident  
I like the idea  
I like the idea I think it would be effective  
I personally don't know if I would use it but I like the



# Appendix J - Posters Midterm



B1 / DPB100 Project 1 Design  
Smart and the City



## ALUX

ALUX is an artificial window that turns your underground living into a lighter, healthier experience. It provides you the feeling that you still live above ground. Our device will turn your underground ceiling into a sky. With adjusted colors for the different weather conditions, you won't even notice it being artificial.

Our goal is to make underground living a better experience. ALUX uses a large number of Light Emitting Diodes with various color tones to provide even, natural lighting into your underground space. Also, a breeze of fresh air is provided by ALUX, to help improve the underground living experience.

### Project coaches:

Sander Lucas  
Tove Elferrich

### Group: 14C

### Students:

Emma van Amersfoort  
Nijs Bouman  
Rachel Feldman  
Wouter Stevens

## ALUX

ALUX is an artificial window that turns your underground living into a lighter, healthier experience. It provides you the feeling that you still live above ground. Our device will turn your underground ceiling into a sky. With adjusted colors for the different weather conditions, you won't even notice it being artificial.

Our goal is to make underground living a better experience. ALUX uses a large number of Light Emitting Diodes with various color tones to provide even, natural lighting into your underground space. Also, a breeze of fresh air is provided by ALUX, to help improve the underground living experience.

### Current Prototype

Our prototype currently consists of a box with many different layers. The first layer is the electronics for the lights. The second layer has a warm LED strip and a cold color LED strip attached to it. The lid has a semi-transparent layer to it to help disperse the light and still let through the optimal amount of light. The box is made from wood, because it is an inexpensive material and it is very practical to work with. The two different LED color strips fade between the warm light and the cold light to simulate all different weather conditions. The warm light mimics a sunny day while the cold light mimics an overcast day.



### Features

- Light fades naturally
- Mimics natural light
- Mounts to walls and ceilings
- Warm and cool tones
- Fans for circulation

### Next Steps

We want to address the second largest problem with underground housing with the next prototype. We will put fans in the base of the prototype to help with air circulation. We also want to look into a way of connecting the light to mimic current outside conditions to help people feel more connected with their environment. We also will be looking into both wall mounting and ceiling mounted apparatuses and doing user testing to validate our product further.



# Appendix K - Posters Final

## The Business Model Canvas

Designed for:

Designed by:

Date:

Version:

<b>Key Partners</b>  Building landlords Architects Doctors/therapists	<b>Key Activities</b>  Promoting awareness about seasonal affective disorder s and depression Health campaigns Promoting underground housing	<b>Value Propositions</b>  ALUX - The artificial light Installing ALUX into homes	<b>Customer Relationships</b>  Integrated into their homes Helps them connect with their outside environments Provides art and imagery in homes	<b>Customer Segments</b>  People living in underground housing and places without many windows. People in large cities People who own buildings which have rooms without many windows
<b>Key Resources</b>  Underground housing complexes Lighting manufactures		<b>Channels</b>  Supplied by lighting companies In the future supplied with windows Built into homes		
<b>Cost Structure</b>  Users buy it for one room in their home if not already installed They buy more screens to change the image			<b>Revenue Streams</b>  Users buying ALUX Installing ALUX charge Landlords or building designers integrating ALUX into their spaces Users buying new image screens	

DESIGNED BY: Strategyzer AG  
The makers of Business Model Generation and Strategyzer

**Strategyzer**  
strategyzer.com



*B1 / DPB100 Project 1 Design  
Smart and the City*



SCAN FOR EXPLANATORY FILES

### PROJECT TITLE

ALUX is an artificial window that turns your underground living into a lighter, healthier experience. It provides you the feeling that you still live above ground. Our device will turn your underground ceiling into a sky. With adjusted colors for the different weather conditions, you won't even notice it being artificial. The implemented imagery creates an illusion of movement like a real window.

Our goal is to make underground living a better experience. ALUX uses a large number of Light Emitting Diodes with various color tones to provide even, natural lighting into your underground space. Also, a breeze of fresh air is provided by ALUX, to help improve the underground living experience.

**Project Coaches:** Tove Elfferich & Sander Lucas

**Group:** 14C

**Students:**

- Emma van Amersfoort
- Nijs Bouman
- Rachel Feldman
- Wouter Stevens

**Experts:** prof.dr.ir. Y.A.W. (Yvonne) de Kort  
Department of Industrial Engineering & Innovation Sciences

# ALUX



## FANS:

Provide you the feeling of natural air circulation.

## IMAGERY:

This creates an illusion of movement.

## LED'S:

With adjustable colors ALUX makes sure you have the outside weather conditions inside your house.

## PROBLEM:

Smart cities are growing in population, everyone wants to live in one. Cities like Beijing are already accommodating people underground and this solution to housing is starting to be a trend of the future. Underground housing has many side effects though, mainly due lack of light, ventilation, and imagery.

## FUTURE PLANS:

- Different sceneries
- Improved control panels
- additional senses
- improved casing
- improved fans

## WEATHER CONDITIONS

### SUNNY DAY: WARM COLORS



### CLOUDY DAY: MIXED COLORS



### COLD DAY: COLD COLORS



