SUPPORTING RESIDENTS TO TRANSITION PRACTICES IN ZERO ENERGY HOMES

Elise Wabeke

COLOPHON

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Elise Wabeke

Supervisory Team
Stella Boess
Froukje Sleeswijk Visser

Client
Sacha Silvester, 2ndSKIN Project

EXECUTIVE SUMMARY

Residential housing has to become more sustainable to meet global energy goals (Silvester et al., 2017), yet the challenge is to integrate the refurbishments that reduce energy with the way people live. The context of this project is the 2ndSKIN project, which refurbishes houses to become net zero energy. Zero energy houses are more airtight as a result of improved insulation, therefore ventilation becomes increasingly important. Yet, residents struggle to integrate the new balanced ventilation system into their practices. Residents use the system different from how it is intended. This does not only impact energy goals (Behar & Chiu, 2013) but can also result in decreased comfort and unhealthy situations. Hence, the aim of the project is to support residents to transition their practices in zero energy homes.

The project first described the practice of maintaining indoor air quality to identify points that hinder a transition of the practice. Insights show that the lack of feedback of the ventilation system makes residents insecure and makes it hard to understand the system. Besides, associations that mismatch the new material make residents reluctant to use the balanced ventilation systems.

In the concept phase, I generated ideas to improve feedback and foster desirable associations with the ventilation system. Through the iterations, I learned feedback on functioning and on the systems' activity helps residents. It helps them to trust the system is working, understand what the system is doing and develop appreciation for it. The final concept is the feedback fan. This add-on to ventilation valves spins on the supplied air. In a natural way, it provides residents with feedback. An evaluation proved that with increased feedback, residents are able to incorporate the system in their daily routines and even align their own actions to the systems' activity.

Future steps are to make a solid prototype and develop the service around it. Besides, future design projects can use further identified points that hinder the transition of practices as a start. Moreover, insights about feedback of the ventilation system and the practice of maintaining indoor air quality will be valuable, when designing future ventilation systems.

In conclusion, both the final design and the insights of the project can contribute to a transition of residents' practices zero energy homes.

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1. INTRODUCTION

This chapter introduces the original objective of the project and elaborates on the approach that has been taken

1. INTRODUCTION

To become more sustainable and meet energy goals, large parts of the existing housing stock have to be refurbished (Silvester et al., 2017). As is agreed in the Paris Climate Agreement, action is required to limit global warming (United Nations, 2016) To reach the necessary decrease of CO_2 emissions, the Dutch government aims to have an energy neutral build environment by 2050.

Applied technical advancements in refurbishments drive the decrease of energy consumption, but how these innovations integrate with the practices of people should not be overlooked. The context of this project is 2ndSKIN project, which refurbishes houses to become zero energy. In the process, heat pumps, increased insulation and solar panels are applied. However, after renovation there is often a discrepancy between the actual and expected energy consumption of the house. Residents' behavior and preference play an important role in this difference (Behar & Chiu, 2013; Paone & Bacher, 2018). Residents for example use the system different from how it is intended and have difficulties to incorporate the systems in their daily routines. This does not only impact energy goals (Paone & Bacher, 2018), but also decreases comfort and lead to unhealthy situations (e.g. low air quality due to poor ventilation).

ASSIGNMENT

New technologies enter residential housing with zero energy refurbishments, but for residents it is a challenge to develop new daily routines that incorporate these technologies. Therefore, the design goal of the project is:

"How to support residents in developing new practices in their zero energy home?"

Targeted practices are maintaining indoor air quality and keeping a comfortable indoor temperature. The new technologies are the heat pump and the ventilation system. The new practices should both fit residents personal practices and energy goals.

Research questions were:

- What practices do residents have in relation to indoor climate?
- What material, skills and meanings are attached to residents' practices (Kuijer, 2017)?
- To what extend do residents transition practices after refurbishments?

APPROACH

Process

This project roughly consists of three phases (Fig. 1). The first phase, the explore phase, scoped the project to the practice of maintaining indoor air quality. I performed explorative interviews and literature research on practice theory and zero energy homes. The second phase, the define phase, I had in-depth interviews with residents. Thereby I was able to describe the practice of maintaining indoor air quality and develop a problem statement. Using the problem statement, three design phases followed. In each design phase, I ideated on solutions, developed and evaluated them. The evaluation formed the start of the following design phase. The result of this project is a description of the practice of maintaining indoor air, a design that supports residents to transition their practices in the current situation and recommendations for ventilation systems of the future.

Practice-oriented approach

A practice oriented approach is central to this project, as project goal is to support residents to transition their practices. Practices are routinized ways of doing (Shove & Watson, 2006). The advantage of taking practice-oriented approach is that it broadens the analysis away from product-user interactions (Kuijer, 2017). By understanding routine actions of residents, I can identify points for intervention to support a desirable reconfiguration of practices in their refurbished house.

In the define phase, the goal is to describe the practices and identify points of intervention. In the design phase, I use these points to develop solutions that support residents to transition their practices.

REPORT

This report starts by describing the context, technologies and theories that are important to the project. Thereafter it discusses all field research and findings, followed by the thee design phases. The third design phase concludes the project with a final design and future recommendations.

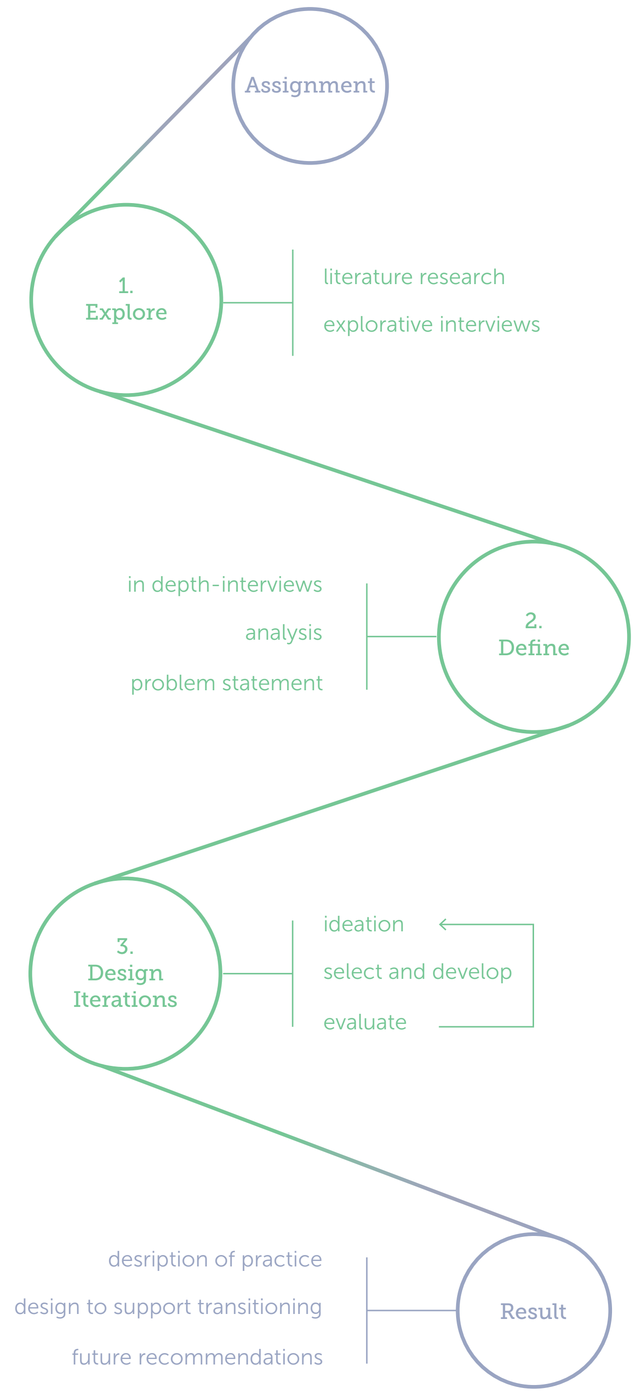


Fig. 1 - Explorative field research creates a scope in the explore phase. In-depth research, in the define phase, results into a problem statement. This statement formed the start for three design iterations

2. LITERATURE

This chapter introduces topics that are relevant to understand the project. It elaborates on the context, zero energy homes, and practice theory

2. LITERATURE

PRACTICES

This project does not primarily focus on a product or interaction. Instead, it takes practices as point of view. Practices are things people do and regard as normal. Cooking is a practice. However, cooking on a camping trip is quite different from cooking at home. This demonstrates the distinction between 'practices as an entity' and 'practices as a performance'. Cooking is the overarching entity; the different observable ways of cooking are the performances (Kuijer, 2017).
In literature, practices are described as a configuration of the following elements: skills, material, and images (Kuijer, 2017). In the cooking example, material are pans and knives. The skill is knowledge required for cooking, for example how to boil an egg. Images are the meanings people attach to cooking, for example on what is healthy or sustainable food.

Transitioning practices

Practices are not fixed; they are dynamic and can transition over time. In the process some materials, skills, and meanings become useless. At the same time, some new ones will be needed. The practice of maintaining warmth is used to illustrate this. With the introduction of gas, coal sheds and the skill of creating a fire became obsolete. Meanwhile, pipes and skill to regulate temperature using knobs became needed. At the same time, related imaged changed as the amount of work involved decreased (Kuijer & De Jong, 2012).
Transitioning practices has been a matter of attention in the design field, especially in the context of sustainability (Jégou, Liberman, & Wallenborn, 2009)(Kuijer & Jong, 2009). Whereas the goal is often to transition practices to become less resource intensive (e.g. using less water), this project aims to support the integration of a new element. With the introduction of the new material in zero energy houses, the challenge is to support residents to integrate the material in reconfigured practices.

Practices in design

To design for practices, literature recommends researching the target practice with its elements and relations (Kuijer & De Jong, 2012). Practices hold many relations, as they are part of a larger ecosystem of practices (Munnecke, 2007). For example, shopping and cooking are related as you need groceries to cook. Along with investigating the current practice, literature suggests to research performances in past times and different cultures to define opportunities for reconfiguration (Kuijer & De Jong, 2012)

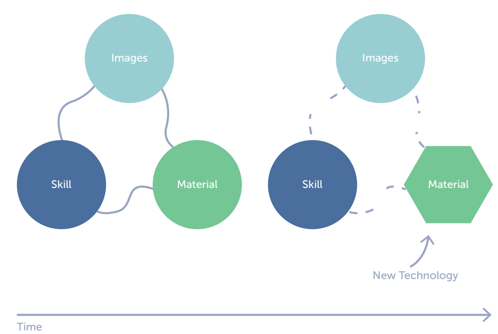


Fig. 2 - The new material that is introduced in zero energy homes, requires a reconfiguration in practices of residents

ZERO ENERGY HOMES

Zero energy homes are houses that have a zero net energy consumption throughout the year (Wang et al., 2009). To establish zero energy consumption the energy demand for cooling and heating is minimized and renewable technologies are used to supply the consumed energy (Li, Yang, & Lam, 2013). To minimize energy need, buildings are well insulated and insulating windows are applied. After insulation the building envelope can be compared to a thermos flask: temperature is very constant. Due to the high thermal mass, the temperature is very stable and not much influenced by outside weather. However, that it is slow in response to changes in temperature also means that it requires more energy to change the temperature if it does cool down (Hoes & Hensen, 2016).
To generate energy, technologies like heat pumps, solar panels, wind turbines and solar water heaters can be applied (Li et al., 2013). Houses of the 2ndSKIN project are equipped with heap pumps. Geothermal heat pumps are seen as a good alternative to heating by fossil fuels, as they have much lower emission rates (Self, Reddy, & Rosen, 2013). In the first place, a heat pump transfers warmth from the earth to the heat the house. In addition heat from the house can be transferred and stored in the earth to cool the house. The heat pump has its highest efficiency when combined with a low-temperature distribution system (radiators, floor or wall heating). As a consequence, this system is slow in response. It could take days before desired temperature is met, therefore residents are advised to maintain a constant temperature on the thermostat (van Vlerken, 2019).

Zero energy houses are often air-tight to minimize the heat loss through uncontrolled ventilation; this makes the ventilation increasingly important. Zero energy homes from the 2ndSKIN project are equipped with a balanced ventilation system with heat recovery. More about ventilation technologies will follow hereafter.

VENTILATION

Why ventilate

Given that people typically spend 90% of their time indoors (Lohani & Acharya, 2016), maintaining proper indoor air quality at home is of great importance. Nevertheless, indoor air is generally five times more polluted than outdoor air (Kim, Paulos, & Mankoff, 2013). Polluted air has negative effects on productivity, health, and comfort of residents. Improper air quality can cause allergies, inflammation, infections, asthma (Dimitroulopoulou, 2012).
Numerous materials and activities can pollute the air with gasses and particles such as fine dust, CO, CO_2, odors and water vapor (Behar & Chiu, 2013). Some indoor activities can quickly increase the concentration of pollutants: for example, cooking, lighting a fireplace, laser printing and cleaning (Kim & Paulos, 2009). Besides, the material of the building and furnishings are a source of pollution: for example asbestos insulations or pressed wood furniture (Kim et al., 2013).
People are often unaware of air quality and pollution sources, since identifying air quality is very difficult. Physically people cannot sense changes in air quality since pollutants are often invisible and odorless (Kim et al., 2013).

How to ventilate

Ventilation is a system that maintains indoor air quality by the supply of fresh air and exhaust of polluted air. Ventilation systems can be distinct in 'natural' and 'mechanical' systems (Fig. 3).
Natural ventilation systems are driven by wind and the stack effect. The stack effect is air movement that is caused by temperature differences between inside and outside air (Khan, Su, & Riffat, 2008). Windows and trickle vents supply and exhaust air. If houses are not airtight, air can infiltrate through the building fabric. Uncontrolled ventilation can lead to energy losses and discomfort; therefore new build houses are increasingly airtight.
Given that houses become increasingly airtight, ventilation becomes more important and mechanical ventilation systems are applied more often. Mechanical ventilation systems use mechanical components like air handling units and ducts to either extract or both supply and extract air. Generall, air is exhausted in 'wed rooms' of the house: the kitchen and bathroom. Fresh air is supplied in 'dry rooms': the living room and bedroom. Some mechanical systems are equipped with heat recovery, which recovers heat from used air to preheat fresh air before supply (Dimitroulopoulou, 2012). Mechanical systems can be equipped with sensors like CO_2 and humidity to regulate airflow.

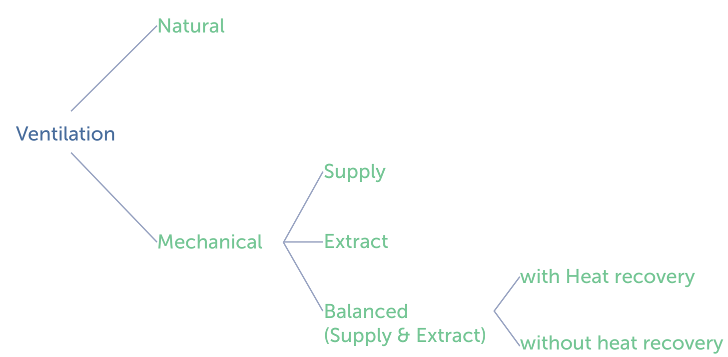


Fig. 3 - An overview of ventilation possibilities. Typically balanced ventilation is applied in zero energy homes

Residents´ role

How occupants interact with ventilation systems impacts indoor air quality and energy usage. Residents' behavior partly causes the performance gap: the difference in expected and actual energy usage of buildings (Behar & Chiu, 2013; Paone & Bacher, 2018). Research shows that residents often use ventilation different than it was intended. They, for example, open windows when heating is on, disable ventilation or block vents (Behar & Chiu, 2013). Furthermore, maintenance like replacing filters, which is crucial to maintain the capacity of the system, is often not performed (Soldaat & Itard, 2007).

CONTEXT

2NDSKIN

2ndSKIN is a new solution to retrofit housing in order to make houses become net zero energy. Unique about the solution is the application of an insulating façade that covers an existing building and functions as the buildings' second skin. Besides the façade, solar panels, insulated windows, a geothermal pump and ventilation with heat recovery are applied (Silvester et al., 2017). So far the 2ndSKIN approach has been fully applied to 12 apartments in Vlaardingen (NL), as part pilot demonstrator. Following this success, 183 units in Vlaardingen are refurbished using the 2ndSKIN façade solution. However, the 183 units are 'zero energy ready' and not fully equipped with a costly heat pump and heat recovering ventilation.

Stakeholders

TU Delft and the general contractor BIK Bouw collaborated on the concept of 2ndSKIN for Waterweg wonen, a social housing cooperation. Within the project all parties had different interests. TU Delft was interested in learning about the energy saving potential of the concept and researching the residents' acceptance, well-being and energy behavior. Running the project brings BIK Bouw at the forefront of zero energy refurbishments. However, it requires taking quite a leap: all is new; money is tight and although it is a pilot, results may not fail. Waterweg wonen has to make their housing more sustainable. This project will make their property meet today's comfort and future energy standards, without having to demolish it.

In the process towards the final design industrial partners were involved. Industrial partners are the ones responsible for applying insulation, heat pump systems, and solar panels. Furthermore, EIT Climate-KIC is supporting the project through sponsorship and support; their aim is to get the new solution to the market. Lastly, the TU München is involved as a research partner by analyzing and advising on the energy modeling and circularity of the project.

Residents rent the property from Waterweg wonen. By law 70% of the residents have to agree to the refurbishment. After refurbishment is approved, residents might experience inconveniences during the renovation. In the end the renovation will probably increase comfort, however residents have to get used to (the new technology in) their refurbished homes.

Process

The pilot demonstrator of 12 houses has been a participatory process between TU Delft, BIK Bouw and residents. The process supported resident to make the decision whether to opt-in for renovation. Foreseeing that the refurbishments would demand a change in living practices, the process aimed to supported residents to anticipate on future.

Fig. 4 - One of the 183 zero energy ready units, with the 2ndSKIN insulation clearly visible

3. FIELD RESEARCH

This chapter elaborates on the methods that were used and the insights that were gained in interviews with residents. The objective was to understand what practices and experiences residents have with regard to maintaining indoor climate. In the process, the scope narrowed to the practice of maintaining indoor air quality

3. FIELD RESEARCH

INTRO

To be able to describe residents' practices and their experiences, I carried out two sets of interviews. First, I did explorative interviews, which scoped the project to the practice of maintaining indoor air quality. Thereafter, I conducted in-depth interviews, focused on only this topic.

The explorative interviews covered practices of maintaining warmth and maintaining indoor air quality. My aim was to understand the different elements of practice theory: material, skills, and images (Kuijer, 2017). I was interested in what tools residents use (material), what they regard as normal (images) and what tricks they had developed (skill). Furthermore, I was interested in what extent available material influenced the configuration of residents' practices.

Thereafter, the in-depth interviews focused on the practice of maintaining indoor air quality. The aim was to gain more in-depth insight into the practice and specific associations that residents hold to indoor air quality. Also, I was interested in the relation residents to develop with their ventilation system, whether they perceive the system turning on and whether they link the activity to sources of pollution.

Fig. 6 - Zero energy ready apartments where interviews were I conducted the explorative interviews

Fig. 5 - Student building where I conducted in-depth interviews

METHOD

Qualitative research is selected as the method because it will result in rich insights and support creation of empathy with residents. In order to design desirable future experiences, it is important to understand the underlying needs and values behind current and past experiences (E. B. Sanders & Stappers, 2012). Needs and values are often the 'why' behind an answer and therefore hard to grasp by means of quantitative research, which address the explicit levels of knowledge. In contrast, qualitative research enables to reach tacit and latent layers of knowledge (Sanders, 2002). These layers of knowledge create insight about what people feel, dream and do and are therefore very informative for this design project.

I conducted interviews with residents in their own dwelling. Interviews were semi-structured and consisted of open-ended questions. The set-up of all interviews was inspired by the path of expression (Fig. 7): sharing current experiences, recalling memories and concluding by defining possibilities for the future (E. Sanders & Stappers, 2012). This framework was used for the set up because it would support participants to not only share about current practices but also explore and express desirable futures. The set-up of the explorative and the in-depth interviews is based on the path of expression, but it is applied differently. Hereafter the two approaches will be explained in detail.

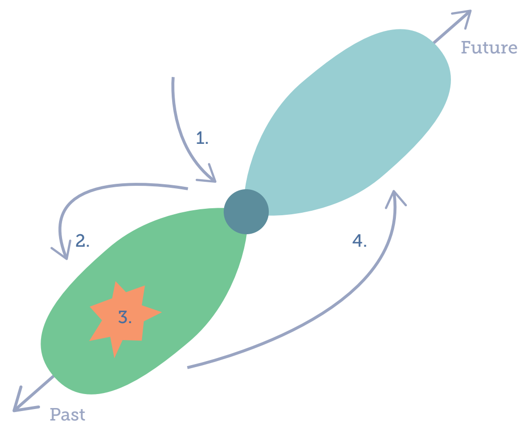


Fig. 7 - The path of expression: going from current to past and future experiences.

Approach explorative interviews

The script of the explorative interviews can be seen in Fig. 9. In the first part, covering past and present experiences, I used stimuli like a timeline, ambiguous pictures and prepared questions to induce stories and memories (Fig. 8.). In the following part I used statements on future scenarios, to catch what residents consider as important or desirable for the future. A statement was for example "with a heat pump it is efficient if the temperature is constant and not too high, for example, 21 degrees". The interview concluded with a home show, where residents often shared anecdotes about how they manage indoor comfort.

In interviews with residents living in zero energy houses, the approach differed. The reason for this adaptation was twofold. First, these residents already live in a house that is to some extent a future scenario. Second, the adaptation ensured that one interview would provide results for both the 2ndSKIN evaluation and this research. Instead of future scenarios' I used provocative statements to uncover what residents regard as normal. Information that challenges beliefs of people can support to critically reflect on practices and reveal thoughts (Scott et al., 2008). A statement was for example: "I always open the window, because it makes me feel more connected to outside". Two interviews were not conducted by myself. I could attend one and used recordings of the second interview.

The complete interview script can be found in the appendix.

Script explorative interviews		
10 min	Introduction	
30 min	Past & Present experience of maintaining indoor climate	
5 min	Introducing the aim of the project	For zero energy residents this was replaced with provocative statements
10 min	Reflecting on future scenarios	
5 min	Home show	

Fig. 9 - The script of explorative interviews with slight adjustments for interviews in zero energy homes

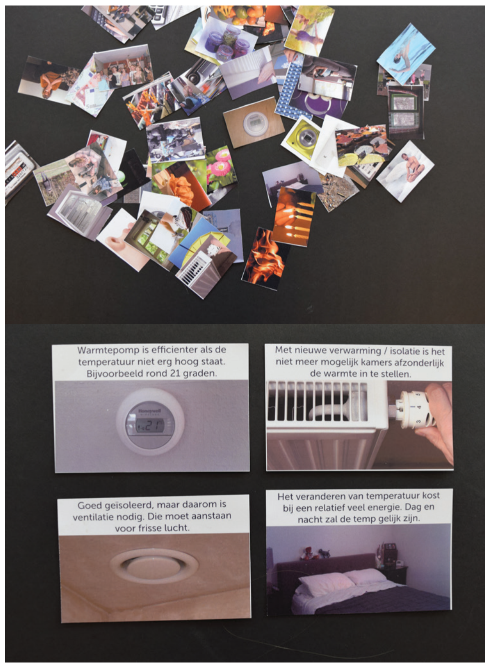


Fig. 8 - Above: stimuli pictures to elicit memories. Below: Future statement cards to reflect on desirable futures

Approach in-depth interviews

The script of the in-depth interviews can be seen in Fig. 12. The script followed the structure of the sensitizing workbook that was used.

I used a workbook, because experiences and practices relating to air are not easy to discuss. The workbooks are based on contextmapping (Sleeswijk Visser, Stappers, Van der Lugt, & Sanders, 2005) and make residents aware of the topic before conducting the interview. Residents were asked to explain their work and the researcher asked questions about it. The structure of the workbook followed the path of expression and also alternated between Make, Say and Do. The interview concluded with a Dolls' house toolkit (Fig. 11), which was used by residents to create and express desirable futures. In the first interview, I noticed the Doll's house had too many materials. Therefore materials were reduced for the following interviews.

The full interview script and workbooks can be found in the appendix.

Script in-depth interviews	
10 min	Introduction
20 min	Experiences of today using a timeline
15 min	Memories and associations using the made collage
15 min	Creating and expressing desirable futures using the dolls' house toolkit

Fig. 12 - Script of the in-depth interview followed the structure of the workbook

Fig. 10 - The sensitizing material supported residents to think about the abstract topic of indoor air

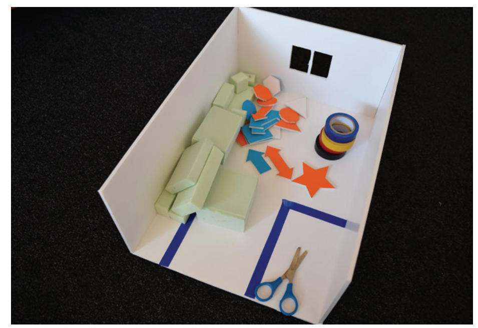


Fig. 11 - the dolls' house toolkit developed during the interviews as it was too overwhelming at first

Residents

Eleven residents took part in the study. Interviewees differ in age, gender, living situation and type of property (Fig. 13). Having a diversity of participants supported to observe variety of configurations of the practice (Kuijer, 2017). The visited properties were equipped with different ventilation technologies (Fig. 14). By visiting residents living with different material, I could study to what extent the material influences the practices.

Nr	Set	Age	Gender	Living situation	Sort of property
1 & 2	Explorative	± 35	Male & Female	Couple	Two story house
3	Explorative	± 40	Female	Alone	Zero energy ready apartment
4	Explorative	± 55	Female	Alone	Zero energy ready apartment
5	Explorative	± 45	Female	With adults son	Zero energy apartment
6	Explorative	± 67	Male	Alone	Zero energy apartment
7	Explorative	± 40	Male	Sometimes together	Zero energy apartment
8	In-Depth	22	Male	Alone	Student studio
9	In-Depth	27	Male	Alone	Student studio
10	In-Depth	23	Female	Alone	Student studio
11	In-Depth	19	Female	Alone	Student studio

Fig. 13 - 11 residents were interviewed; their housing, gender and living situation differed

Zero energy	Zero energy ready	Student Studio	Two story house
Well insulated (2NDSkin)	Well insulated (2NDSkin)	Well Insulated	Poor insulation
Apartment	Apartment	Studio	Two story house
Balanced ventilation with heat recovery	Mechanical exhaust natural supply	Balanced ventilation with CO2 and humidity sensors	Minimal mechanical extract, natural supply

Fig. 14 - : The visited houses have different material for ventilation

Analysis

I combined qualitative data of both the explorative and the in-depth interviews and analyzed it in an on the wall analysis. Activities involve different levels of sense-making and escalate in the DIKW scheme (Ackhoff, 1989) from data to information to knowledge. The qualitative data set, gathered in interviews, includes pictures, sensitizing booklets and transcripts. To move towards information, I read through the transcripts, marked interesting quotes and wrote my interpretation on post-its. Thereby, I gave an interpretation and attached meaning to it. Thereafter, I moved towards the level of knowledge as I clustered and sought for patterns. In clustering, I involved practice theory and grouped insights in the different elements: images, material and skill. I also developed personas to typify the different approaches, values and beliefs I had seen.

Fig. 15 - I interpreted insights and clustered the information on the wall to find patterns

RESULTS

This section will discuss findings from both the interviews. First I will explain why I decided to focus on the practice of maintaining indoor air quality after the first explorative interviews. Thereafter I will cover insights from the interviews; these are structured according to the three elements of a practice: material, images and skill.

Decision for indoor air quality

After a short analysis of the explorative interviews, I decided to continue with a specified focus on indoor air quality. Results showed that residents struggle to incorporate the balanced ventilation system in their habits, because it is difficult to understand what the system does and hard to develop trust in the system. The disintegration in practices is critical, seeing that ventilation becomes increasingly important with houses that become more air-tight. The topic is currently not in the center of attention, although it is of great importance for comfort, health, and energy. Given these points, I see it as a meaningful challenge to bridge technology and people in the context of ventilation.
The insights into the practice of maintaining warmth can be found in the appendix.

Ecosystem of practices

The practice of maintaining indoor air quality is interconnected to many other practices (Fig. 16). Showering, cooking, drying laundry and cleaning are polluting and causing an increased need for air. Sleeping and cleaning are associated with the need for fresh air. Furthermore, images are linked to the following practices: maintaining a comfortable indoor climate, managing energy loss through windows, managing energy bills and keeping the house safe.

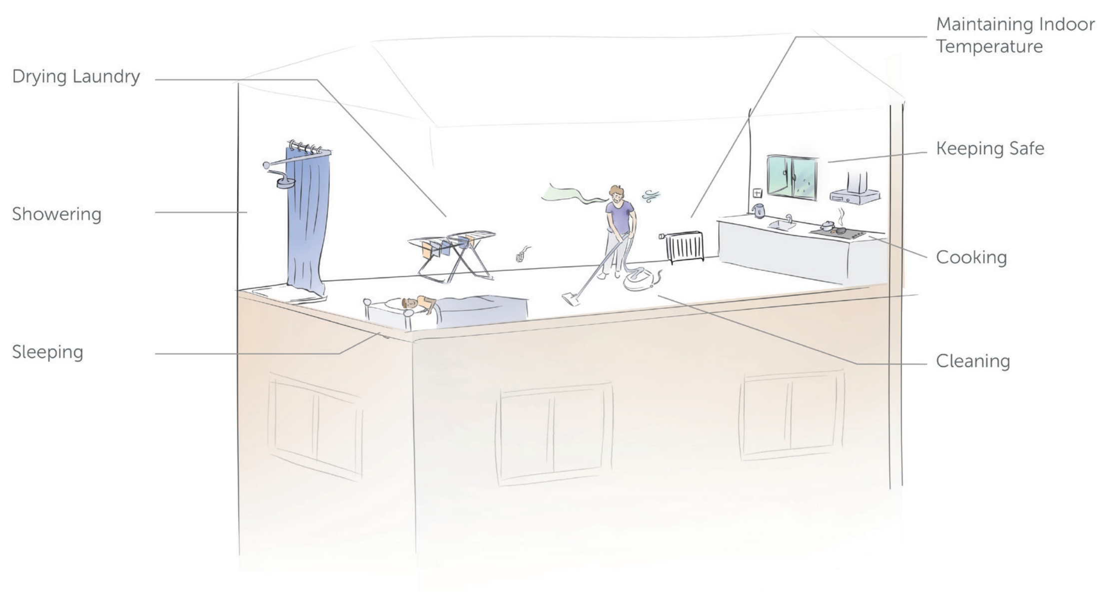


Fig. 16 - the practice of maintaining indoor air quality is connected to many other practices

Material to maintain indoor air quality

In non-refurbished housing, the following material is used to maintain indoor air quality: windows, doors, the extractor hood, cracks, trickle vents, ventilators, air fresheners, and plants (Fig. 18).
Windows, trickle vents and doors are regarded as the most obvious and important materials to ventilate. Cracks create uncontrolled ventilation with the outside, which is often unnoticed by residents. Ventilators are used to create airflow, especially in warm periods. Air fresheners were also mentioned by residents as material to maintain indoor air quality.
With refurbishments, material changes. Improved insulation makes uncontrolled infiltration impossible. Furthermore, new material like supply and exhaust channels, a ventilation control panel and sensors are installed (Fig. 17).

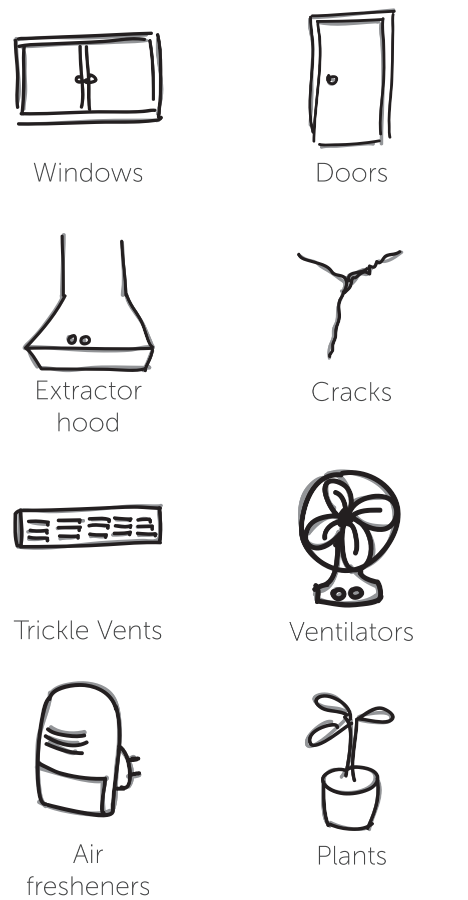


Fig. 18 - Material associated with natural ventilation

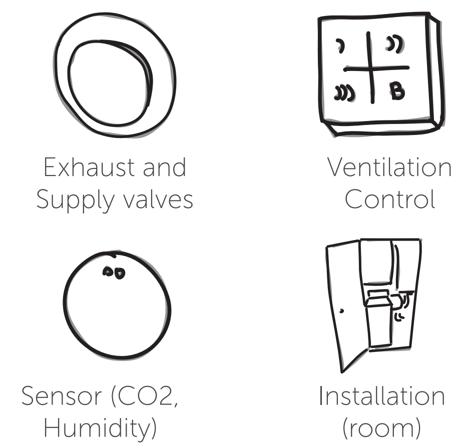


Fig. 17 - New material associated to the balanced ventilation system

Insights related to Material

1. The system's feedback and feedforward poorly communicate systems functioning and functions

This use of the ventilation can be described with the seven stages of action cycle(Norman, 2013) (Fig. 19). On the action side, residents struggle to select a setting. In zero energy homes, residents have to choose from 1,2,3 and boost (Fig. 20). Residents have to learn the settings and when to use them. In interviews, they often recalled their instructor. Residents with an automatic ventilation combined with a boost control were insecure about what the control did. This also had to do with the feedback, because it is difficult to perceive what the system does and therefore hard to evaluate the performed action. Overall residents feel insecure and frustrated when selecting a setting (Fig. 21). Due to lack of feedback residents lack trust in the system's functioning.

"As Stella [the instructor of the system] said of course, I have to keep it on level two; she mailed what the impacts are on air quality. So now I put it on three at when cooking."

"But it is unclear what it is doing, really. They say that it will turn on if you press the control once and increase intensity if you press twice. Maybe you can also turn it of using the control, but I don't know about that."

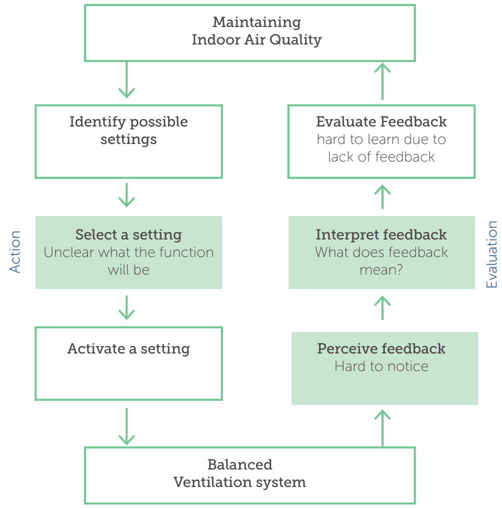


Fig. 19 - Seven stages of action cycle for the balanced ventilation system (Norman, 2013)

2. Residents often rely on natural ventilation, because they perceive the effect better

It is hard to sense an effect with balanced ventilation. Linking back to the seven stages of action (Fig. 19)(Norman, 2013), natural ventilation allows for an evaluation phase by feeling the airflow and lower temperature of incoming air. With balanced ventilation evaluating the effect of the action is difficult because no temperature difference or airflow is felt. The system does not compensate for the lack of natural feedback.

"But if it is warm and a bit stuffy I would rather open a window, because it feels like it has a quicker effect. Therefore I would not press the button."

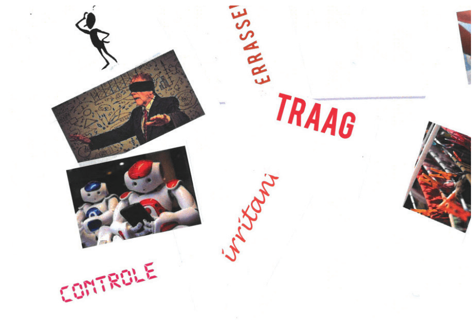


Fig. 21 - Collage from sensitizing workbook of the in-depth interviews it displaying the resident' annoyance and insecurity about the ventilation system

Fig. 20 - Residents of the explorative interview showed this ventilation control. The resident has to select the function suitable for the situation. The control gives no indication of the setting it is currently on.

3. The new installation room is a technical black-box to residents

To fit all equipment belonging to ventilation and heat pump an installation room is made on the balcony of zero energy houses. Although the room is their house, it is not designed for resident interaction.

"Where that technical stuff is, no girl. That door remains closed... I don't have anything to do with that".

Fig. 22 - This is the installation room in zero energy houses. It houses the equipment, but is a black box to residents

4. Residents do not realize the impact an air-tight house has on ventilation

With refurbishments houses become air-tight, therefore ventilation becomes increasingly important. However, some residents did not seem to be aware of this change. One resident of a zero energy home mentioned to rarely open a window and had the ventilation on a low setting. This is not healthy due to the increased air-tightness of the house.

Images related to maintaining indoor air quality

Indoor air quality is something most residents are usually quite unmindful about: air is always there. However, at the moment of entrance, people are shortly sensitive to it. Also when signals like moist, smell and warmth are felt they become aware for a short period. Sometimes they take action to improve indoor air quality. However, people generally quickly adapt and forget about it.

Insights related to Images

1. Quality of indoor air is important for health

Residents mentioned sufficient oxygen and the right level of humidity as important for their health.

"Yes air is important for my health, for example it is important to have sufficient oxygen to live."

"Since I have skin problems it is very important for me to have fresh air. Not too moist, not too.. Not too dry air. Well, just nice and fresh."

2. It is comfortable to have good indoor air quality

Mainly unpleasant smells were mentioned to decrease comfort. Residents also recognize that pollen and a lack of oxygen can make them feel less fit (Fig. 23).

"That window is open all day, because it will get moist and smelly if I don't. And well, I don't like that of course"

3. Maintaining quality of air is connected to energy consciousness

By ventilation through windows, heat is lost. Therefore it is associated with energy consciousness.

"And if it then gets really cold actually, I close the open windows on both sides. Because you would be heating the outside air, if you wouldn't "

Fig. 23 - This collage was made by a resident in the in-depth interviews. She expressed feeling tired and sneezing (from pollen) as uncomfortable elements to indoor air quality

4. Air quality is important during sleeping

During sleep residents find ventilation important, not only to have healthy air but also to have comfortable cool temperatures.

"If I go to sleep, I always find it pleasant to open a window. To notice a bit that there is fresh air coming in"

"Yes, I indeed always have my bedroom window open. Yes, I find it.. I like it better if it is nice and cold than when it is hot in the bedroom."

5. The practice of maintaining indoor air quality is part of a tradition

Residents perform practices as part of a tradition.

"my mother told me open the window and exchange air. I was told."

6. Air from outside is considered as healthy and feels pleasant

"Well, I do really enjoy the air from outside. The smell and the freshness of the air. And usually I don't like the airco. Maybe they could fake air at the window, but I can't imagine that would work."

"I find it pleasant that even when the window is closed semi-fresh air is coming in with the ventilation system. But well, I do notice that it is a different experience in my room, when the window is open. "

7. Increased insulation and balanced ventilation restrict the feeling of being connected to outside

Sounds, air, and smell make residents feel connected to outside. Due to the mechanical supply of air and insulation, this changes: residents hear fewer sounds, smell less and feel less of the airflow.

"At your parents they have insulated the place so incredibly that it seems like you live in a vacuum. I think that is also... You do have to hear some from outside, I think. To have a bit the idea, at least I find it pleasant to have the idea that things are happening around me..."

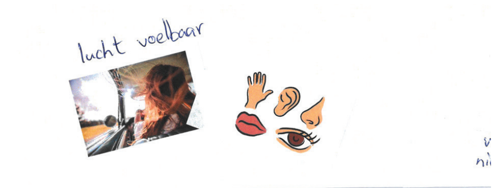


Fig. 24 - This collage from a resident in the in-depth interviews shows she wants to be able to detect the air, the way you feel air in a car with an open window

8. Air from balanced ventilation feels less clean because it is indirect

"Well, with ventilation it is like there is old air circulated in the room. While with an air grill, you know it is air from outside. So maybe an air grill would give me a fresher feeling."

9. The ventilation system is sometimes regarded as a waste of energy

Residents with automatic ventilation mentioned they find it unnecessary that the ventilation is always on. They regard it as a waste of energy when they have their windows open or when they are not at home.

" I find it a waste that it is always on and that you can't control it the moment you want to, that is a waste of energy. On those moments when I am not here, the air here does not have to be ventilated."

10. On one moments a breeze is experienced as pleasant, while it is unpleasant at an other moment

On some moments residents enjoy the feeling of incoming air: the movement and its temperature. However, on other moments residents experience the same breeze as an uncomfortable draft.

11. Outside air has more positive associations compared to balanced ventilation

"They say that you can leave the windows closed in summer, in theory, that sufficient air is coming in. But personally, for my own feeling it is in some way nicer to have the window open. Not needed, but well..."

Skills needed to maintain indoor air quality

Typically residents act upon indicators of pollution. Pollution motivates residents to do something about indoor air quality. Pollution is often hard to sense. However, in comparison, it is easier (e.g. when entering a room).

Residents with natural ventilation make use of the following skills: to create airflow, to balance noise pollution and the need for fresh air and to balance fresh air and a comfortable indoor climate. When equipped with balanced ventilation, residents need competence in selecting settings, managing energy usage of the system and cleaning the filters. After refurbishments, limiting heat loss through windows is another important skill.

Fig. 25 - The construction work besides the student building made the skill to balance noise and fresh air very relevant.

Insights related to Skill

1. Using ventilation control is troublesome and confusing

As mentioned earlier residents have to decide whether setting 1,2,3, or boost is proper for the situation. Setting '1' is intended for situations where residents are not at home, however, residents tend to select this setting because it is more silent and energy efficient. The control demands of residents to recognize situations with an increased need for air. When there is a party, for example, residents should increase ventilation. Residents have to learn these situations. This knowledge is not required for residents with automatic ventilation. However, it is unclear for them what the boost does and how long it is active. They also doubt how manual control and automatic function together. They are insecure whether they should take action.

"Here, it has apparently, an orange light could burn and that should mean that air quality is poor I believe. But I am not sure whether I have to put the ventilation on myself, or whether that happens automat-ically."

2. Residents doubt systems functioning because they are unable to perceive it

Feeling the decrease of temperature and airflow are means to observe ventilation through windows. Both means of feedback are absent in the balanced ventilation system. As nothing makes up for this feedback, residents doubt the systems' functioning.

"yes, then I put it to level three, but you don't feel anything from that"

"there is the ventilation control, there I press then. I hope it works, but I do not know, really"

3. Residents lose interest because they experience a lack of control

Residents experiment with the controls at the start, but if they do not perceive changes or the system does not meet their wishes they lose interest (Fig. 27). The ventilation system will continue to work, but residents only incorporate natural ventilation in their practices.

"and you get used to the way it is. At one point you just accept the way it is. I have researched the system and tried what I can do. It ends at one point and then you make time for other things."

Fig. 27 - In the in-depth interviews this residents showed the control. She had lost interest and placed a clothes rack in front of the ventilation control

4. Residents are not as careful with the configuration of the valve as the design demands

The configuration at the valves is very delicate and specific for the room it is installed, however, residents are unaware of this. Besides, they are expected to clean them. By cleaning the configuration can accidentally be adjusted and during cleaning, valves from different rooms can also swap as valves of all rooms look similar (Fig. 26).

In the interview, one resident said that he sometimes completely closes the valves of the ventilation to decrease noise pollution.

"For example, when my mother comes to stay for the night. She is annoyed by the noise of the system, then I sometimes turn it to close. "

Fig. 26 - Residents are expected to clean the valves, however cleaning the valve without adjusting configuration or mixing valves is a challenge

Personas

To show the different attitudes towards ventilation, I created four personas. Personas are fictional people that represent a type of behavior, attitude or motivation. The personas facilitate empathy for residents and can be used to test scenarios.

To differentiate people I used the following axes: 'interest in indoor air quality' and 'making sense of technology'. The first axes represents the extent to which people is engaged with air quality. Some people, for example, have strong motivations on what is healthy. Motivations are reflected in their attitude and behavior; some residents act preventive before signals become apparent, while others do not recognize signals. The second axis is about the ability to understand technology: does the resident understand the ventilation system?

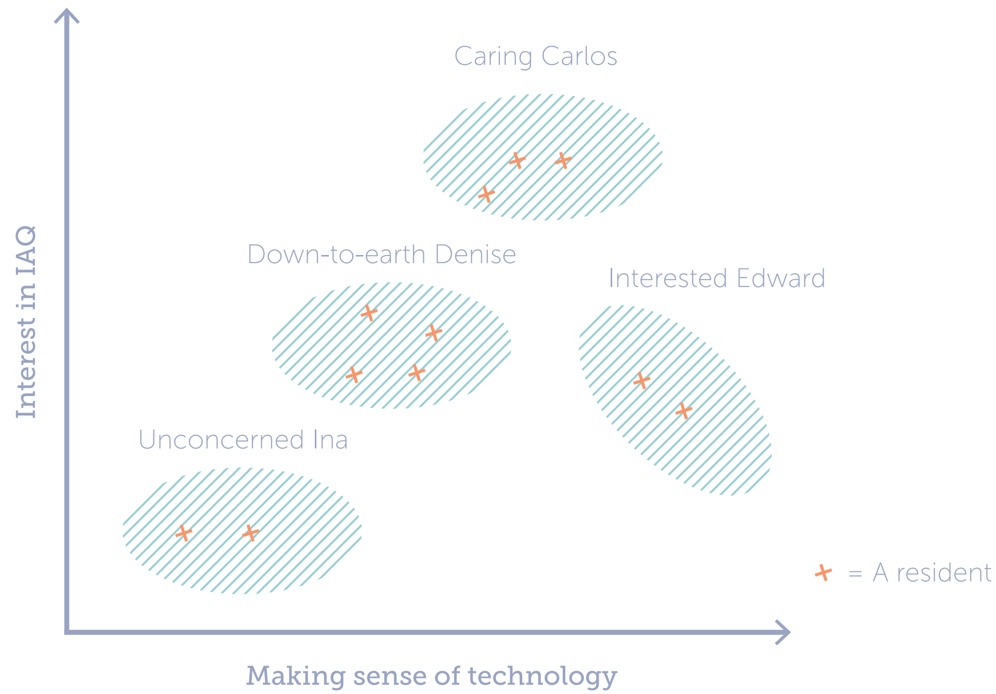


Fig. 28 - The residents were grouped in personas using the axes of 'making sense of technology' and ' interest in indoor air quality'.

Caring Carlos

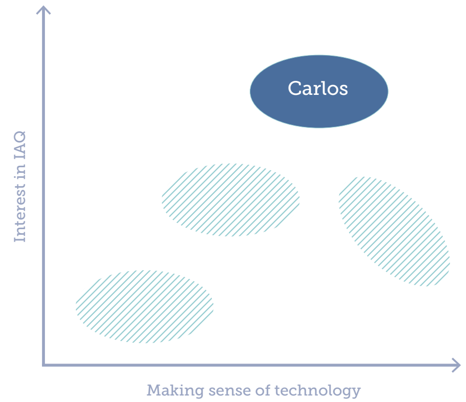
Caring Carlos is 34 and working at the municipality. He and his wife live together and like to spend their time at home. However he is recovered, Carlos has been seriously ill in the past.

Carlos has strong opinions on what is healthy air and takes preventive action. He, for example, bought plants to decrease CO2 levels. For Carlos it is important the system proves healthiness in order to trust it. His motivation to find out how it works is to improve and validate healthiness of his environment.

Organized

Responsible

Emotional



Carlos keeps his bedroom window open in all seasons.

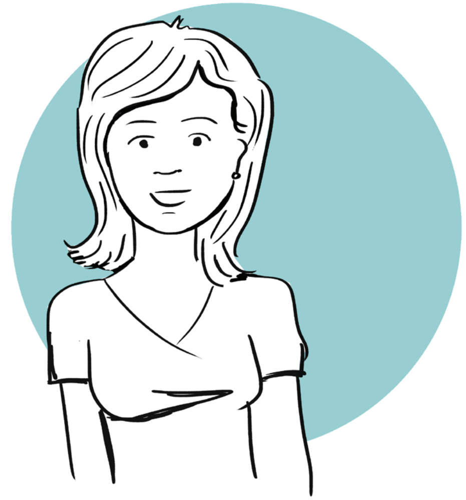
"For me it is really important that there is fresh air. Not too moistly, not too dry air. Just nice and fresh."

"Ventilation air is also good, but it is less direct. It may sometimes contain dust from the tube. I read about it."

Down to Earth Denise

Denise is 45 and single mother of an 18 year old daughter. She works as sales in the local bakery. Denise is organized and cares both about her own appearance and the appearance of her house.

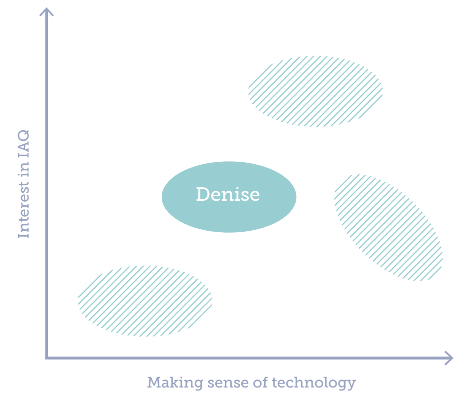
Although Denise recognize the impact of air quality on health she sometimes regards a comfortable temperature or noise level as more important. She is motivated to find out how technology works, because she wants to perform well and is worried about the costs. However if it takes too long, she will lose interest.



Tidy

Flexible

Social



Denise uses air freshners to make sure her house always smells good.

"There is the button for ventilation, sometimes I press it. I hope it works, but I am not sure. I don't know. Sometimes I open the window."

"No I don't think mechanical ventilation is healthier. well, air from outside is also not healthy anymore.. But for my idea it brings in fresh air..."

Unconcerned Ina

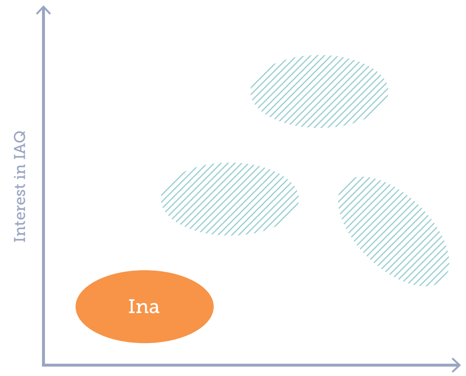
Ina is 54 and long-time unemployed. She is quite on herself, lives with four cats and likes to make art. She spends most of the day at home. At night she often eats with her father or a good friend, who live nearby.

Ina has no interest in air quality, she does not know it impacts her health. She likes silence and therefore aims to decrease noise from appliances and outside. Ina would easily accept new material, since she does not have strong opinions on what is healthy. However, for Ina it is important to limit system noise and complexity.

Humble

Disorganized

Individual



She used paper on the door to maintain privacy and keep light out.

"No, shut up, I never open my windows ... yes, maybe in summer, if I come home at night I open the windows and the door for a while because it is warm.. "

"I mostly have the vents and windows closed, not to noise from the street."

Interested Edward

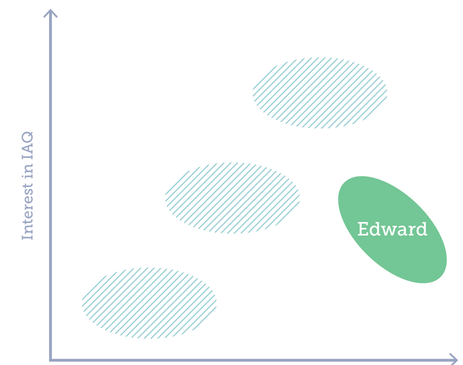
Edward is 35 and lives alone. His girlfriend often stays at his place and invites friends for dinner. Edward works in security and has late shifts. In his free time he likes gaming.

Edward is driven by curiosity and likes to tweak and experiment with technology that is installed. He could for example close of a duct, to see whether it would have a positive effect on his energy bill. Although he is interested in air quality he does not have as strong associations and beliefs as Carlos does. Therefore he is easier in transitioning his practices.

Curious

Rational

Independent



Edward favorite spot is his game corner

"I look at the meters to see whether numbers it is decreasing."

"Now the distance between supply and exhaust is quite short, I think it would be better if this distance was bigger."

CONCLUSION

In this part, I will reflect how the insights I gained from the interviews contribute to the design goal I have, which is to support residents to transition their practices relating to indoor air quality.

A lack of feedback, unfavorable associations and unmet needs currently lead to the disintegration of balanced ventilation into residents' practices. Due to the lack of feedback that the new material provides, the ventilation system is experienced as a black box. Residents become insecure about the systems functioning and as a result of the poor feedback residents lose interest (Fig. 29). Besides, residents hold associations which make transitioning practices more difficult. For example, residents regard air from ventilation as less fresh, because it is indirect. Also, ventilation is associated to be energy consuming, rather than saving. Furthermore, the new system does not meet the desire to feel airflow and the need to feel connected with outside. The experience of balanced ventilation should match residents' needs, as long as it does not they are likely to use the windows.

The persona's made clear that people have different concerns and motivations. Most residents might be like Denise, with a moderate interest in air quality and moderate technical understanding. However, it is important to also think of the more extreme cases. Carlos, who holds strong opinions on what is healthy, should be supported to transition his practices. But also Ina, who is lacking interest in technology and air, should be able to make the transition.

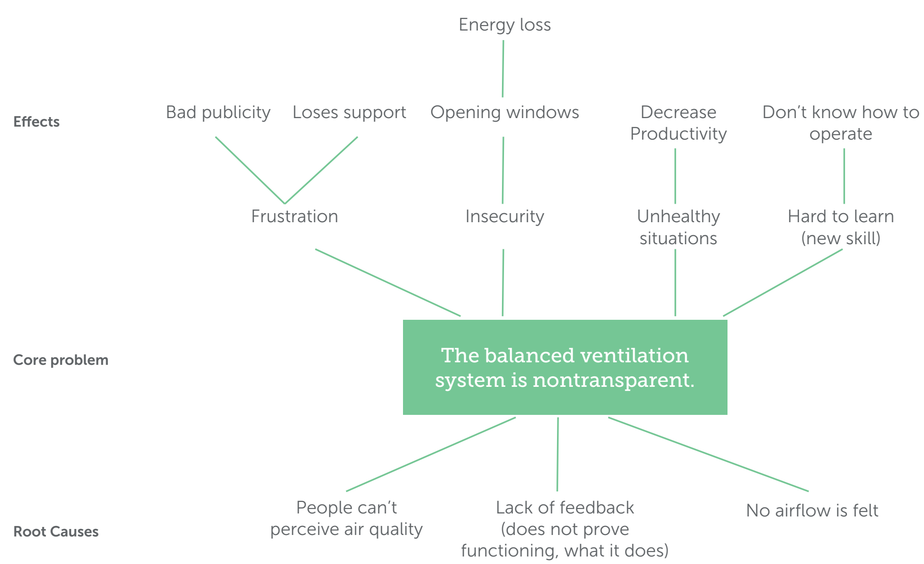


Fig. 29 - Problem tree reflects that lack of feedback is a root cause to the problem that the system is nontransparent.

DISCUSSION

In this section, I will discuss the limitations to the field research. I will highlight aspects, which could have an influence on the results.

Residents

The small number and selection of interviewed residents limits the findings. The interviewed students have above average technical knowledge. The residents from the explorative interviews have been interviewed before for other research and might therefore be more aware of their practices. Furthermore, a limitation to the selection of residents is that almost all residents live alone.

Housing

The interviewed residents live distributed over two residential buildings, therefore elements specific to the installations of these dwellings might impact results. For example, in the student housing residents share the ventilation system with the neighboring studio. This could make the behavior of the automated system more difficult to understand. Furthermore, all residents live in rental housing. Although rental housing is the context of this project, this aspect is important to keep in mind with an eye on the transferability of the results. Results might be different from residents owning a house because house owners might feel more involved and show more interest in the installed system.

Method

Some used tools, like the dolls' house toolkit, developed along the way and were not consistent throughout the interviews. Furthermore analysis was performed alone; data is therefore only interpreted by the perspective of the researcher.

4. REFRAMING

This chapter describes how various acts contributed to a better understanding and better framing of the design challenge

4. REFRAMING

Making future scenarios modified the design goal to the near future

Since my aim was to design for future practices, I decided to create future scenarios (Fig. 31). I made future scenarios as they are a way to explore what directions the future could take. In each scenario, I could assume what residents needs would be. For example, with increased pollution, residents might want to feel protected from the outside. With regard to practices, I felt I lacked knowledge. Far-future practices might involve different images, skills, and material. Residents might for example, never have opened a window. Therefore, it makes more sense to design for near-future practices, which are grounded on practices of today.

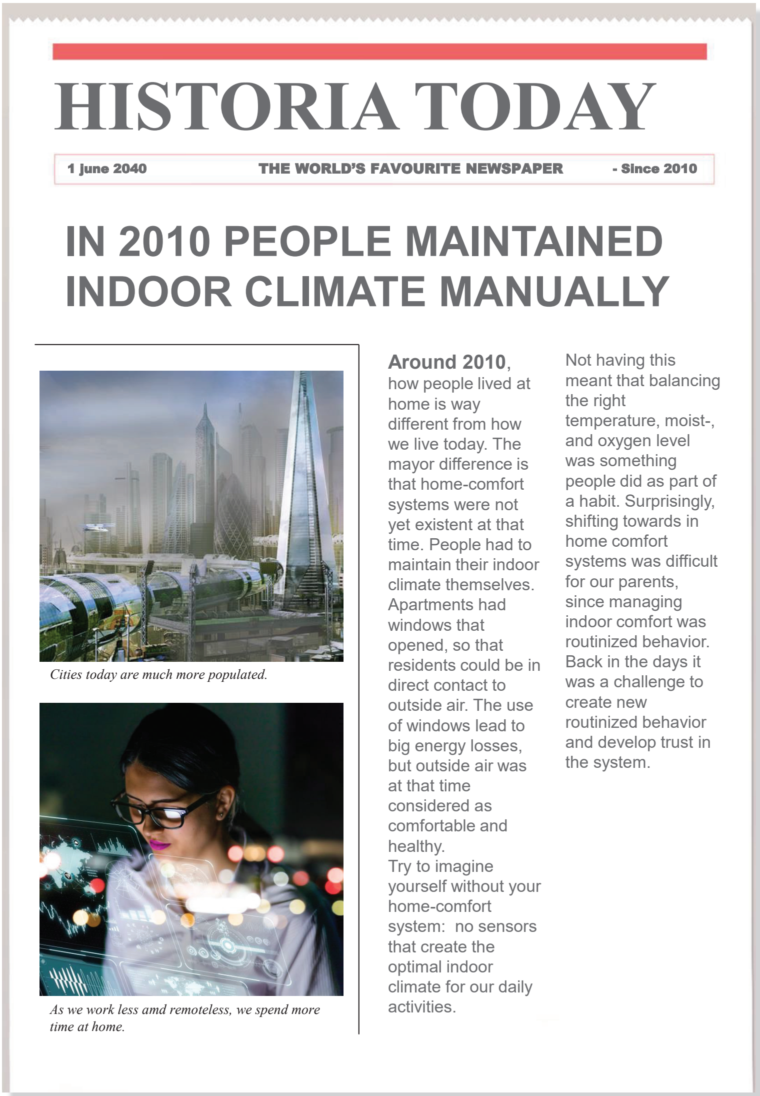
A creative session with designers set 'trust' and 'understanding' as criteria for solutions to support transition

I did a creative session with four fellow designers. They were challenged with the question: 'how might residents like to maintain their indoor air quality in 10 years'. By clustering generated ideas, they defined 'trust' and 'understanding' as important criteria to support a reconfiguration that adopts ventilation systems near-future practices.

By making an interaction I learned I will focus on an orchestration of interactions

In order to develop a vision of the desired interaction in the future, I aimed to develop an interaction vision (Pasman, Boess, & Desmet, 2011). The attempt helped to understand that residents have many interactions to maintain indoor air quality, rather than one.

Fig. 30 - By clustering ideas of the creative session clusters of ideas in 'trust' and 'understanding' appeared



HISTORIA TODAY

1 June 2040 THE WORLD'S FAVOURITE NEWSPAPER - Since 2010

IN 2010 PEOPLE MAINTAINED INDOOR CLIMATE MANUALLY

Cities today are much more populated.

As we work less amd remoteless, we spend more time at home.

Around 2010, how people lived at home is way different from how we live today. The mayor difference is that home-comfort systems were not yet existent at that time. People had to maintain their indoor climate themselves. Apartments had windows that opened, so that residents could be in direct contact to outside air. The use of windows lead to big energy losses, but outside air was at that time considered as comfortable and healthy.
Try to imagine yourself without your home-comfort system: no sensors that create the optimal indoor climate for our daily activities.

Not having this meant that balancing the right temperature, moist-, and oxygen level was something people did as part of a habit. Surprisingly, shifting towards in home comfort systems was difficult for our parents, since managing indoor comfort was routinized behavior. Back in the days it was a challenge to create new routinized behavior and develop trust in the system.

Fig. 31 - Making the scenario, that reflects on the transition in practices from a far-future perspective (2040), supported the realization that far future practices are hard to target as they are based on an unknown near-future.

To open solution space I investigated the practice in past times and another culture

Investigating the practice in past times and different cultures will open up solution space because it shows different performances of the practice (Lenneke Kuijer & De Jong, 2012) (Shove & Watson, 2006).

History

In the past, houses were not well insulated and heated using stoves and fireplaces. Windows and stoves were material to create airflow. Stoves generate an under pressure, which draws in fresh air (Olsson, 2016). At the same time, warm air is exhausted through the chimneys. Images were related to removing products of combustion. For example, cooking led to air pollution due to the combustion of fossil fuels (Sherman & Matson, 1997). A threatening image was the danger of CO pollution, as it could be very dangerous and is connected to poor ventilation. Skills related to the practice were to fire a stove and to open a window. Besides, the chimney required occasional cleaning for safety reasons.
From the 1960ties, central heating became commonly applied in residential housing (Koops, n.d.). With that, the practices of maintaining warmth and air became less connected and the skill of firing a stove became obsolete. In that time, buildings got higher while ceilings lowered. As a consequence, ventilation became more important and mechanical extract became common (Olsson, 2016). Even though mechanical extract was a new material, residents still mainly interacted with the window to control air quality. Also, air-conditioning system started to develop with the introduction of electric power. They control moist, temperature and pollutants. Images changed, as people got used to all-time availability of comfortable climate.

Today houses are made airtight to decrease energy loss through natural infiltration. The material changes: houses are equipped with balanced ventilation systems that both supply and extract air. Hence, windows are no longer the main way to regulate air quality and new skills are needed to interact with the systems.

Practices in China

As a result of pollution, outdoor air quality has been under interest in China for years. Recently indoor air quality became a matter of interest. With the increased interest, materials have expanded: numerous applications and purifiers exist on the Chinese market (Roxburgh, 2018). Hence, residents obtain more skill in monitoring and controlling air quality. Services like schools and hotels are increasingly competing on air quality rates by implementing high-quality filtration systems (Roxburgh, 2018). People seem to be interested in the offerings and services due to their images connected to health.

Conclusion

Past performances hold opportunities for future practices. For example, the past practice of cleaning the chimney could be an inspiration to new practice of cleaning filters. The insights on practices in China show that residents can become more aware of indoor air quality. These alternative images might make a transition towards mechanical air supply easier. Altogether, the practice is quite discrete in its performances, compared to other practices. Air is always what is distributed and the possibilities of how that could happen are limited. For the future, I think qualitative research in other cultures might create more insight into images and skills that come in to play.

5. CONCEPT ITERATION 1

This chapter elaborates on the first concept iteration. Insights from field research formed the start of the creative process in which I explored the opportunities and created three solutions. Solutions aim to support residents to develop new practices that incorporate ventilation technologies

5. CONCEPT ITERATION 1

Developed solutions are grounded on insights from field research. Insights from field research identified the lack of feedback of the system and existing meanings that do not match the new material as friction points. First I started with an explorative ideation, through which I defined the design goal. Based on this goal I started a scoped ideation phase, which resulted in three solutions.

EXPLORATIVE IDEATION

To explore a diversity of solutions practices I generated various 'How To's' (Van Boeijen, Daalhuizen, Zijlstra, & van der Schoor, 2014). The following were selected to continue with:

- How might the ventilation system become understandable for residents?
- How might we create an experience that feels healthy and fresh?
- How might residents develop a relationship with their ventilation?
- How might we fulfill the need to feel connected to outside?

Based on the How To's I started generating ideas. I used an online picture generator as a random stimulus, to force random connections and provide fresh input. When ideation had slowed down and sufficient ideas were there, I clustered ideas.

Fig. 32 - I ideated on how to's which followed from field research. The following two provided the most interesting results: How to create understanding for the system? How to create healthy and fresh associations?

Results

Results can be categorized into three types: add-ons, ideas on system level and ideas that are tied to touch points in life (Fig. 33, Fig. 34, Fig. 35). All ideas target some reconfiguration in practice, by adapting the material or introducing new skills or meanings (Fig. 36). Add-ons can trigger a new reconfiguration of practices by integrating the meanings or skills that were identified as missing in the refurbished context. However, I find this direction uninteresting, because as it alleviates the pain rather than creating a better future.

The direction I found interesting was to support residents to understand the system. I clustered ideas that aim for increased understanding and found these two clusters most interesting: 'feedback of the system' and 'transparency of the system'. The assumption is that increased understanding helps residents to transition their practices, as it supports to acquire the new skills. Besides, it supports to develop trust and images of a functioning system.

In conclusion, the design goal was specified to:

"design an interaction with the house that provides feedback on functioning and quality of air."

Feedback is not only considered as feedback on action, but also a general proof of functioning and air quality.

Fig. 33 - Idea on system level. Making ducts and air flow visible supports transition by trust (meaning) and understanding (skill)

Fig. 34 - An add-on: curtains that change color on quality of air. It supports residents to understand when air is poor (skill).

Fig. 35 - Idea tied to life: plant object fosters healthy associations during sleeping (meaning) and provides feedback (skill).

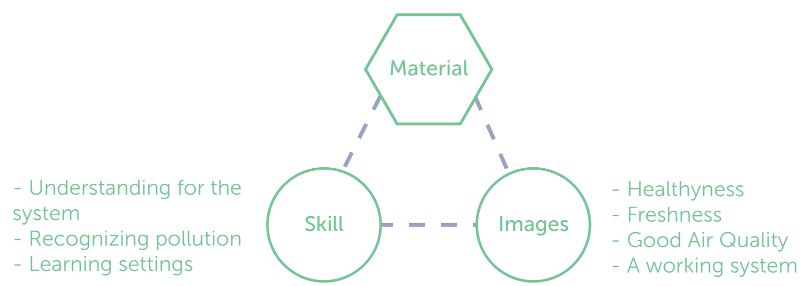


Fig. 36 - The image shows which images and skills were targeted by the ideas. The overall goal is to support residents to integrate the new ventilation system (material) in their practices.

SCOPED IDEATION

The set design goal is to design an interaction with the house, that proves the systems functioning and quality of indoor air. To tackle all elements of the design goal, I formulated the following sub-questions:

- When and where should the interaction and feedback be?
- How to provide feedback on functioning?
- How to confirm freshness of the air?

I used a probe to explore how to confirm the quality of air towards residents. At the same time, I ideated and developed concepts. Both are discussed hereafter.

Probing feedback on Indoor air quality

Part of the design goal is to confirm residents the quality of indoor air. The motivation is that this confirmation supports residents to transition practices because meanings of healthiness and functioning of the system are fostered. Also, the resident can acquire skills in recognizing polluting activities.

Method

I explored feedback on current air quality by a probe measuring and communicating indoor air quality in real time. Similar to technology probes the device is used in context to gather inspiration for future designs through reflection on use (Hutchinson et al., 2003). The prototyped device measures CO2. It communicates measured air quality through a LED that changes color and an LCD screen that provides a quality statement combined with an exact value in ppm (parts per million) (Fig. 38).

The probe was used in the context of cooking and spending the night by the researcher and her roommates. At university two students had it at their desk for half a day. After usage the participants were interviewed about their experience.

Results

The probe helped to learn when air quality is poor, how people interpret information and to what extent people engage with information. First, the probe demonstrated that air quality is seldom poor. Besides, the probe showed that the response of the machine on small changes helps to create understanding. By blowing in the CO2 sensor, participants saw the ppm values rise and statement change from "good" to "poor" (Fig. 38). People did not care for the actual ppm values, but numbers were a means to see how they influenced air quality. In the actual zero energy housing context, there is no feedback on such small changes. In general, participants were not very engaged with the device. Also, participants mentioned the object provides too much information. Only to see whether the quality of air good is sufficient in most cases. On the other hand, the numbers help to create understanding. A solution would be to layer information and only display ppm details when residents are interested and want to learn.

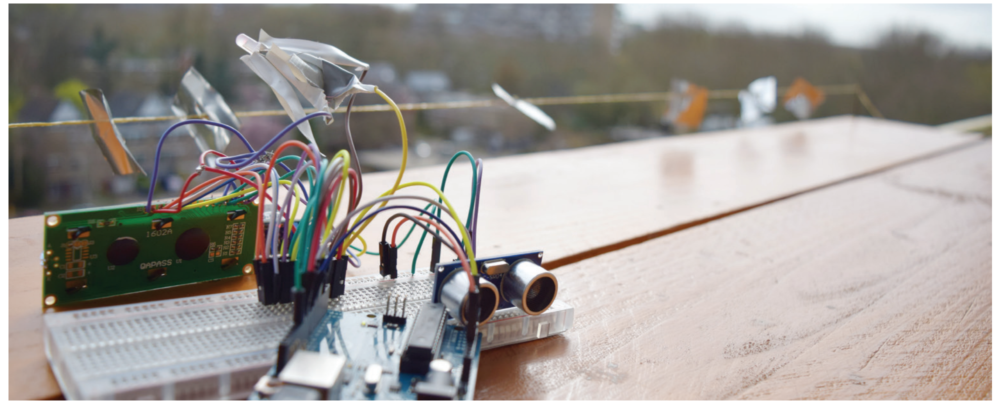


Fig. 37 - The prototype is calibrated to CO2 levels. The prototype measures and communicates CO2 levels

Fig. 38 - The probe communicates air quality in various ways. The aim of the probe is to learn how people experience real-time feedback on air quality

Fig. 39 - Two students experiment with the device, by blowing in the sensor. The sensitive sensor of the device allowed to see change in value and learn what impacts quality of air

Concepting

I used a morphological chart (Van Boeijen et al., 2014) to divide the overall design goal into sub-functions. I ideated on these sub-functions. By creating combinations with ideas for sub-functions, I developed three concepts. Sub-functions in the chart were 'to confirm functioning', 'to confirm the quality of air' and 'suitable touchpoints' (Fig. 40). I communicated the concepts using storyboards to understand how the ideas would fit in the context.

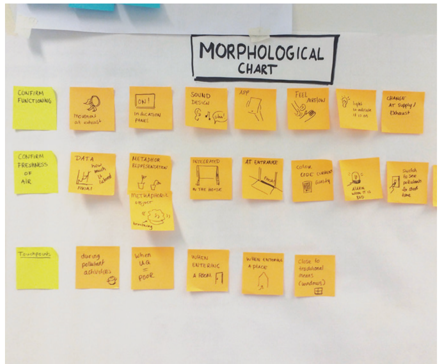


Fig. 40 - using a morphological chart I combined ideas for sub-functions into three concepts

1. Audio feedback

In this concept (Fig. 41), the resident is welcomed by a breeze and some sound as he enters the house. The moment residents enter the house, is usually the moment residents are sensitive to air quality. The air flow is meant to foster associations to freshness and health. Sound and airflow both intend to foster associations with the systems' functioning. The sound could work as a smoke detector and notify the resident if air quality is poor.

Using sound to provide feedback is troublesome. First, will it be heard in the context with other sounds? And second, it is probably undesirable when decreasing noise pollution of the ventilation systems is a big topic.

2. Smart Doors

This concept (Fig. 42) uses doors to indicate air quality on the moment one changes rooms. Air quality is communicated using a visual metaphor. When touched, one can see more detailed information.

The idea is that the concept fosters the meaning of trust in the system as the quality of air is proven. Besides, it supports residents acquire the skill to learn what activities are polluting.

Reflecting on the concept, the question is whether doors are a suitable location to provide feedback. Doors are not always closed like in the storyboard. Furthermore, the question is whether prove on quality of air supports transition practices. In the probe demonstrated people are not very interested in the quality of air.

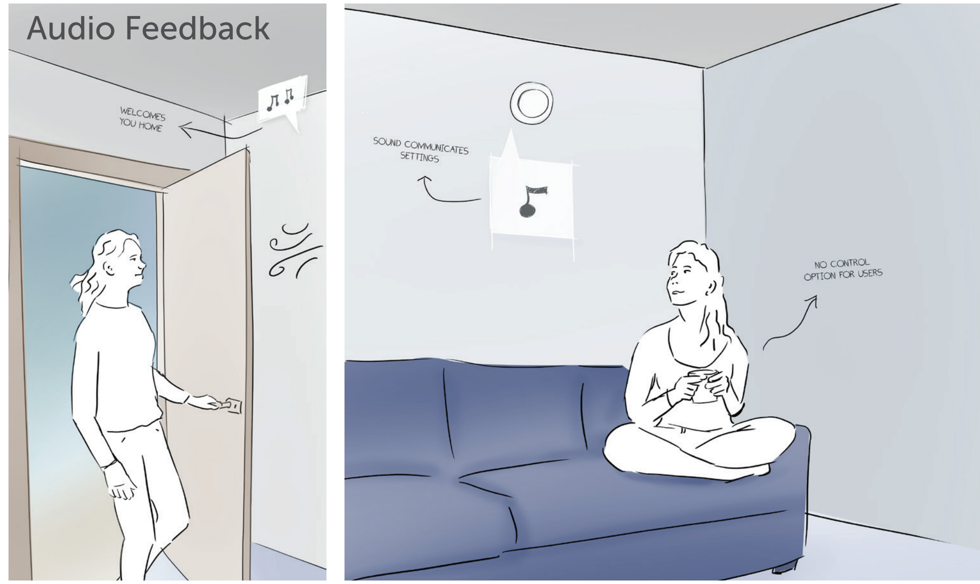


Fig. 41 - This concept welcomes the resident with a breeze to foster associations that the system is present and healthy. Audio feedback is used to communicate what the system is doing

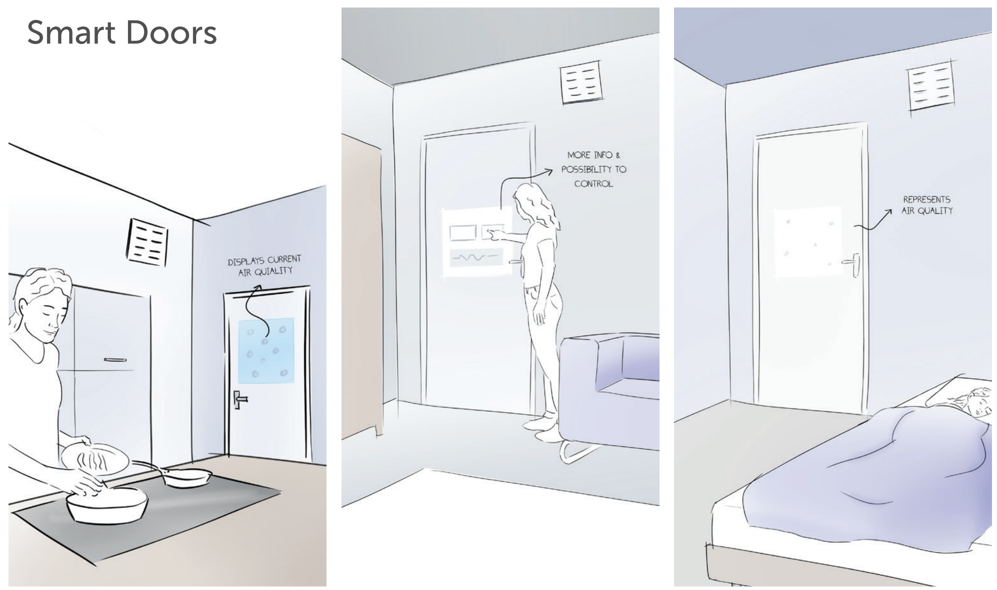


Fig. 42 - The concept uses doors to provide information on indoor air quality. Residents can access more information in a second layer of information. Information on air quality proves the quality of air and supports learning about pollution

4. Visual Supply

Unique about the concept is the location of feedback: it provides feedback on the systems functioning on the supply valves of the ventilation system. In terms of practice, the concept aims to target the meaning of a functioning system by making airflow visible. Furthermore, it supports to learn the skill to influence the system as feedback on action is provided.

Supply and exhaust valves are currently not used to provide feedback. Today the supplies are quite hidden, but in order to make the system more transparent, it could be logical to make the elements through which air enters more central. The paper prototype was a quick way to validate the direction (Fig. 44). The concept supports the idea something is happening and makes it visible when settings have changed. Moreover, I know cleaning the valves is not integrated in residents practices. In next steps I can try to integrate this element.

Fig. 44 - Paper prototype that moves according to the air that is supplied

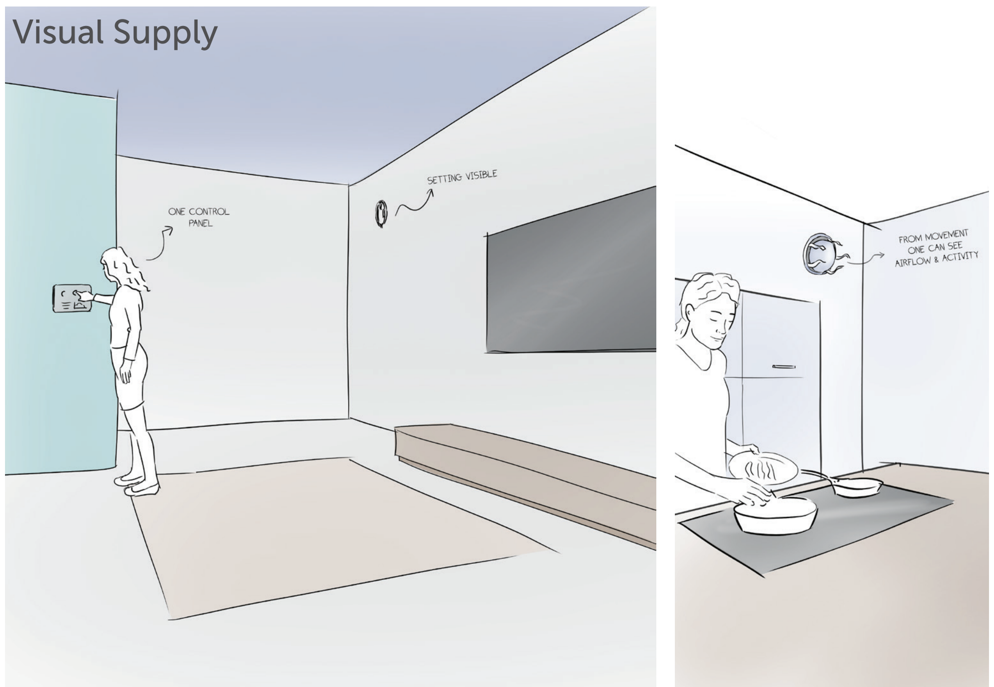


Fig. 43 - The concept uses the supply valves to prove the system is working and show what it is doing. Through increased trust and understanding for the system it supports integration in practices.

CONCLUSION

The storyboards helped to evaluate the concepts in context. Visual supply seems like a promising solution as integrating the supply and exhaust valves to provide feedback could make the system more transparent and easier to understand. Thereby it could support integration of the material into practices.

The two other concepts mainly aim to prove the quality of indoor air. The assumption was that this would support residents in understanding. After all, the probe showed that residents do not show much interest in indoor air quality. With that the direction became less interesting.

6. CONCEPT ITERATION 2

This chapter covers the second concept iteration. It describes the two concepts which were developed and how they were evaluated. The first concept aims to make the ventilation system easier to understand and the second aims to foster fresh associations

6. CONCEPT ITERATION 2

This ideation continued on insights from the previous concept iteration. The aim was to prove the systems functioning and quality of indoor air at the ventilation valves. In ideation it was a focus point to incorporate the cleaning habit (Fig. 44). However, cleaning is left out in concepts, because the focus became too broad. Two concepts are worked out in storyboards and evaluated in lab-setting.

CONCEPTS

Feedback Valve

The feedback valve feedback on the amount of air that it brings in. The valve opens and closes according to its setting: the more it is open the harder it is on (Fig. 46). The aim of the concept is to support residents to develop trust in the system and create understanding for what it does. Also, it will take away the insecurity about the system's functioning which some residents had expressed in the interviews.

With the introduction of material, the practice will reconfigure. The new material supports the change of the meaning from the idea that a system is not working towards a system that is working and supporting the resident in living. Residents will be able to adopt ventilation in their practices, as a result of increased trust and understanding.

Windy Welcome

The second concept, Windy welcome, provides an airflow directed towards the resident that enters the house. Envisioned is that this supports the meaning of a working system and support healthy associations with the ventilated air. Associations with freshness will be evoked through the wind which is after all the traditional way to detect fresh air.

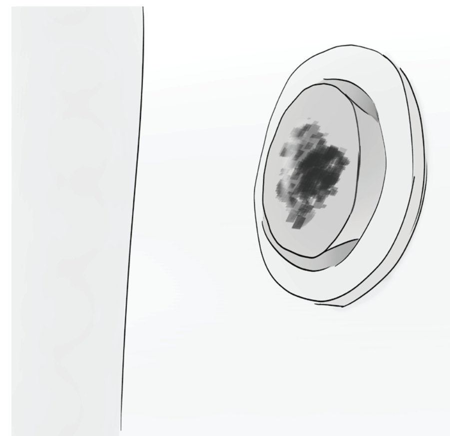


Fig. 45 - This idea aims to support residents to develop a cleaning ritual by showing dirt. Cleaning is left out in selected concepts as focus became too broad

Feedback Valve

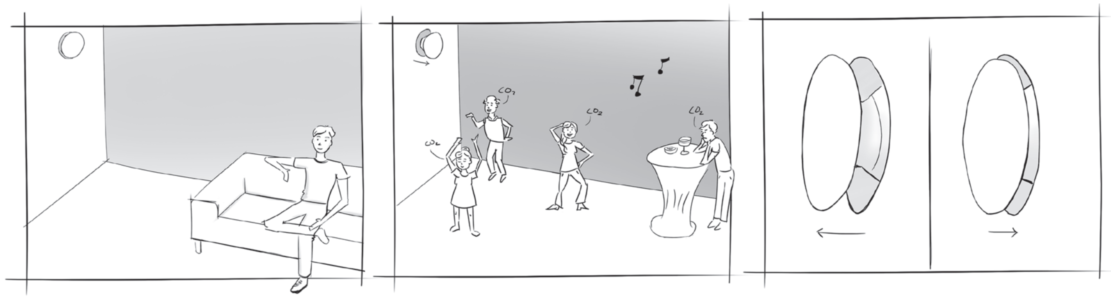


Fig. 46 - The feedback valve moves according to the ventilation system activity. If there is a party, the ventilation system works harder. The valve will move out to show more air is supplied

Windy Welcome

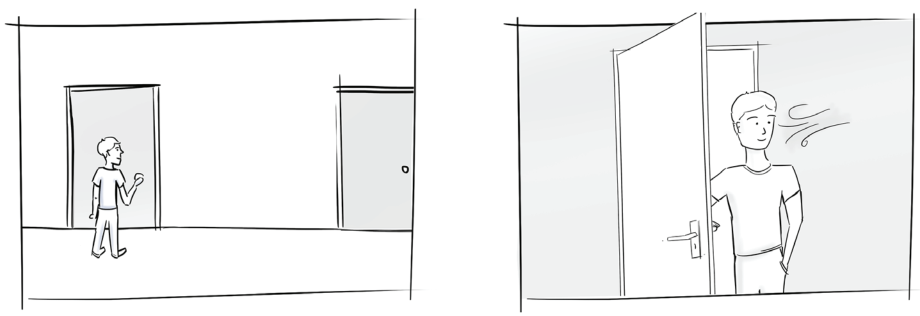


Fig. 47 - Windy Welomce welcomes the resident with a breeze, as he enters the home

Evaluation

Prototypes

Both concepts were prototyped in order to evaluate them. The feedback valve was prototyped using a Wizard of Oz installation (Fig. 52). The valve had lights around it and its position was controlled by the researcher from behind the fake wall. Residents could influence settings using the control that belongs to the valve. To support residents to link the valve and the control they were designed in a form family: they were both circular, white in color and surrounded by blue lights. Additionally, motion is similar: the control and the valve move out when the system is set to maximum. The concept windy welcome was prototyped by means of a ventilator at the door, which could be turned on and off.

Set up

Six participants experienced both concepts in one lab evaluation, participants were asked to perform various in-home activities (Fig. 49). Props stimulated residents to enact and immerse in the experience as if they were home. Residents were asked to think aloud and interviewed about their experience afterward.

Participants

Six students took part in the evaluation. Three of them live in a house with balanced ventilation (Fig. 48). Depending on whether participants were interviewed for the field research, they had longer or shorter pre-interview to warm them up.

Fig. 50 - props support participants to engage in enactment. In the pan were burnt onions to simulate a situation of pollution

Nr	Balanced Ventilation	Previously Interviewed
1	Yes	Yes
2	Yes	Yes
3	Yes	No
4	No	No
5	No	No
6	No	No

Fig. 48 - Six students participated in the evaluation. Three of them live with balanced ventilation systems

Fig. 49 - Participants experienced the two concepts in scenario that they acted out

Fig. 51 - The prototype of the feedback valve includes a control and a valve. The two are a form family and indicate the systems' activity by the position. The interaction of the control works using an arduino and a solenoid.

Fig. 52 - The valve its interaction is simulated by 'Wizard of Ozz'. The researcher behind the fake wall controlling the position of the fake valve.

Fig. 53 - Residents experience Windy welcome as they enter 'their house'. The wind was controlled by the researcher. The ventilator was noisy loud and had an intense airflow

RESULTS

Feedback Valve

The evaluation proves the feedback valve as a way to support integration of the ventilation system in residents' practices. Five out of the six participants understood the feedback of the opening and closing valve naturally. In interviews participants mentioned the valve would provide clarity and support them to trust and use the ventilation. One resident living with balanced ventilation mentioned:

"an indication would help me if I have the feeling my room is not really nice, then I think oh, I could open a window. But well, if I then see the ventilation is working hard, I think it is not necessary. I can leave the windows closed, the ventilation will do its work and the heating can then remain off."

From this quote I learned the new material at the valve introduces the meaning of saving energy. The window can remain closed and thus heat can be saved. Lastly residents mentioned feedback from the system will support them to develop appreciation for the system, this is another new meaning that is introduced with the material.

Control

Positive was that residents linked the valve to the control, as was intended. However, the feedback and feedforward of the design were poor. The the small round sensor on the button was interpreted as a signifier for a turning knob, therefore participants turned the knob instead of pushing it. The control came out when it was activated, however, the distance was too small to be seen by participants, which made them insecure. In the interviews, residents were positive about the idea of seeing change both at the valve and the control. However, residents mentioned being confused about how their control interfered with automatic functionality.

"If you see the control coming out, you know it went on automatically. So, then I don't have to put it on myself. And if I actually would do so and see it going in again, you know what is happening."

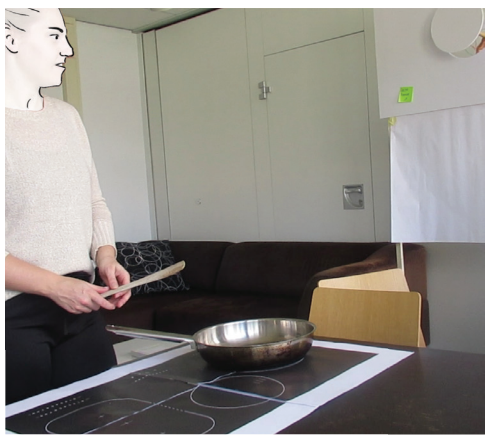


Fig. 54 - Participants looked at the valve during cooking and understood the feedback

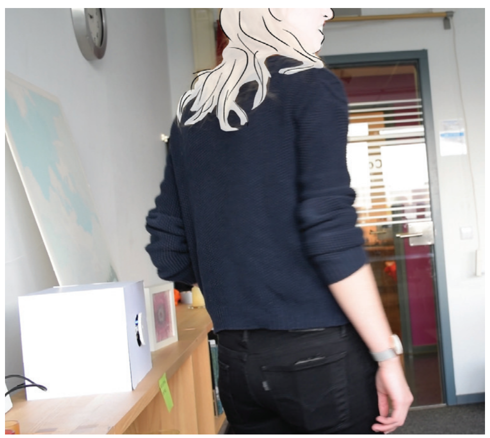


Fig. 55 - A participants looks at the valve after pressing the control. Participants understood the link between the valve and control

Windy welcome

Two participants experienced windy welcome as pleasant, but three participants found it unpleasant. One had not noticed the airflow. The wind did support residents in the skill to recognize ventilation is on. However, two participants thought the ventilation had been on when they were not at home, and mentioned it was a waste of energy. Waste of energy is a new meaning, which was not expected. Only one resident mentioned having fresh associations, as was intended. The concept could prove systems presence and functioning. Although evidence is from only one participant, fresh associations could be created. The airflow was quite intense and loud, it would be interesting to reevaluate with a more subtle airflow to find out whether this is more pleasant.

"that was really like a airco right in your face. Not very pleasant such cold air in your face."

"Well, the corridor is often quite dusty and stuffy. And if you than come in with air flow which is not too cold. That would be pleasant and it would instantly feel fresh. "

Fig. 56 - A participant experiencing the airflow at the entrance. Three residents experienced the windy entrance as unpleasant

CONCLUSION

In conclusion, the feedback valve is seen as the most promising direction, as residents living with balanced ventilation mentioned it would support them to integrate the system into their practices. However, the valve in its current fashion is not realistic.

Currently the valve is the place to set configuration, which is a very delicate matter. Hence, the movement of the cover is difficult. Besides using a motor to move an extra cover will consume energy, which is does not align to the the purpose of zero energy houses. Thus, feedback at the valve seems promising but there is a need for another, more simple solution.

These lab-evaluations were tested with students and over a short time. For the next steps, it would be interesting to test how people perceive constant feedback over a longer time. In the lab evaluation participants could observe change quickly; would the feedback also work without recent comparison? Also, it would be interesting to include a more diverse group in evaluation. This is important to capture a diversity of practices.

7. FEEDBACK FAN

This chapter presents the design iteration that resulted in the final design: the feedback fan. In the process, it elaborates on ways to provide feedback at the valve. It concludes with the results of the final evaluation

7. FEEDBACK FAN

AIM

The aim of this concept iteration is to translate the idea to provide feedback at the valve into a realistic solution. The previous iteration proved feedback at the valve as a promising direction. However, the it was unrealistic as it was costly and interfered with configuration.

Desk research highlights the following elements as important for a realistic redesign of ventilation valves. First, noise and drafts should be limited. Besides, the static pressure of the system should not increase by the adaptations that are made. The higher the pressure gets the more power the fan requires (Tamminen et al., 2016). Generally, the configuration happens at the valve. In order to be integrated into existing systems, the redesign should allow for a configuration at the valve.

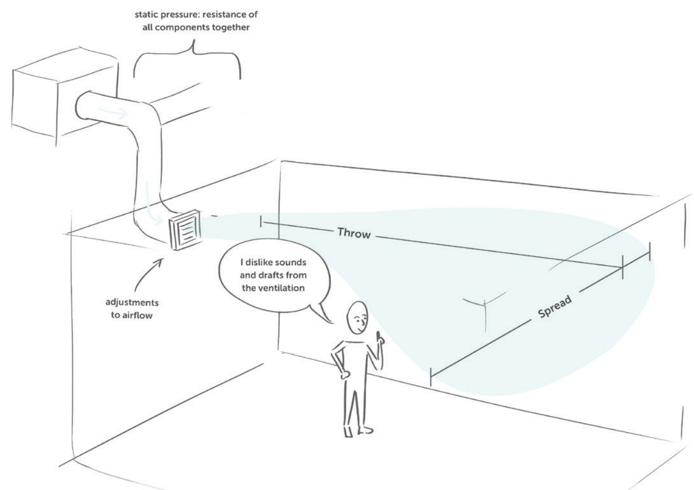


Fig. 57 - Including feedback at the valve has limitations: static pressure, throw, spread and the opportunity for configurations are important elements

DEVELOPMENT

To creatively explore the possibilities in feedback, I made a collage in which I grouped feedback in existing products. This resulted in three opportunities: movement, shape change and lights (Fig. 59). Lights are not desirable as residents mentioned to dislike lights in their living room in the feedback valve evaluation. The other option, shape change, could be either 3D or 2D. It could be an indication, like a speedometer. It could also be more metaphorical, like for example an hourglass. The third option, movement, is an interesting direction, as it could be induced by the wind. Ferraris meters are an inspiration for this direction as these meters use constant movement to communicate energy usage (Fig. 58).

Besides forms of feedback, I researched what could induce this feedback. How this could be done using minimal energy, how data can be communicated to the valve and whether I could make use of the power of the wind. The two steps combined resulted in the following four concepts.

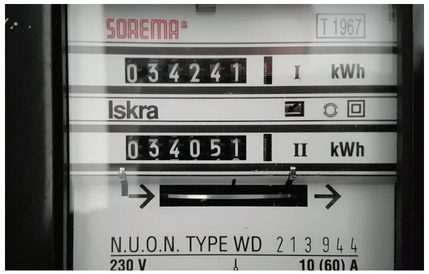


Fig. 58 - Ferraris meters were an inspiration for the Windy Valve concept, as it also provides feedback by means of motion (source: Youtube.com)

Fig. 59 - By collaging I defined movement, shape change and lights as options to provide feedback

Feedback fan

This is an add-on to existing valves, which uses the supplied wind to provide feedback. The speed of the fan will adjust based on the amount of supplied or extracted air. Movements prove functioning and speed communicate settings.

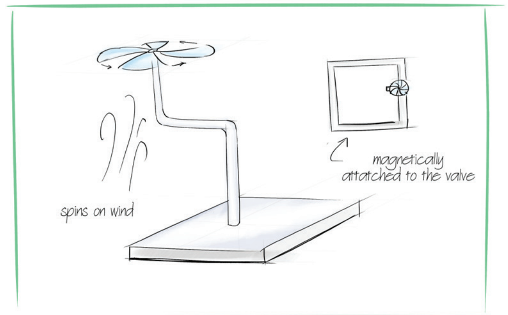


Fig. 60 - Feedback fan is an add on to the valve that communicates wind flow

Windy valve

This concept provides feedback in the form of motion: an element of the valve will move according to the setting of the system. The concept uses the existing airflow inside the valve to induce movement of the element that provides feedback. The movement of the wind can be communicated in various directions, as movement can be transferred using gears.

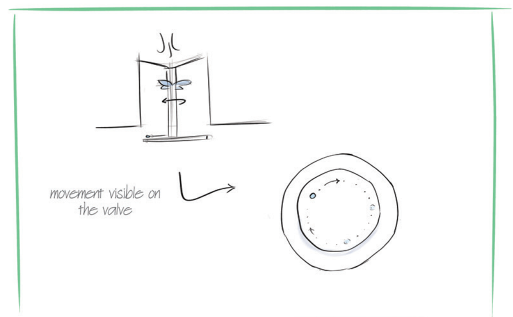


Fig. 61 - Windy valve uses airflow in the valve to create feedback

Settings meter

This concept indicates current settings of the system similar to a speedometer. The settings of the system are communicated from the control to the step-motor on the valve using Bluetooth.

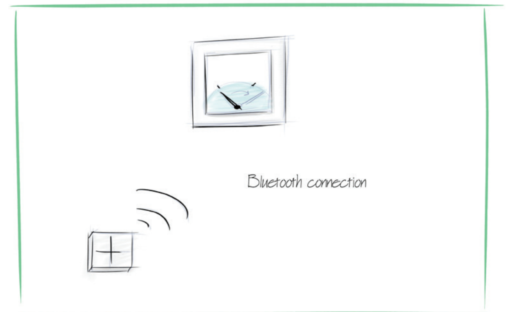


Fig. 63 - An indicator communicates current settings of the system on the valve

Data visualization display

This concept uses E-ink displays, which are flexible and not light emitting, to communicate the current settings of the system. Bluetooth is used to communicate the settings of the control to the valve. E-ink displays combined with Bluetooth are widely used by supermarkets for shelf price tags; therefore the technology is relatively cheap (about 10 euro including Bluetooth).

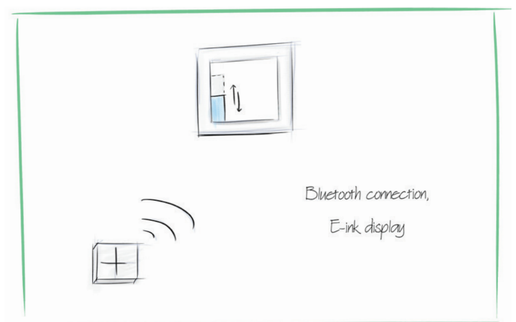


Fig. 62 - An E-ink displays the current settings of the system on the valve

SELECTION

I evaluated the developed concepts using a decision matrix (Fig. 64), similar to the Harris profile. Criteria in the evaluation are experience, price, effort and the impact of the concept on airflow. The concepts windy valve and feedback fan are interesting in terms of experience, as they are induced by the wind flow. I expect that seeing airflow supports trust, understanding and thus supports residents to transition practices. Besides, the other two concepts have the drawback that they require batteries and Bluetooth communication. From the matrix, I decided that the feedback fan is the most promising concept, as it bridges ideas for the future to a realistic solution for today. From the start, my aim was not to design an add-on, but this add-on is an impactful solution which can be easily implemented. Also, findings from use of the add-on could be transferred to future recommendations for the windy valve concept.

CONCEPTS	Windy valve	Feedback fan	Settings meter	Data visualization display
Type of feedback	*Motion change*	*Motion change*	*Shape change*	*Shape change*
Experience	++	++	+	+
Cost Price	+	++	-	-
Energy usage	++	++	+	-
Effort to make	-	++	+	+
Influencing aifllow	-	-	++	++
Creating noise	-	-	+	++

Fig. 64 - From the weighted decision matrix I decided to continue with the feedback fan

PROTOTYPING

To develop the feedback fan I experimented with materials and attachments. I also developed an accompanying flyer and started to experiment to better communicate gradations in airflow.

Fig. 65 - I learned light materials spin better

Fig. 66 - Fan attached to extract valve by means of elastic

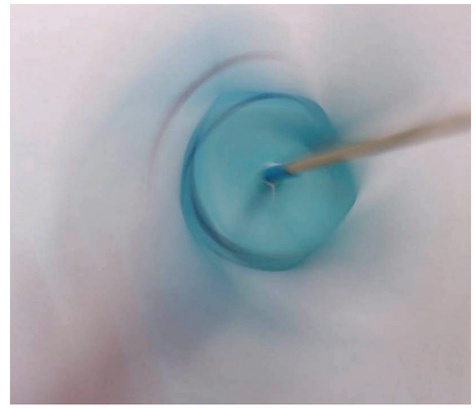


Fig. 69 - Experimenting with patterns, which change according to speed. The higher the speed, the more lines become visible

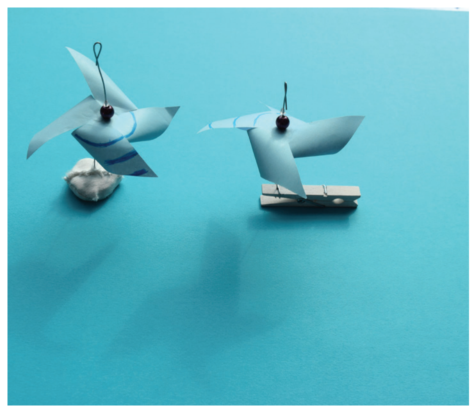


Fig. 67 - Exploring different ways of attachment, the magnet attachment is best

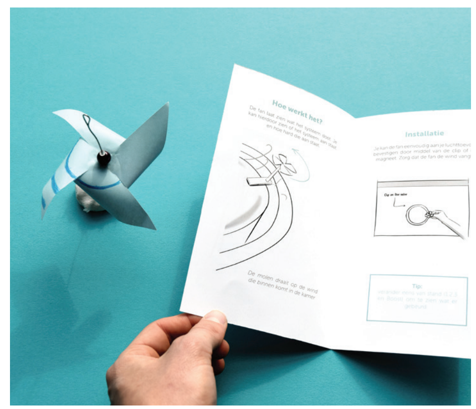


Fig. 68 - Fan with flyer as it was evaluated with a zero energy resident in the interview

EVALUATION

To evaluate the feedback fan, I conducted two types of concept evaluations. In the first, residents experienced the fan over two days in their own dwelling. To have a more diverse group of residents I also conducted a single-use evaluation. This was an in-home product experience combined with an interview.

Questions I had for the evaluations were whether residents perceive feedback, how they integrate it into it their daily practices and on which moments they are aware of the feedback. I was interested in how residents would experience feedback in their actual home and over time. Since the concept is an add-on, I was also interested whether residents would be able to attach it themselves and whether they think it would have supported them in the time shortly after the refurbishments.

Method

For the two-day evaluation I installed the fan in the apartment of two residents. These residents live in the same student building as residents from field research. During installation, I interviewed residents about their current experience with the ventilation system. After two days, I uninstalled the fan and interviewed them again about their experience with the fan.

The single-use evaluation was conducted in a zero energy home in Vlaardingen. First, the resident expressed her current experience and her experience shortly after installation. Thereafter, I gave the prototype and accompanying flyer (Fig. 68). The resident installed the fan and expressed first thoughts. Supported by a scenario of the concept, the resident reflected on the concept. Stripes on the fan were added and intended to support the resident to recognize different speeds (Fig. 69).

Final Concept Evaluation

#	Evaluation	What	Who
1	Two-day	Feedback fan	Student
2	Two-day	Feedback fan	Student
3	Single-use	Feedback fan and flyer	Zero energy resident

Fig. 70 - The final concept was evaluated with three residents

Results

From the two-day evaluation, I learned the fan enables residents to see what the system does. This makes residents more aware of the system and supports the meaning that the system is working. One resident said:

"I still do not 100% know what he does, but I do have more the feeling, he does something. While I before had the feeling it is existent but is it working?"

Residents experienced the feedback from the fan as a trustworthy prove of the systems' functioning, one resident mentioned:

"I think that seeing something that moves validates what you think, while light could, of course, be fake.".

At the same time, seeing what the system does also makes residents more critical towards the system. Residents try to understand why automatic ventilation is on a certain setting and find it a waste if the system does not decrease intensity when windows are open. Residents mentioned they looked at the fan on moments when they wanted to improve indoor air quality. For example, when the air was unpleasant they looked at the fan to verify whether the system was taking action or whether they should take action themselves.

"Well, when the fan is not turning and I think gosh, what a dry air in here. Then I would walk to the button and push it to make the system ventilate".

In this sense, the fan supports residents to integrate the system into their practices. Furthermore, seeing the fan supports residents to acquire the skill of controlling settings. Through experimentation, residents acquire understanding, as residents can now see what impact controls have on systems' intensity. Residents mentioned showing gradations in airflow would be important for the fan in order to remain useful after residents have developed trust that the system is working. In term of skills, seeing gradations would enable residents to align their actions even better to the ventilation systems' actions.

The interview evaluation provides insight in the handover procedure. First, the evaluation proved residents are able to install the fan by themselves since the residents put up the valve herself after reading the flyer. The prototype was supposed to communicate settings by means of stripes (Fig. 69), but the resident mentioned not to see settings. She underlined that seeing gradations is an important element to support her in use. Another new insight was that the fan could foster associations to freshness, as is reflected by the following quote:

"maybe that it is a bit more visual for some people indeed, like oh, it is on and maybe a bit of a placebo effect: as long as the thing is spinning you also feel fresher yourself. Then you have more the idea that the air is being filtered and that it is cleaner and feels more comfortable, I can imagine."

Fig. 72 - The fan is attached by the resident in the single-use evaluation. The fan supports the idea that the system works

Fig. 73 - The fan is attached to the ceiling supply valve for the two-day evaluation. Residents used to fan to align their actions to system activity

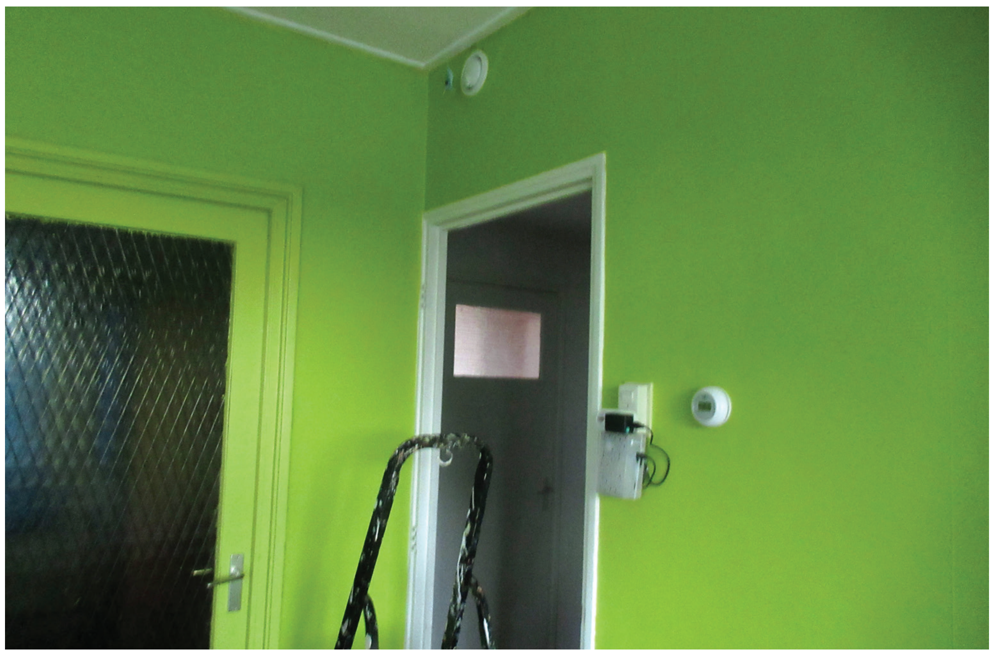


Fig. 71 - In the single use evaluation the resident attached the fan herself using a ladder. The magnet was easy to attach

Conclusion

In conclusion, the evaluations show that residents perceive the feedback. Residents mostly look at the fan the moment when they were interested in the activity of the system (e.g. when they feel the air is stuffy). Feedback supports residents to integrate the system into their practices and supports learning. However, residents try to understand the change of settings of the automatic system and get confused when it is illogical. The evaluation shows wind induced feedback at supply as is very natural and trustworthy. However, the design should communicate the differences in system intensity better to become useful for a longer time. Next steps should be to better communicate gradations and develop the supplemental package which is accompanies the fan.

Discussion

The concept evaluations have some limitations. First only three residents were part of the evaluation. The residents of the two-day evaluation were both living in the same building. Testing in the same building makes results more dependable on the configuration of the system in this specific dwelling. The attached fans were low-fi prototypes and not completely consistent in spin. Furthermore, fans were attached to supplies at the ceiling in tiny studios. This means that residents never saw the fan from the corner of their eye, which would be the case in dwellings which are bigger. With the single-use evaluation, I aimed to evaluate with a more diverse group, however, selection is still rather small.

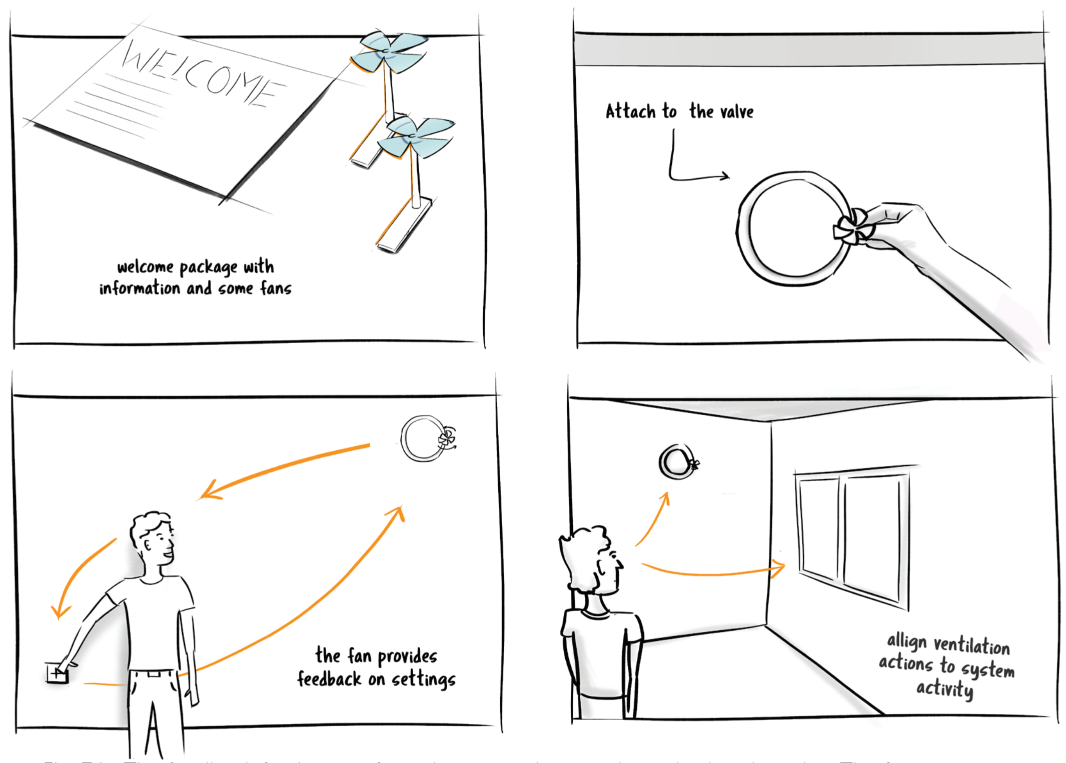


Fig. 74 - The feedback fan is part of a welcome package and attached to the valve. The fan supports learning though feedback and creates images of trust

Evaluation BIK Bouw

I had the opportunity to discuss the feedback fan with a project coordinator of BIK Bouw, the general contractor in the 2ndSKIN project. I was curious whether they recognized the problem and curious how they would see the service as part of their offering.

The project coordinator recognized the problem that resident doubt whether the system works. She mentioned using a paper at the exhaust valve to prove the systems' functioning. The paper will stick to it due to the suction. In her opinion, the feedback fan is used temporary and creates awareness about the system. It could be part of the welcome package residents already receive. Although she was interested to test the design in future projects, she mentioned she would not like to pay much for it. She mentioned choosing the right moment and right accompanying information as important future steps. From the meeting, I learned that the value for the stakeholder should become clearer and well-communicated. This is essential to get stakeholders on board.

8. CONCLUDE

In this chapter, I will reflect on the original goal of the project and will present conclusions. Recommendations for the feedback fan will be given, together with recommendations for future ventilation systems. Furthermore, I will reflect on the project and my own development

8. CONCLUDE

CONCLUSION

The goal of the project was to support residents to transition their practices in their zero energy homes.

Insights from field research revealed that residents struggle to develop new practices that incorporate the balanced ventilation system. I described the associated practice of maintaining indoor air quality in order to identify points that hinder a transition of the practice. I found the lack of feedback makes residents insecure and makes it hard to understand the system. Besides, associations that mismatch the new material make residents reluctant to use balanced ventilation systems.

In the concept phase, I generated ideas to improve feedback and foster desirable associations with the ventilation system. Through the iterations, I learned feedback on functioning and on the systems' activity helps residents. It helps them to trust the system is working, understand what the system does and develop appreciation for it. The final design, the feedback fan, is an add-on to ventilation valves that spins on the supplied air. In a natural way, it provides residents with feedback. The evaluation proved that with increased feedback, residents are able to incorporate the system in their daily routines and even align their own actions to the system's activity.

For the future, I recommend exploring how the fan can better communicate the different gradations of the supplied air. Besides, the service around it should be designed: what touch point is it given to residents and how does the supplemental package and information look like. Furthermore, it is important to get stakeholders like the general contractor excited about the potential of the solution, as they will be the ones implementing it.

I see opportunities for future design projects to tackle the other points that I identified to hinder a transition of practices. For example, design to foster desirable associations in balanced ventilation systems (e.g. fresh associations). Also, I believe insights I gained about the practice of maintaining indoor air quality and feedback of the system can be applied, when designing future ventilation systems. For example, by integrating feedback in valves.

In conclusion, both the feedback fan and the insights of the project can contribute to a transition of residents' practices zero energy homes. Hence, it can contribute to decrease the performance gap and increase residents' comfort after refurbishments.

RECOMMENDATIONS

Field research

It would be interesting to do additional field research to create an improved description of the practice and define further opportunities for reconfiguration.

Additional research should cover more types of housing, topographical locations and a bigger variety of households. It will probably reveal other performances of practices and make findings more suitable for generalization. It will also help to evaluate and improve personas.

Moreover, it would be interesting to research how house owners transition practices after refurbishments. The hypothesis of other research is that ownership influences the domestication of ventilation systems (Behar & Chiu, 2013). If this indeed is the case, it would be valuable to explore how to translate elements of ownership back to the rental context.

Furthermore, further field research could capture the practice in other cultures to open opportunities for new reconfigurations (Kuijer, 2017). China would be interesting as residents associations to indoor and outdoor air seem to be quite different.

The feedback fan

The improved design should be solid and better communicate the specific settings. Optical illusions that change depending on the speed (e.g. the wagon wheel effect), hold potential to communicate gradations. Valuable would be to keep the fan element modular. In this way, the fan could be used on both supply and exhaust channels.

Besides the fan, the supplemental package and touch point should be designed. Important to consider is that information in the package should fit all residents. For this, personas will be useful. Concerning the service, it would be good to evaluate the fan in the context of other information that is provided after refurbishments. To pick the right touch point, it would be valuable to use a journey of the process. Furthermore, it is essential to get stakeholders on board. An evaluation with more residents that evaluates the impact of the design on energy consumption could - with positive results - easily convince stakeholders.

Future design projects

Future design projects can to start from the points which were identified to hinder the transition of practices. First, a design goal could be to foster more fresh associations to ventilated air. Likewise, a project could focus on fulfilling the wish to feel connected to the outside in the refurbished context. Furthermore, insights revealed cleaning filters is troublesome. It would be good to redesign the valves to simplify the act of cleaning and make it resident-friendly. Also, a project could focus on supporting residents to develop a cleaning ritual, as it is currently often not part of routines.

Feedback in ventilation

The project displayed how increased feedback can support residents. Therefore, it would be good to integrate more feedback in future ventilation systems. The potential of providing feedback on the systems' functioning and setting on valves is demonstrated. It would be good to further explore how feedback could be integrated in future system and valves. There are opportunities to use the natural force of the wind, which does not consume energy. In realization, it is important to involve a partner that develops valves (e.g. Itho or Zehnder). Such a partner is more aware of limitations and can support to take the next step.

Development of ventilation systems

Through this project on balanced ventilation systems, opportunities for change were identified. First, it would be good to aim for a ventilation system that is clear without handover. This is important as the handover is not always happening. In rental housing, new residents are not always introduced to the system as they moved in.

Moreover, it would be good to take a more holistic approach to designing a ventilation system, rather than combining individual elements. A holistic approach opens opportunities for user-friendly solutions. For example, a solution could be to communicate the link between the valve and the control by means of a form family. This simple idea would not have come up by combining individual elements to the best configuration.

Furthermore, insights from field research show that future ventilation systems should preferably be semi-automated. Manual controlled systems are troublesome, as residents have to learn settings and remember to set them back. Residents sometimes feel the need for increased air. The semi-automated system fits the need, as residents can press boost on this moment and then again forget about it.

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PERSONAL REFLECTION

With this project I will conclude my studies. The realization that I was quite effortlessly combining many elements that once had been new or difficult, hit me as I was making a prototype to measure air quality. Doing that, I remembered the day I struggled to light an LED, because I consistently forgot the ';' in my code. It was great to recognize how many small and big lessons together enabled me to do what I did.

For this project, I set the goal to develop my visual. I took the opportunity to explore different styles and learned some new tricks. I made progress, but still see room for improvement. I will keep practicing and by doing so I hope to find my own style.

In the project I not only learned from the interviews and the used tools, but also from the analysis and communication. Applying practice theory has been a challenging, but valuable addition to my experience as user-centered designer. By taking this perspective, I could expand my analysis beyond the user, the product and its context. However, the challenge was to maintain the level of abstraction in concept development as I tended to solve problems that I saw on product interaction level.

After field research, I found myself in the luxurious position of having identified many opportunities for improvement. In the end, this luxury turned into a pitfall as I tried to solve too many problems with only one solution. In hindsight, solving too many problems made it hard to reach a level of depth with the concepts. I previously learned that procrastinating the convergence of ideation, hinders the progress. With this project, I experienced that solving too many problems with one solution has similar limitations. Overall, it has been a pleasure to work on the project. I would have loved to take the next step with my concept.

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