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# Behaviour change in home ventilation

## Learnings from Dutch refurbishment projects on residents' actions and motivations

In this article, we highlight some of our learnings from realised refurbishment projects on residents' actions and motivations in the various ways they aerate their home. The aim of the projects is to contribute to global climate change mitigation goals by developing residential energy-reducing refurbishments that can be upscaled (Silvester et al., 2017). Our research has a design research perspective, which means that we enquire into the relationship between the residents and the user interfaces and building elements in their refurbished home. We draw these learnings from our involvement as observers and advisers in several recent zero-energy refurbishment projects in social housing in the Netherlands. We will show that the residents' actions are related to their trust in the user interfaces. This trust is in turn related to some of the values that the residents expect their home to address: support keeping healthy, facilitating their activities and lifestyle, and having systems that are easy to use and control (Guerra-Santin et al., 2017).

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A well-known issue in processes of realising zero-energy (ZE) home refurbishments is that residents sometimes use ventilation differently from how it was designed to be used: rather than using the mechanical ventilation control, they open windows while heating is on, and disable ventilation or block vents (Behar & Chiu, 2013). This can jeopardize a zero-energy outcome and can lead to decreased comfort and health risks from polluted air (Kim, Paulos & Mankoff, 2013). It can also cause what is known as *the performance gap*, the difference between expected and actual energy usage of buildings (Behar & Chiu, 2013). The reasons for the residents' actions are not yet fully known.

We often interpret the situation that residents use windows to aerate as a challenge to influence the residents' behaviour and to ensure that their behaviour is in line with energy goals, health and comfort. In this article, we aim to shed some light on the residents' own motivations by highlighting some of our learnings from realised refurbishment projects on how residents interact with their various possibilities to aerate their home. We derive these learnings from data from the projects in which we observed and advised (Silvester et al., 2017). Our research has a design research perspective, which means that we enquire into the relationship between the residents and the user interfaces and building elements in their refurbished home. Our research questions are: what can we learn about the relationship and interactions between the residents and the user interfaces and building elements in their refurbished home? How do they interact, and why?

### Method

To answer these questions, we draw on some examples from two types of data. Firstly, air quality measurement data. These provide insight into the actual quality of indoor air. Secondly, qualitative research. This sheds light on the residents' and the buildings' actions that led to these outcomes and the residents' reasons for their actions.

#### Air quality measurements

Using sensors provided by Office Vitae (officevitae.com), we measured $CO_2$, temperature, light, humidity, and motion in three rooms of each apartment: the kitchen, the living room and the spare room. In addition, data on the outside temperature were collected from public records.

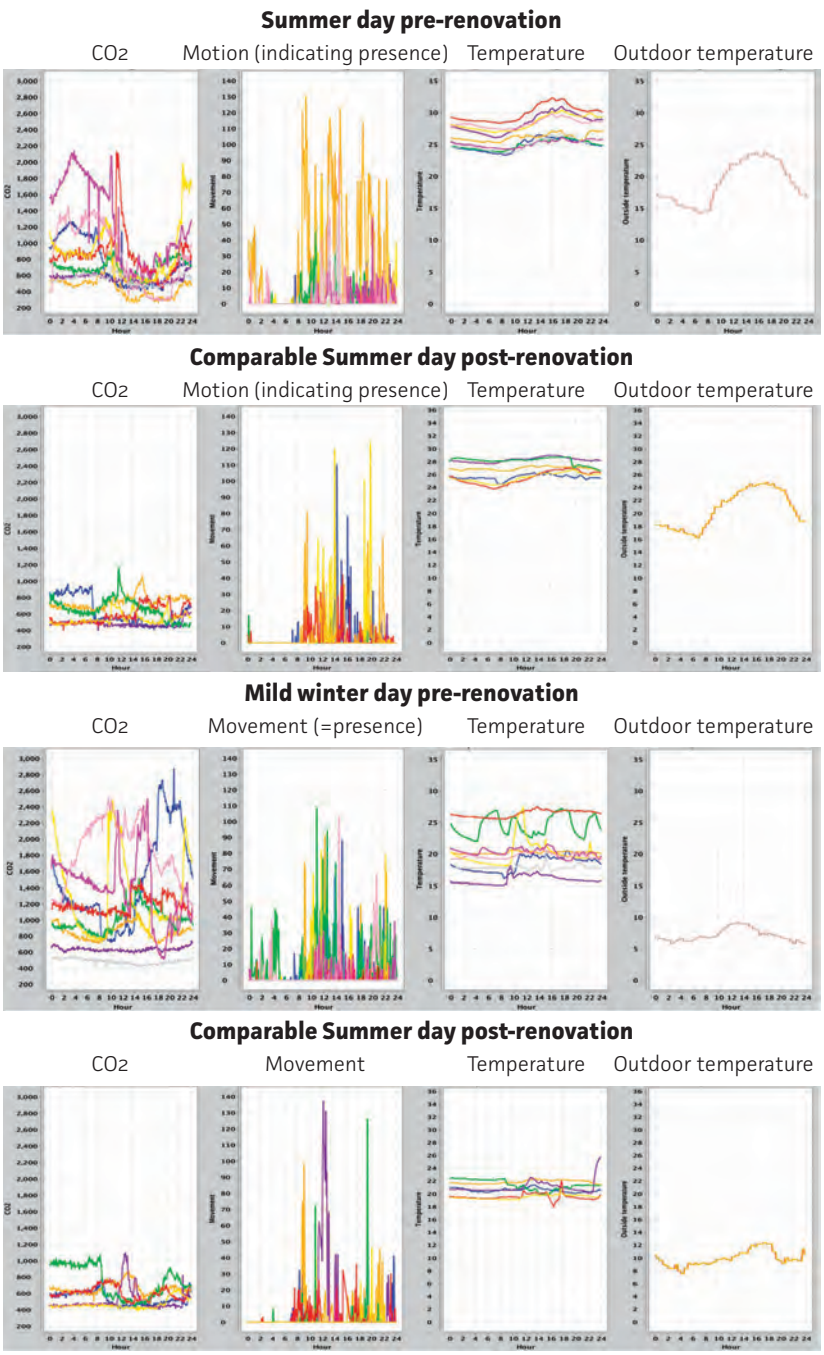


Figure 1: Comparisons of data for a single comparable day pre- and post-refurbishment. Data presented are from one summer day and from one mild winter day for each period.

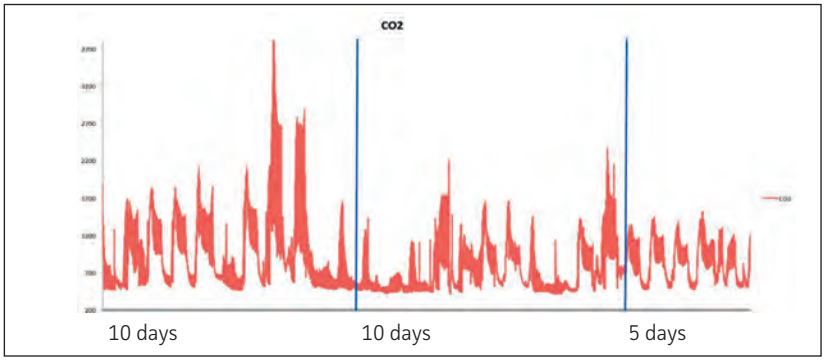


Figure 2. Changes in CO2 level over a three week period in response to a resident's deliberate adjustments.

## Qualitative research with Residents

In addition to the measurements, we also conducted qualitative research into the residents' experience. We visited them in their homes several times before, during, and after each refurbishment. During those visits, we interviewed the residents about their home experience and sometimes requested walkthroughs from them. As explained previously (Guerra-Santin et al., 2018), a walkthrough consists of asking residents to walk through their house with the researcher and to provide descriptions and re-enactments of the ways they usually control their indoor environment and of their daily practices related to energy consumption. This technique is a situated and embodied 'telling' activity that enables users to participate in understanding and communicating their daily practices (Brandt, Binder & Sanders, 2012) and is suitable to elicit residents daily life practices in their home environment (cf. Kuijer & De Jong, 2012).

## Participants

The data presented here are drawn from eight apartments in post-war industrialised housing in the Netherlands which were comparable in location. They were roughly 55 m2 single-level apartments, distributed across several stories. We measured before and after refurbishment for a few years. The data was collected from 2017 onwards, pre- and post-renovation. There was some variation in the occupancy: the majority of residents were single dwellers, with some dual occupancy. The residents varied in age.

## Analysis

To answer the research questions into the relationship between resident and building and into the reasons for their interactions, this article draws on both the

measurement data and the home visits to present a selection of reflexive ethnographic narratives (Blomberg & Karasti, 2012) on the residents' interaction with their ventilation system and building elements. This approach in general comprises ethnographic documentation and analysis in everyday settings, taking a holistic view on the process, providing descriptive understandings and showing members' point of view (ibid., p. 88).

## Results

We present a selection of pre- and post-refurbishment monitoring data and some data from our visits that serve particularly well to illustrate and explain the relationship between residents and their home and its motivations.

### *Illustrative findings from indoor air quality measurements*

Figure 1 shows a comparison of measured values for two selected pre- and post-refurbishment days: one in the summer season, and one in the winter season, for 8 households with a zero-energy renovation. The respective season days to compare against each other were chosen to be as close as possible in the temperature line and in sunshine hours to provide a good comparison.

The comparisons in Figure 1 reveal that the indoor climate calmed down significantly as a result of the refurbishment. The temperatures are much more constant than before and follow the outdoor temperature less. Nonetheless, they are quite high on the warm summer day sampled: around 27 degrees, with little cooling down in the night. On the mild winter day, they also remain constant, at a pleasant temperature of around 21 degrees, even as (as we know from qualitative research) some residents keep windows open for short or longer periods. This evenness of the temperature allows for a great improvement of air quality. Fungus and dampness that arises from temperature variability and was present in some of the houses, disappeared after the refurbishment.

Likewise, the $CO_2$ levels in the homes calmed down significantly as a result of the refurbishment. These levels too are much more constant than before and follow resident activities less. They mostly stay below 1000 parts per milion (ppm), which can be taken as an indication for a healthy indoor air climate. However, we also saw that the $CO_2$ levels peaked much higher occasionally, at up to 3000 ppm (not shown in Figure 1). The air quality has mostly improved, with some exceptions. We turned to qualitative research to enquire into the residents' experience of this.

### Results from qualitative research

From interviews and walkthroughs we came to know about the residents' interactions with their home to regulate their indoor air climate and about the residents' reasons for their actions.

Figure 3. Ventilation controller without guidance on its standard setting nor feedback on which setting it is on.

### *A residents' trust in the various ways they can areate their home*

We present here a reflexive narrative from one of the residents. During a winter period, we had measured high levels of $CO_2$ in one room of her apartment and alerted her to this, explaining that there was some risk to health and listing the risks. This happened specifically in one of the rooms, a room of 6 m2. It showed high $CO_2$ levels at night, indicating presence of a person (although we did not measure bedrooms that residents had described as such). The residents of this apartment were not aware of the reduced indoor air quality. To help the resident achieve a healthy $CO_2$ level in all rooms of her apartment, we recommended to her to adapt her ventilation setting over a period of several weeks to reduce the $CO_2$ levels. First, we extracted the measurements for the room with the high $CO_2$ levels over a period of ten days. Then, we advised the resident via text message of this and invited her to put the ventilation setting to position two, which should normally be the standard setting when someone is at home. She did so and the $CO_2$ levels decreased sustainably for a period of 10 days (Figure 2). However, the levels were still sometimes what can be considered as too high, above 1200 ppm. We then advised the resident, again via text message, to also include a short period of activating the 'boost' function of her ventilation system in the evening for about half an hour. She did so and the $CO_2$ levels improved to healthier, more satisfactory levels.

Some weeks after this interaction with the resident, we saw that the $CO_2$ levels had increased again. We enquired with the resident about the reason. She explained that she worried that the high ventilation settings contained frequencies that would cause her cats auditory distress, and that she had reverted to the

Figure 4. Adaptations through which the residents sought to ensure the health and comfort of themselves and their pets.

lowest ventilation setting for this reason. In addition to these misgivings about the ventilation system, she mentioned maintaining her habit of always keeping her bedroom window (in another room than the one measured) on a tilt position at night. She explained why: this was for her the reassurance she needed of having fresh and healthy air to breathe. She explained that the ventilation system was not trustworthy to her, because it had already broken down once in the first year post-refurbishment. In addition, it provided no indication of which was the preferred setting, nor was the setting easily detectable (Figure 3). This narrative brings several insights:

- Residents can indeed be unaware of the air quality in their homes, as has been found previously (Kim et al., 2013), even if they are actively trying to have healthy indoor air.
- It is possible to communicate with residents about their ventilation settings and they are able to adapt them purposefully (similar narratives could be gleaned from other residents, too).
- The residents' trust in the new systems is fragile. When system functioning was called into question because of a breakdown, the resident stopped trusting the system. She continued to use it but also relied on the assurance of fresh air from something she knew, could control and see: a window.
- Residents may have other reasons for their choice of settings than envisaged by the stakeholders choosing and implementing the systems. Such reasons can include the health of their pets and experiencing reassurance of fresh and healthy air.

### The residents' use of ventilation interfaces to influence indoor climate post-refurbishment

We heard similar stories as the one described above from many of the residents. Intrigued by the finding that the resident in the previous story described the window as the interface she could rely on, we looked at the ways other residents interacted with the windows of their ZE-renovated home. We found similar trust issues with the ventilation system, and that these other residents had developed multiple ways to adapt their windows to ventilation and other purposes (Figure 4). The windows had not been designed for these, because the assumption was that the residents would use the ventilation controller. The windows were large, heavy tilt and turn windows. To ensure sufficient ventilation, cool their homes and also to arrange aspects of their lives such as letting pets in and out, the residents resorted to multiple adaptations to their windows. In some cases, these went so far as to affix cabin hooks or other fixtures possibly impacting the

integrity of the window frames. They always had good reasons for doing so. For example, if a cat should be able to get in and out, the tilt position would not be safe for the cat – so a stable ajar turn position was needed.

## Discussion

In this paper we have given some examples of the realities of behaviour change in relation to indoor air quality after a ZE refurbishment. We have shown that the residents' actions are related to their trust in the user interfaces. This trust is in turn related to the values that the residents expect their home to address, which we have reported previously: support keeping healthy, facilitating their activities and lifestyle, and having systems that are easy to use and control (Guerra-Santin et al., 2017). In the projects we witnessed, the residents received a refurbishment of high quality that was successful and satisfactory to them, also in terms of successfully achieving a ZE-outcome. However, the projects did not provide the residents with sufficient support for their lifestyle nor feedback and guidance on how their home is behaving and why it is doing so. The residents then resorted to a trusted and manageable user interface: the window. We have seen that they even went to great lenghts to adapt it to their needs.

A much-cited problem in the literature is that residents might open the windows in the winter, thus letting heat escape from the home and jeopardising the zero-energy outcome (Behar &Chiu, 2013). In our findings presented here, we have shown that residents have good reasons to do so and that they actually feel forced to resort to some coping strategies to ensure their home is healthy and liveable for them and their pets and that it corresponds to their values. The residents' actions were entirely reasonable from their point of view: they were based on a need to be able to trust user interfaces, and on a need for the home to correspond to their values. If ZE home refurbishments are to be acceptable to residents, they need to earn the residents' trust. An initial way this can be done is that systems clearly communicate the setting they are on and the setting to which they should be set depending on what the residents are doing at that moment. There is also a need for new building elements and user interfaces that facilitate residents' daily life activities and values better.

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## Summary

Resident's satisfaction with home refurbishments can be undermined by non-transparency of home user interfaces, which can result in residents using ventilation differently from how it was designed to be used. This phenomenon is called a *performance gap*. This gap can be closed when designers understand better which factors affect residents' ventilation behaviour. This article presents learnings from refurbishment projects on residents' actions and motivations related to aerating their home. The current lack of trust in the system can be improved by reassuring residents on the system status, air quality, and the residents' health, including that of domestic animals.

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