

# Healthy Home – Taking Health into the Design and Use of (Dutch) Dwellings

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## ABSTRACT

In the coming years, the Dutch construction industry will be faced with a major energy transition. This means that dwellings should be built more sustainable and energy efficient according to the guidelines drawn up by the Dutch government. However, does this transition also include the individual health and comfort aspects of occupants or is there too much focus on achieving the energy-saving guidelines? This research about healthy living shows that a home environment has a great deal of influence on the physical, mental and social conditions of its occupants. Unfortunately, this is negatively influenced by, among other things, limited guidelines from legislation and regulations, the disinterest of the construction sector, and the unhealthy and unpredictable behaviour of residents. Therefore, change is needed in the current way of building as we know it in the Dutch building sector.

## INTRODUCTION

According to RIVM (Jongeneel, 2009), residents are increasingly concerned about their health in relation to their dwelling. Despite progress in the quality of the building stock with respect to mould, moisture and noise pollution, indoor environment-related complaints remain. The link between a reduced indoor climate and health problems has been in the news for some time, but has only been given more attention in recent years, partly due to the emergence of the sick building syndrome (Nag, 2015). The link between non-specific health problems and buildings has been established. In addition, practical examples point to a revised and improved quality of building and installation design. A good example of this is the new housing estate Vathorst in Amersfoort, where various health complaints arose during the user phase of a set of newly built houses (Sataloff et al., 2009). The cause was a lack of a good ventilation strategy, whereby the ventilation did not meet the health and satisfaction requirements of the residents.

In addition to the shortcomings of building installations, the influence of building and interior materials on the indoor environment is increasingly being discussed (A. Boerstra, A. Gelderblom, C. Hegger, D. Jochems, R. Kerkhoff, J. Odink, E. Peeters, R. Slob, 2007b). Volatile organic compounds (VOCs) can be found in building materials that are still used today and have an impact on people's health. Other substances

that pose a health risk include cleaning agents, pesticides and household dusts (A. Boerstra, A. Gelderblom, C. Hegger, D. Jochems, R. Kerkhoff, J. Odink, E. Peeters, R. Slob, 2007a).

In addition to building materials, building design also has a major influence on people's neurotic and mental health. By not only considering functional requirements, but also adapting the building to people's expectations, the building can provide more than just a place to live for its users (International WELL Building Institute, 2016).

In response to the above points, supplemented by a call from the field, research has been carried out into improving the living quality of newly built homes in the Netherlands. Ultimately, two documents emerged that provide advice to the construction industry and residents on how to develop and use a home in a healthy way.

## METHOD

The study on healthy homes was carried out as a graduation project at Avans University of Applied Sciences in the Netherlands for the improvement of the Dutch new-build housing stock in terms of building physics and architecture. The research consists of a combination of literature review, a measurement of air quality in a practical case study and a survey among future residents of healthy houses. The aim of the study is to identify relevant components for designing a healthy home from the design and user perspective.

For the literature review, first a trend analysis was done using the DESTEP+S method, looking at where the bottlenecks in building healthy homes are, and where there are openings in the problem to address. DESTEP+S stands for Demographic, Economic, Social/Cultural, Technological, Ecological, Political and Security. It is a method that makes it possible to visualise the threats and opportunities caused by the landscape in which the situation finds itself. The scope of this analysis was the integration of healthy measures into a sustainable (energy) transition of housing construction.

Next, consideration was given to the definition of a healthy home. This definition is the starting point of the study and has formed the basis for the positions taken in the study.

On the basis of a literature study, various health risks in a dwelling are described from the point of view of

building physics, installations and design. These health risks were divided into four themes: outdoor environment, indoor environment, design and communication between builder and resident. Ultimately, an advisory report was written in the form of these four themes.

To determine a starting point for the research, the Dutch building code was examined. This involved looking at what Dutch legislation does to prevent health risks. The 2012 Buildings Decree was used for this purpose.

Based on the definition of a healthy dwelling, the trend analysis of the urgency of the research, various health risks in a dwelling and the current measures from the Dutch building code, recommendations have been issued to improve the health of the indoor environment and building design. These recommendations are supported by a measurement in a living lab, an interview with the residents of the living lab and a survey among 68 future users.

The living lab consists of a house with a number of measures to stimulate the health of the residents. The measures include: Loam plaster walls, flax insulation in the roof and in the walls, air-water heat pump, mechanical ventilation without air circulation with particulate filter and direct air extraction in the kitchen. In addition, sensors have been installed in each living area of the house to measure CO<sub>2</sub> concentrations, Relative Humidity (RH), temperature (°C) and formadehyde. During the study, only the CO<sub>2</sub> measurement functions were accessible.

## RESULTS

### Urgency of Health in the Dutch Housing Sector

Various trend scenarios emerged from the trend research, with the most realistic outcome being that housing construction currently focuses on sustainability within the sector. However, very little attention is paid to the health of residents. It is therefore important that the construction sector focuses on the technology of both sustainable and healthy developments, whereby residents are given a more active role in the healthy use of their homes.

### Definition Healthy Dwelling

Health in housing is, like the term sustainability, a very general term. It is therefore difficult to capture the concept in a simple definition. In order to provide a framework for the definition, use has been made of existing definitions from, among others, the World Health Organisation (World Health Organisation, n.d.) and the Institute of Positive Health (Huber et al., 2011). In addition, the range of topics within this research falls within architecture and building physics, and is carried out within the building practice, so the concept development is connected to this scope. Ultimately, the following definition for a healthy home emerged:

'A healthy dwelling is a house or accommodation in which the individual's physical, mental and social well-being is positively promoted from the individual's state of mind by optimally combining the factors of the indoor environment, architecture and human attitude through preventive action, both in the dwelling and in the surrounding environment'.

In short, a healthy home promotes the individual health of its occupants in a positive way, regardless of their state of health. It is important to keep an eye on the physical, mental and social aspects. A home must ensure that the resident feels comfortable with his or her own body, mind and social environment.

### Health risks

The health risks in a home focus on the physical, mental and social condition of the resident. Some well-known examples are too high an indoor temperature, poor air quality due to particulate matter and Volatile Organic Compounds (VOCs), and removal of nature. For example, too high a temperature can lead to night-time restlessness and fatigue (Kuindersma & Ruiter, 2007). Poor indoor air quality depends on a number of factors, such as the degree and form of ventilation, the use of artificial materials in the home and the behaviour of occupants. Poor air quality can lead to headaches, concentration problems or tightness in the chest, among other things (SBRCURnet, n.d.). And finally: due to increasing urbanisation, people are becoming more and more distanced from nature. This is caused, among other things, by the reduction of greenery in the environment, over-stimulation of the body and the incorrect use of daylight and artificial light (Oerlemans, B; de Kok, n.d.), which prevent people from being able to relax. This can result in stress and invites unhealthy behaviour by residents (Van den Berg, 2013).

Some of the causes of the health risks can be sensed, such as the amount of daylight in a room or the temperature. This is also referred to as the resident's comfort. This comfort influences the physical and psychophysiological state and is bound up with an individual. Different people can experience comfort in different ways, which is why it is difficult to measure. Health problems often arise in the area of comfort, because each person feels comfortable in a room in a different way. Other causes of health risks cannot be sensed, such as some volatile organic compounds (VOCs) or the level of fine dust in a room. It is therefore understandable that people sometimes experience inexplicable complaints that they cannot place by means of physical sensors. This is why it is important for technology to help people increase their sense of comfort in the home.

In order to reduce the risks in practice, it is practical to divide them into themes, so that work can be done on improving a home in a targeted way. The research carried out has shown that the risks can be divided into

four themes: outdoor environment, indoor environment design and communication. The outdoor environment is in the direct surroundings of the dwelling. A number of issues within this theme are: poor outdoor air quality due to a nearby motorway or livestock farm, removal of nature due to urbanisation and social isolation due to unconscious discouragement of social cohesion. Indoor environment risks are characterised by discomfort due to too high or too low temperatures, poor indoor air quality due to, among others, inappropriate ventilation, artificial materials emitting volatile organic compounds, such as formaldehyde, improper use of the home by residents, noise and light pollution. Light pollution (the excessive use of artificial light) has a disturbing effect on animals, plants and people. The excessive use of artificial lighting causes the production of the hormone cortisol ('waking up' hormone) in humans and inhibits the hormone melatonin ('sleeping' hormone). This results in a reduction of the human immune system, sleep disorders and stress (Van den Berg, 2013).

The design brings with it the risk that the experience of space can be reduced by experiencing a feeling of being locked up. This is caused, among other things, by a ceiling height lower than 2.7 metres (Augustin, n.d.) and the design of spaces that are too small (Pagel & Choukèr, 2016).

Finally, communication is extremely important. Poor communication increases the risk of unhealthy behaviour. The responsibility for this lies with both the builder and the resident. The greatest risk lies in taking responsibility for the house. Due to limited explanation of techniques to the resident, these techniques can be used incorrectly by residents (Boerstra, A.; van Dorst, 2002), as a result of which a healthy technical system can still cause major health risks.

### **Current laws and regulations**

The definition of a healthy home states that a healthy home should contribute positively to the health of its occupants. This means that a dwelling should be designed and built in such a way that the risk of health complaints is zero. When looking at the Dutch Buildings Decree, this positive health contribution is not addressed. The Buildings Decree consists of regulations for safety, health, usability, energy-efficiency and the environment. All buildings in the Netherlands must comply with these regulations.

The requirements set by the Buildings Decree are minimal. Yet many builders see this as the maximum they are willing to deliver (Bouwmeester, 2016). The theme of 'health' is mentioned in the Building Decree, but has only limited content. The positive stimulation of health is not included. In contrast, it is stated that the risks must be limited or must not have a negative effect

on people. An example of this is the repulsion of moisture. The Dutch Building Decree states that the formation of allergens due to moisture must be limited. The word limited is remarkable. According to the legislation, a risk may be taken with regard to the formation of allergens.

A risk to health may not be taken with every regulation. For noise, the word 'protected' is explicitly mentioned. According to the Building Decree, residents must be protected against noise pollution from in and around the dwelling. This is remarkable. On the one hand, residents must therefore be protected, while on the other hand they may be exposed to the boundaries within the word 'limited' via other indoor environment aspects. No further investigation into this has been carried out in this study. However, a proposal has been made for an approach to better protect residents in their home environment.

A solution for the adaptation of the current building standards will have to be found at both national and regional level. At the national level, it is desirable to look again at the terminology in the Dutch Building Decree to see if there is an opportunity to better ensure the protection of occupants. In addition to the changes in the Dutch Building Decree, further consideration should be given at the regional level. In order to achieve a healthy living environment, it is important that municipalities take more action in this regard. Because of the decentralisation of tasks and the arrival of the new Environmental Act, it is up to the municipalities to include health in their local environmental vision and plans. It is precisely this decentralisation that the municipality can see as an opportunity to improve health at the neighbourhood level, so that the individual resident can benefit from a healthy living environment.

### **Guidelines Healthy Home**

Following the health risks in homes and the current measures in the Dutch Building Decree, an advisory report has been drawn up for improving the quality of life for residents. The recommendations are based on a large literature study and interviews with experts, taking into account the most relevant data. By applying these recommendations, the health risks in homes could be reduced and it might even be possible to exert a positive influence on the physical, mental and social condition of residents.

Returning to the aforementioned four themes for healthy living, measures can be taken at every level to effectively improve the sustainable home. In the thesis research, an extensive guideline has been written containing practical starting points that can be added to a dwelling. A small selection of these measures is described below.

Within the environment theme, the macro level (seasonal rhythm), meso level (reduce the distance

between the house and traffic and keep the house out of the nuisance circle of companies) and micro level (relationship with nature and building with a south orientation) must be taken into account. In addition, social interaction should be improved by the use of small front gardens, benches on the street and parks in the area, among other things. The stimulation of recognisability in the neighbourhood is also important. This can be done by using materials and colours for specific sub-neighbourhoods. Finally, privacy safeguards are important. There should be a clear privacy shield by placing small windows on the busy street side and large windows on the garden side.

Within the theme of the indoor environment, the temperature in the house must be kept comfortable by placing the house in a south-facing position, applying sufficient shade and using light-coloured or green facades and roofs. In summer, the living room temperature should not exceed 25.5°C and in winter it should not fall below 21°C. The bedroom should always be 3°C cooler than the living room. An important principle is that these values for temperature are advisory values and the resident must always be able to exceed the temperature. In this way, the house satisfies the psychological comfort feeling. The main heating and cooling system must consist of radiant heat/cooling. The emission system should preferably be a simple, cleanable system. To keep the air quality in the house comfortable, the air humidity should be between 30 and 50% RH (relative humidity). It is also important to use only natural products that contain little or no formaldehyde (advised: <30 ug/m<sup>3</sup>), acrolein (advised: <50 ug/m<sup>3</sup>), or benzene (advised: <20 ug/m<sup>3</sup>). The total VOC should not exceed 200 ug/m<sup>3</sup>. The CO<sub>2</sub> level in the house must also be kept low to keep the residents fit. CO<sub>2</sub> itself does not pose a direct health risk, but should be seen as an indicator of the waste substances emitted by the body. The maximum CO<sub>2</sub> value in a room is <750 PPM. This means a maximum of 350 PPM on top of the average outdoor value of 400 PPM. Finally, particulate matter (PM) in the house must be limited. This can be done by using an extractor with a minimum capacity of 300 m<sup>3</sup>/h and a particulate filter with at least class F7. The maximum fine dust value may not exceed: PM<sub>2,5</sub> 10 ug/m<sup>3</sup> and PM<sub>10</sub> 20 ug/m<sup>3</sup>.

The design must improve the mental aspect of people. This can be achieved by providing a view of nature, preventing a feeling of confinement by using ceiling heights higher than 2.7 metres and providing opportunities for minimalism. By designing minimalist, less material is wasted and more quality can be added to the house.

Finally, the communication between builder and resident can be improved by providing tips to both parties. The builder can then provide targeted information about, for example, the technology in the home using a simple technical manual. The resident

can use the tips to identify problems sooner and deal with the home more consciously in terms of sustainability and health. This can be done by an information booklet containing general tips for maintaining the home.

The above measures could serve as guidelines so that builders and designers can use them as tools to put the healthy theory into practice. They could be starting points to help build healthy homes. These principles are not obligatory, but any additional principles that are included are welcome. In this way, the package of guidelines for healthy living can be expanded, next to, for example, Fresh Schools and Well Building Standard.

### **Raising awareness among residents**

Besides the construction industry and the municipalities, residents themselves can also contribute to the solution. To a certain extent, they can influence health in the home. The first step that needs to be taken is to raise awareness of health problems in the home. The building sector can do this by providing information to the residents by means of a positively worded PromoPaper (information pamphlet on health in homes) that conveys the meaning of a healthy home, and a sensor-controlled device with clear visual support. In this, it is important that it becomes clear to the residents what is going on, why they should pay attention to health and how they can approach it most effectively.

An example for a Promopaper would be to give a number of tips that they can immediately apply in their house, such as tips on ventilating the house (in combination with an accessible technical manual on the installed techniques), letting daylight in and avoiding materials containing VOCs. During the graduation research, a first draft of a PromoPaper was used to give residents more information on the use and maintenance of the house. By means of a survey among 68 future users and a discussion with residents who are currently living in a living lab with healthy measures, it emerged that the wishes for a healthy home are considered important and that a visual representation by means of a PromoPaper is highly desirable. The preference for the visualisation is for a physical version of the PromoPaper to be given to the residents when they move into a new home. In addition, a digital version via social media or e-mail would be desirable.

### **Test results living lab sensors**

In the section 'Risks', it has already been explained that some aspects cannot be observed by humans, such as the fine dust content or volatile organic compounds. For the risks that cannot be observed by the residents, they could use a tool such as a sensor in the house that measures the risks and communicates them to the

users by means of a simple visualisation. This would give residents better insight into when it is best to open the windows or turn on the extractor fan. The survey showed that users would find these sensors a pleasant tool for implementing healthy tips.

During the study, one measurement was carried out using the sensors in the living lab. The measurement took place in May 2019. At the time of the measurement, the sensors could measure CO<sub>2</sub>, temperature (°C), relative humidity and formaldehyde. The results from the measurements were not representative, as only one measurement was carried out. However, it did appear that the installations were set up properly, so that the CO<sub>2</sub> level did not exceed 750 ppm for a long time and the formaldehyde remained within the limits of the Buildings Decree (formaldehyde < 120 µg/m<sup>3</sup>).

However, a cautious conclusion can be drawn that the values set for the installations may be more stringent. For formaldehyde, the limit value of the Dutch Building Decree has now been adopted, but a reduction of this limit value could be considered.

Another remarkable outcome of this study is the privacy of the sensors. Because the measurements were taken and stored per room, it is easy to read in which rooms the occupants are present the most and to observe the increase in CO<sub>2</sub>, among other things. It is therefore important to establish with the occupants what may and can be done with this data. This study did not discuss this further.

## DISCUSSION

It is necessary for the Dutch construction sector to pay attention to the health of homes in addition to sustainability. Most of the interest within the construction sector has so far been focused on sustainability. This is a logical choice, since the building sector is faced with major challenges in this area. However, the health of residents should not be forgotten in the design and realisation of homes. In addition to construction-technical principles, residents are not always aware of the health hazards in their homes. That is why it is time to raise awareness of health in housing.

What is the best way to do this? A healthy home should make a positive contribution to the health of its occupants. In order to realise this, it is important to adapt the insights of current legislation and regulations in such a way that the risk of health risks becomes minimal. The opportunity for this will have to be found at national and regional level. It is important that the construction sector, the government and residents act together in this regard. Up to a certain height, residents can influence a healthy indoor climate. After that, it is up to the builder to make adjustments to the design through architectural and building physics measures. The starting points of the measures should be laid down in a new set of measures

that should improve the health of homes. This graduation project has made a first move in this direction. New measures of this type could serve as guidelines so that builders and designers can use them as an aid during the design phase. This type of package already exists for schools and offices. Now it's time for the buildings where people spend most of their time: homes.

Residents can also work on the health of the home themselves. They need to be informed about the health effects of homes. A good way to raise awareness is to make a positive PromoPaper that adds meaning to the story. To involve residents in this process, tips can be given on how they themselves can exert a healthy influence on the home. By applying sensors in the home, the health tips can be monitored.

A follow-up study is needed to test the literature found in practice. At the moment, assumptions have been made on the basis of found literature, a small-scale survey and one measurement. Eventually, it will have to be investigated more thoroughly per theme how healthy requirements and measures can best be applied in practice. This research can offer a first start in this respect.

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