

HEALTHY INDOOR CLIMATE, RESOURCE SAVINGS AND CLEANER OUTDOOR ENVIRONMENT – ALL-IN-ONE AS “ACTIVE HOUSE”

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Abstract. Among the most recent concepts of energy performing buildings stands the “active house” one, that opposes to many others a strong highlight on users’s adaptive comfort and on a detailed influence of buildings on the environment over their whole life cycle. This paper aims to emphasize the importance of indoor climate quality (ICQ) for the health and wellbeing of building users, which should be a primary objective when building/renovating buildings, especially when excesses in saving energy consumptions tend to jeopardize it. Main parameters to ensure acceptable ICQ are described, together with the need to educate users in the spirit of saving energy as well as keeping their homes healthy. The level of ambition of the “active house” is described in terms specifications and guidelines. For best illustration, a study case is presented, currently under monitoring and certification procedure.

Key-words: energy performing buildings; indoor climate quality; user health; active house

1. Introduction

In the last decade there is a tremendous number of studies and legal documents on energy efficient buildings, with or without Renewables included. Some of them mention the quality of indoor climate, mostly in terms of temperature and humidity or CO₂ levels. These parameters have a significant influence on user perception of indoor air quality but are by far insufficient in creating real healthy conditions for humans. Acoustic and visual comfort, as well as natural light are rarely explicit in assessing the quality of so called “energy efficient buildings”. The emphasis on saving energy and reducing greenhouse gas emissions is so strong that quite often the primordial purpose of the built environment for creating a healthy climate for users is often secondary in the whole approach. Concepts like Passive House, NZEB or nZEB and many others impose restrictions for energy use, but very few, like “e4” or Active House mention emotion or natural light and landscape in

addition to energy efficiency and environmental aspects. Given the proven fact that people spend almost 90% of their lives indoors, at home, at their work place, or during leisure activities, it is important not to forget that the primary function of buildings is to provide safe and enjoyable living environments for its inhabitants, aspects that should never be compromised.

This paper aims to present the pledge of the Active House concept for healthy and comfortable indoor climate, prior to specifications on energy and environment targeted indicators levels. Its slogan: “the building that gives more than it takes” expresses exactly the idea that it offers such a good climate to users that what it takes in terms of payable uses seems totally acceptable and undisputable.

2. What is a healthy building and the role of users?

While comfort is a state of mind, health is

something more complex. A building should enable comfort and support health, but it cannot supply any of these two. A healthy building should protect from the outside as much as necessary, but also connect to the outside as much as possible. In addition, it is important to emphasize that acceptability of indoor climate quality rises significantly with personal involvement and adaptive options.

A Faunhofer study [1] suggests that 80 million Europeans live in moist or damp homes with an increased risk of developing diseases, like asthma. Lack of fresh air and poor indoor climate also hampers learning and working capabilities.

A recent European survey performed by the VELUX group [2] indicated that exposure to indoor environment (i.e., air contaminants, thermal comfort parameters) can lead to respiratory and other health related effects. The survey presents an indoor wellbeing model, where satisfaction couples with health perception to achieve accepted quality for users. For example, home satisfaction relates to size of available rooms, state of renovation, quality of sleep, and relation to neighbours. While, health perception is given by the following building characteristics:

✓ *Comfortable indoor temperatures.* As many as 82% of Europeans felt that their homes were too cold in some days during the last winter, and about 87% experienced overheating at some point during last summer. Congested nose, dryness or irritation of throat were directly linked with such conditions.

✓ *Fresh air.* The survey showed that 48% of Europeans who never air out their homes also did not feel energized and suffered from throat infections more than others. Opening windows 2-4 times daily mitigated such symptoms.

✓ *Satisfactory daylight levels.* About 37% of Europeans who lack daylight in their room rarely felt energised. Daylight is known to be beneficial improving mood and productivity. Moreover, it was shown that insufficient daylight may cause sleep disturbance, stress, obesity, fatigue and seasonal affective disorder.

✓ *Appropriate humidity levels.* The survey indicated that 60% of the people with mould in their homes complain about dryness,

throat irritation or develop asthma. A family of four people produce in daily activities 10 litres of water that should be evacuated somehow.

The identified symptoms related to an inadequate indoor climate are not minor; moreover, they cause huge consequences at the society level: treatment in hospitals or at home, loss of working days, low work performance, family problems generated by depression- all of these being estimated by statistical studies at billions of Euros yearly. For example, in France, pollution of indoor air has a health and economic costs of nearly 20 billion euros annually, while in U.K. same problem had a cost of 1,8 billion pounds in 2013.

The same survey [2] indicated that most of the people in Europe have an inadequate behaviour and their lack of proper knowledge lead to situations for which the building itself is not responsible. For example, in order to keep costs down, most of the people complaining about being cold in winter do not heat their homes to a comfortable temperature, do not air out or, the opposite, keep the windows too much time opened. This aspect shows very explicitly that great attention should be paid to the building features but also to the instincts, routines and habits for which the users are prone to.

3. Active house concept and specifications

“Active House” is a vision of buildings that creates healthy and comfortable lives for their occupants without negatively influencing the climate and environment – moving us towards a cleaner, healthier and safer world [3]. Hence, its holistic approach is evaluated on the basis of the interaction between indoor climate conditions, energy consumption and impact on the environment, defining three strategic objectives:

A. An active house creates *healthy and comfortable indoor conditions* for the occupants, ensuring a generous supply of daylight and fresh air. Materials used have a neutral impact on comfort and indoor climate.

B. An active house is *highly energy efficient*. All or most of the energy needed is supplied by renewable energy sources integrated in the building or from the nearby collective energy system and electricity grid.

C. An active house *interacts with the environment through an optimised relationship* with the local context, focused use of resources, and a minimal overall environmental impact throughout its life cycle.

For each of these strategic objectives, three quantitative criteria are defined and classified in four levels of ambition for each indicator, where 1 is the highest level and 4 is the lowest. The performance assessment for Active House includes all nine parameters and requires at minimum the lowest level for each of them [4].

3.1. Comfort

The Active House specifications aim to promote solutions for people to live in comfortable buildings designed for human needs. Intelligent systems may be important in a modern building and help optimize the indoor climate.

Daylight conditions are an important aspect of comfort in an Active House and can have a strong impact on our wellbeing. Findings in the field of lighting research have revealed that the quantity and quality of light received by our eyes not only affect our vision, but influence an array of non-visual effects including sleep and wake cycles, mood, productivity and alertness among others, and most importantly our long-term health. The amount of daylight in a room is evaluated through average daylight factor levels on a horizontal work plane. Direct sunlight availability should also be provided in the most used rooms. Table 1 indicates levels of daylight quality for residential buildings.

Thermal comfort plays a vital part in achieving healthy indoor environments. An Active House should be designed to provide optimal thermal comfort both during the winter and summer periods. The human capacity to adapt to different temperatures, as well as our needs for temperature variation through the course of the day and different rooms of the house should be taken into consideration. When air conditioning is not used, thermal comfort is evaluated based on the adaptation of the indoor operative temperature $T_{i,o}$ to the running-mean outdoor temperature T_{rm} , rather

than based on fixed set values. Maximum indoor temperature limits apply to periods with outside temperature of 12 °C or more, while the minimum indoor temperature limits apply to any other outside temperature.

Table 1. Active House daylight specifications

Parameter	Classification criteria
Average daylight factor	<ol style="list-style-type: none"> 1. DF > 5% 2. DF > 3% 3. DF > 2% 4. DF > 1%
Probable sunlight hours between autumn and spring equinox	<ol style="list-style-type: none"> 1. at least 10% 2. at least 7,5% 3. at least 5% 4. at least 2,5%

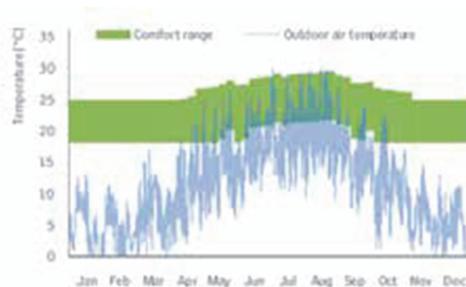


Fig. 1. Perceived comfortable indoor temperature range for the adaptive comfort approach relative to the outdoor temperature [3].

Table 2 indicates values for residential type of Active House buildings [according to the European standard EN 15251/2007]. The building system should be designed to achieve the recommended values, the users can however choose other settings

Indoor air quality is another crucial factor in achieving healthy indoor environments. The amount of air humans breathe per day reach 15 kg, and as we spend up to 90 % of our time indoors, it is indoor air we breathe. Good indoor air quality can prevent humans from getting mucous membrane irritation, asthma and allergy. It can also contribute to prevent some cardiovascular diseases.

Table 2. Active House thermal comfort specifications

Parameter	Classification criteria
Maximum operative temperature	<p>- without air conditioning</p> <ol style="list-style-type: none"> 1. $T_{i,o} < 0,33 \cdot T_{r,m} + 20,8^{\circ}\text{C}$ 2. $T_{i,o} < 0,33 \cdot T_{r,m} + 21,8^{\circ}\text{C}$ 3. $T_{i,o} < 0,33 \cdot T_{r,m} + 22,8^{\circ}\text{C}$ 4. $T_{i,o} < 0,33 \cdot T_{r,m} + 23,8^{\circ}\text{C}$ <p>- with air conditioning</p> <ol style="list-style-type: none"> 1. $T_{i,o} < 25,5^{\circ}\text{C}$ 2. $T_{i,o} < 26,0^{\circ}\text{C}$ 3. $T_{i,o} < 27,0^{\circ}\text{C}$ 4. $T_{i,o} < 28,0^{\circ}\text{C}$
Minimum operative temperature	<ol style="list-style-type: none"> 1. $T_{i,o} > 21^{\circ}\text{C}$ 2. $T_{i,o} > 20^{\circ}\text{C}$ 3. $T_{i,o} > 19^{\circ}\text{C}$ 4. $T_{i,o} > 18^{\circ}\text{C}$

High indoor air quality helps to avoid odour problems, which can positively affect the overall well-being of the building's occupants. An Active House should provide good air quality for the occupants while minimising energy use e.g. for ventilation. This means that natural ventilation should be used where possible, or so-called hybrid systems (combination of natural and mechanical ventilation) as these systems provide the best energy performance. There are different types and sources of pollution within a building. Although CO₂ is considered as non-toxic, very high levels can cause health problems to the occupants as its high concentration indicates low oxygen levels. Such high levels are typically not seen in residential buildings. From an indoor air quality standpoint, CO₂ is a surrogate for indoor pollutants emitted by humans and correlates with human metabolic activity.

Moisture is probably the most significant of these because of the large quantities generated by human breathing and other activities and because of the associated problems of dust mites and consequences of condensation such as mold growth. For best

health conditions, relative humidity should be kept in the range 45-70%. Active House reflects those needs by setting ambitious requirement to the indoor air quality of homes, as in Table 3.

Table 3. Active House IAQ specifications

Parameter	Classification criteria
Standard fresh air supply	<ol style="list-style-type: none"> 1. 500 ppm above CO₂ outdoor level 2. 750 ppm above CO₂ outdoor level 3. 1000 ppm above CO₂ outdoor level 4. 1200 ppm above CO₂ outdoor level

3.2 Energy

Energy is needed to achieve a comfortable indoor environment throughout the year. The energy type and quantity depend mainly on the differences that exist at each instant of time between given outdoor climatic conditions and desired indoor conditions, as well as on the existing installations, design and quality of the building. The available energy is thus used to ensure user comfort in terms of (day)light, hot water, air quality and indoor temperature.

With the rise of the standard of living, so has the consumption of energy increased, with total consumption sometimes, over the past 45 years. Globally, it is estimated that heating, cooling and electricity for domestic appliances in buildings account for about 40% of the total energy consumption. The energy performance of a building and the energy efficiency of its energy sources are therefore important issues when considering climate change and the reliability of energy supply. The design, orientation and products used in an active house must be optimised to demand as little Energy as possible and to utilise renewable energy sources as much as possible, following the Trias Energetica strategy. The main focus of this approach is the fact that saving energy by reducing losses and wastes of all kinds represents the highest potential and thus the most sustainable choice. In addition, recovery of waste energy/water are to be considered wherever possible.

Active house focuses on *energy demand reduction, use of renewable energy* either on plot, nearby or from the grid and small, and on *very efficient use of regionally or nationally available primary energy resources of fossil origin*. Noteworthy, the primary energy performance is equal to the energy used, minus renewable energy supply, and then multiplied by the national primary energy factors.

Energy consumption in buildings depends also on user behaviour. Experience shows that different users in the same building can easily cause a factor of 2 difference in the energy consumption. It is therefore important to guide the homeowners in their use of the building. In addition, installing of a monitoring system for different energy consumptions (like intelligent meters) in the building allows the user be aware of the effects of its habits. Table 4 indicates energy related specifications for a residential Active House.

Table 4. Active House energy specifications

Parameter	Classification criteria
Annual energy demand	1. $\leq 40 \text{ kWh/m}^2$ 2. $\leq 60 \text{ kWh/m}^2$ 3. $\leq 80 \text{ kWh/m}^2$ 4. $\leq 120 \text{ kWh/m}^2$
Origin of energy supply: how much of the energy used in the building is produced on the plot or in a nearby system	1. $\geq 100\%$ 2. $\geq 75\%$ 3. $\geq 50\%$ 4. $\geq 25\%$
Primary energy consumption for the building	1. $< 0 \text{ kWh/m}^2$ 2. $0\text{-}15 \text{ kWh/m}^2$ 3. $15\text{-}30 \text{ kWh/m}^2$ 4. $> 30 \text{ kWh/m}^2$

3.3 Environment

According to the TC-350 standards (sustainability of construction works), the environmental loads are described by 5 different categories of emissions

(equivalents); Global Warming Potential CO₂-eq, ozone depletion R₁₁-eq, photochemical ozone creation potential C₃H₄-eq, acidification potential SO₂-eq, and eutrophication PO₄-eq. Besides that, the primary energy redrawn directly from the nature is also part of the evaluation. The use of resources and materials in buildings account for up to 24% of our resources worldwide. Moreover, currently, around 33% of the global greenhouse gas emissions from human activities can be attributed to the building sector. Given these aspects, environment is chosen as one of the three main parameters in the active house vision. Moreover, Life Cycle Analysis (LCA) evaluation and sustainable sourcing as well as use of water are the main parameters for environment in Active House.

The environment strategic objectives of an Active House are in three directions:

- *Limit the environmental loads* during the whole life cycle of the building.
- *Minimise freshwater consumption.*
- *Consider sustainable constructions and sourcing.*

Table 5 presents the four levels of ambition of an Active Home for different relevant parameters.

Besides the many quantitative criteria, there are more *qualitative criteria* related to the attitude and approach of architects, builders, and users when building or renovating.

When designing an Active House, it must be ensured that the building in operation works as intended and that the users are capable of behaving as intended. For this purpose, the *building management* should cover energy, indoor climate and environment. Among recommended actions are training of building users' inefficient behaviour by yearly performance check of building and systems (service contract), as well as user guidelines on operation of building and technical systems by continuous (hourly) monitoring and display of performance and indoor air quality.

Table 5. Active House environment specifications

Parameter	Classification criteria
Building's primary energy consumption during entire life cycle	1. < -150 kWh/m ² year 2. < 15 kWh/m ² year 3. < 150 kWh/m ² year 4. < 200 kWh/m ² year
Globalwarming potential (GWP) during building's life cycle.	1. < -30 kg CO ₂ -eq./ m ² year 2. < 10 kg CO ₂ -eq./ m ² year 3. < 40 kg CO ₂ -eq./ m ² year 4. < 50 kg CO ₂ -eq./ m ² year
Ozonedepletion potential (ODP)during building's lifecycle.	1. < 2.25E-07 kg R11-eq./ m ² y 2. < 5.3E-07 kg R11-eq./ m ² y 3. < 3.7E-06 kg R11-eq./ m ² y 4. < 6.7E-06 kg R11-eq./ m ² y
Photochemicalozone creationpotential (POCP) duringbuilding's life cycle.	1. < 0.0025 kg C3H4-eq./ m ² y 2. < 0.0040 kg C3H4-eq./ m ² y 3. < 0.0070 kg C3H4-eq./ m ² y 4. < 0.0085 kg C3H4-eq./ m ² y
Acidification potential (AP) during building's life cycle.	1. < 0.010 kg SO ₂ -eq./ m ² y 2. < 0.075 kg SO ₂ -eq./ m ² y 3. < 0.100 kg SO ₂ -eq./ m ² y 4. < 0.125 kg SO ₂ -eq./ m ² y
Eutrophicationpotential (EP) duringbuilding's life cycle.	1. < 0.0040 kg PO ₄ -eq./ m ² y 2. < 0.0055 kg PO ₄ -eq./ m ² y 3. < 0.0085 kg PO ₄ -eq./ m ² y 4. < 0.0105 kg PO ₄ -eq./ m ² y

Minimisation of freshwater consumption during building's use (versus average)	1. Improvement 50% 2. Improvement 30% 3. Improvement 20% 4. Improvement 10%
Recyclable content	1. 50% 2. 30% 3. 10% 4. 5%
Responsible sourcing	1. 100% certified wood and 80% certified suppliers. 2. 80% certified wood and 50% certified suppliers. 3. 65% certified wood and 40% certified suppliers. 4. 50% certified wood and 25% certified suppliers.

3. ACTIVE HOUSE DIAGRAM

The values of all nine quantitative indicators are represented graphically in a radar diagram for best visual message to the customers, as shown in Figure 2.



Fig.2. Radar diagram to classify an Active House quality

The light green area indicates the overall building performance, while each corner relates to specific performances, as described above. It is therefore extremely descriptive

and transparent about the building quality from all comfort, energy and environment points of view. The radar becomes a very useful instrument for the designer and user as well, spreading awareness by its simple concept.

On the diagram, there may be represented values pertaining to different other relevant conditions, like before versus after renovation, calculated versus measured indicators, specific design ambition versus national standards for new/renovated buildings. An example is given in Figure 3.

4. STUDY CASE

A building that was built after an “e4” project based on emotion, energy efficiency, economics and on environment protection and corresponds in most aspects with the Active House principles, is presented in Figure 4 [5].

Increased daylight and connection to the outside through very generous windows placed on the south walls and roof is apparent in Figures 4 and 5. Large windows also allow for efficient air-out or cross ventilation when needed.

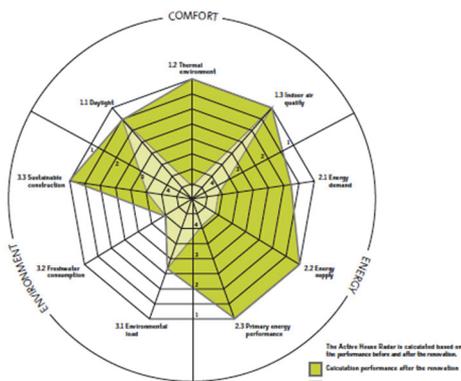


Fig. 3. Active House performance before and after renovation.

The energy efficiency is ensured by a management system that optimizes energy supplied by a heat pump, a solar Trombe wall, solar thermal panels, and PV panels. The

system displays values making the users aware of levels of consumptions for the comfort they need.



Fig. 4. A model for healthy home



Fig. 5. Daylight, connection to landscape and fresh air

The building indoor quality is monitored for at least two years to check for the features that were assumed at the design stage and by the energy performance assessment at the commissioning stage. Indoor temperatures, humidity and luminance are recorded and correlated with the outdoor similar parameters, as well as with the users regular activities. Examples of time-samples of recordings are represented in Figure 6 for different rooms.

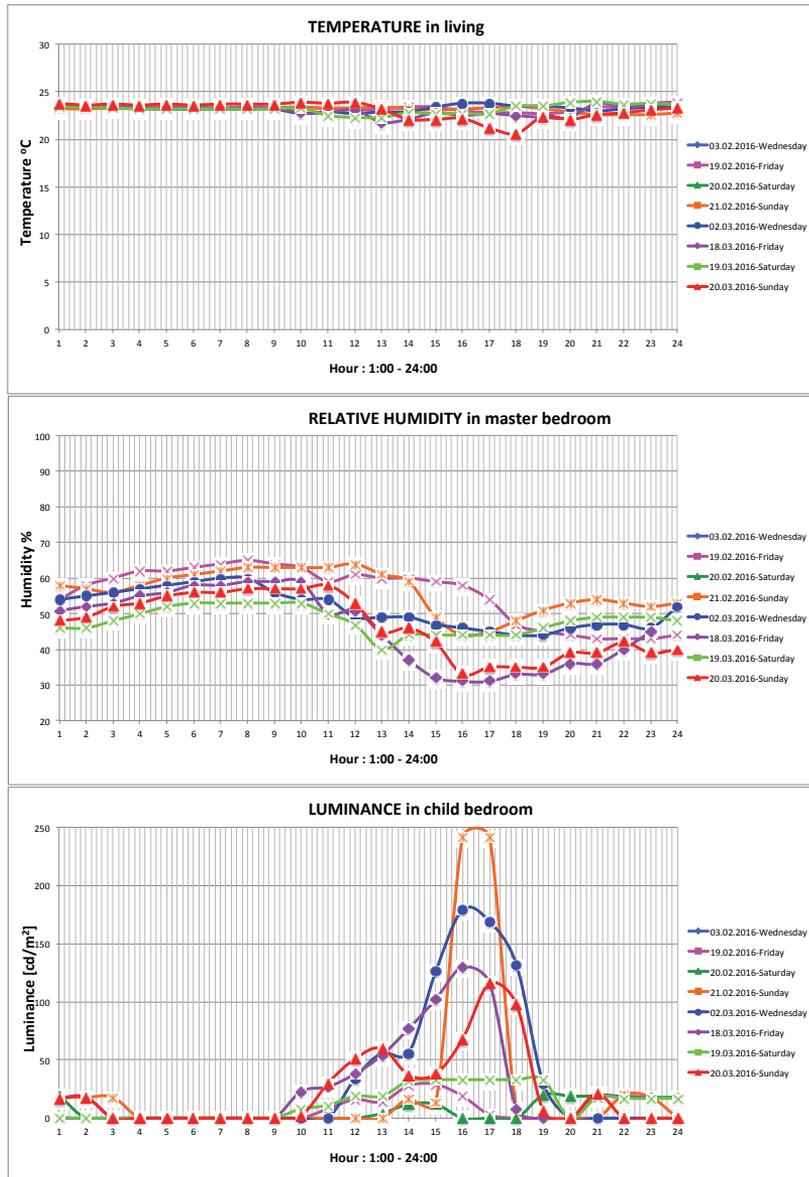


Fig. 6. Building monitoring for indoor climate quality

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