

Sustainable architecture and the Passive House concept: achievements and failures on energy matters

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ABSTRACT: *The Passive House approach meets increasing success and will continue to spread in coming years. But conceptual thinking about sustainable architecture also goes forward. This paper intends to confront the Passive House approach with 5 principles of sustainability. These principles are based on de Myttenaere's attempt to give a holistic definition of sustainable architecture. Although sustainability is a very large concern, only energy related matters are examined. This paper concludes on recommendations to extend or adapt the Passive house approach.*

Keywords: *Passive House, Sustainable architecture*

1. INTRODUCTION

1.1. Energy performance

Energetic considerations in building design have in the last decades been focused on the reduction of energy demand, resulting for example in the Passive House standard [1]. Thanks to the combination of passive strategies and renewable, "net-zero energy buildings" are achieved. Such buildings intend to deliver as much or more energy than they use.

However, "zero-energy" is a concept that can be discussed, since its definition is unclear. The European Parliament recently approved a recast of the Energy Performance of Buildings Directive [2]. This recast defines net-zero energy building as "a building where, as a result of the very high level of energy efficiency of the building, the overall annual primary energy consumption is equal to or less than the energy production from renewable energy sources on site". A more detailed definition is aimed to be released by 2011. This definition has a major flaw: it focuses on primary energy consumption only, missing embodied energy and other environmental threads related to buildings. Alternative concepts such as life cycle zero-energy buildings (LC-ZEB) may prove in coming years to be more appropriate [3].

Nevertheless, considering that "a very high level of energy efficiency" is asked for, and that the Passive House concept is one of the most comprehensive, structured and ambitious concept of low energy construction available today, this concept is about to become the usual standard in construction in various European countries [4, 5, 6].

1.2. Sustainable architecture

Next to those energy-related developments, the thinking about environment-friendly buildings has gone forward on a broader scale, including larger environmental concerns through methods such as BREEAM, LEED or HQE. Meanwhile, the relation between architecture and nature is far broader and richer than the quantitative aspects developed in those methods and includes symbolic, cultural and

spatial elements [7]. In consequence, investigations handle last years the question of a holistic definition of sustainable architecture, including environment, societies, economics and culture [8].

1.3. Objective and methodology

In this context, this paper proposes considerations on whether the Passive Houses concept is coherent with the notion of sustainable architecture. This confrontation of both Passive House and sustainable architecture concepts intends to help developing a critic vision of the passive house standard and to point methodological adaptations and improvements of this standard.

Obviously, many dimensions of a sustainable architecture are not part of the Passive House approach, that focuses only on energy and comfort matters. Hence this paper also focuses on energy-related elements only, but tries to discuss them in the light of the larger concept of sustainability.

The structure of this paper is the following: In a first part, a generic definition of sustainable architecture is proposed, along with 5 principles developed to make this definition of greater practical use. This section is integrally based on previous work from de Myttenaere [9]. In a second part, the passive house principles are examined in the light of these 5 principles.

2. SUSTAINABLE ARCHITECTURE

2.1. Generic definition

This paper refers to the definition of sustainable architecture developed by K. de Myttenaere in 2006 [9]: "a sustainable architecture is an architecture that deserves to be sustained because of its pertinence according to local and global challenges."

de Myttenaere develops this definition in the following way: "Sustainable architecture consider spatial context in order to take advantage of its benefits and protect itself from its limitations; integrate actual and future generations' spatial needs in a way that create positive inference for both;

understands and uses interactive and retroactive mechanisms of mater and human beings at various spatial and temporal scales."

The major originality of this definition is that it goes past environmental concern. It includes theoretical architectural concepts, through the idea that mater (the physical world) and human beings are interacting at various scales. So architecture is presented as a way to create or express a relationship between man and his natural and cultural environment.

2.2. Effective principles

In order to be of more practical use, de Myttenaere proposes to work according to 5 principles, inspired from the Rio Declaration on Environment and Development [9]. The 3 first principles challenge the architectural design while the 2 last principles challenge the design process. The explanations of the principles given here are extremely summarized and only partially reflect the full meaning of them.

1/Principle of integration of environmental, social, economical and political dimensions: this principle enlightens the complexity and paradoxes of the environment. It reminds us that our world (as well our planet as our artificially built living places) has an obvious physical dimension, but also is the place of social and political interaction where we develop our human culture. Sustainability is the look for a global optimum between those dimensions rather than the maximization of one aspect. Sustainable architecture should therefore combine high performance levels and the simultaneous enhancement of all those dimensions, including for example architectural quality and cultural pertinence.

2/Principle of equity between present and future generations: Equity between present generations implies that sustainable architecture consider its impact on various scales (spaces, building, community, district, world), including spatial, social and environmental aspects. Equity with future generations urges to consider the temporal dimension of architecture, including concerns about patrimonial considerations and adaptability to unknown future needs.

3/Precautionary principle: Sustainable architecture has to consider its behavior and impact in an unknown future context. The challenge is to design buildings according to actual needs, coherent with our historical background but taking into account uncertainty about the future. For example, this principle supports the idea of deconstruction abilities as an element of sustainable architecture. It urges to consider impacts of the building on various time scales: centuries for urban form, decades for the building forms, and years for indoor furniture.

4/Principle of shared responsibility: Everyone being part of a society, we all have to reconsider our behavior in the light of social and environmental challenges. This is all the more true for designers who build our physical environment.

5/Principle of participation: this principle emphasizes the need for decision procedures including people who will face the consequences of

the decision. In architecture, examples of design process including future inhabitants and neighborhoods are numerous [see for example 10, 11, 12]. Reversely, we should also keep in mind the influence of the built environment on its occupants. Sustainable architecture must therefore valorize the creation of healthy and inspiring ambiances and the exemplarity of designs.

3. CONFRONTATION WITH PASSIVE HOUSE PRINCIPLES

3.1. Definition of passive houses

Passive house principles have been developed 20 years ago and since the CEPHEUS project rapidly spread in Europe and abroad [1]. Thanks to compact shape, air tightness, high insulation and ventilation systems with heat recovery, Passive houses' heating power by design conditions is lower than 10W/m². It results in standardized annual energy needs lower than 15kWh/m² in central Europe and allows simplifying heating production and distribution. Air heating based on fresh air needs has proved to be adequate [13]. Technical recommendations for Passive Houses are summarized in table 1.

Table 1: Requirements and recommendations for Passive Houses

Requirements	
Annual heating energy consumption (per net floor area)	≤15 kWh/m ²
Total primary energy consumption for all uses	≤120 kWh/m ²
Air tightness at 50 Pa over and under pressure	n50≤0.6/h
Recommendations	
Building opaque envelope	U≤0.15W/m ² K
Windows including the frame	U≤0.8W/m ² K
Glass g-value	≥ 0.5
Efficiency of ventilation heat recovery	≥ 75%

3.2. Principle 1: integration

Economic, energetic and social aspects of the Passive House approach have been studied in the context of the CEPHEUS project. We discuss all three aspects in the following paragraphs.

Energetic achievements have been assessed regarding heating demand [14]. The integration of requirements expressed in primary energy allows, when formulated, a proper integration of energy resources matters. Two elements could be said against actual requirements: First, the primary energy does not account for carbon emissions differences amongst energy sources. Evaluations of CO₂ equivalent emissions or non-renewable primary energy consumptions could remedy this gap. Second, this criterion does not consider embodied energy, while it is now demonstrated that Passive House's extra-embodied energy, when not properly handled, may counterbalance or exceed the relative energy consumption benefit [15].

Economical pertinence of the concept has been demonstrated. Since Passive Houses allow avoiding static heating, initial extra-investments are limited but the initial cost remains higher than for a traditional building. Life cycle costs are nevertheless reduced compared to traditional buildings [14]. It can be argued that the increased initial investment restricts the ability of low income families to afford passive houses. An ideal sustainable approach would ask for environment friendly building to be less expensive than traditional ones, in order to allow a quick and large diffusion of the concept. Public investment programs could artificially create such conditions allowing mass production of Passive Houses. But the coherence of sustainability with the need for public funding is questioning. Another way is to consider that the cost of energy improvements should be compensated with savings on other constructive aspects, such as a reduction of area per capita, costs sharing thanks to joint owning or the promotion of self-construction.

Social studies about passive buildings have shown increased comfort feelings and good acceptability among inhabitants [16, 17]. The Passive House ability to created healthy indoor environments at minimal operating costs also tackles fuel poverty. Nevertheless those important aspects do not cover all social impacts. Especially, health concerns regarding improper design, operation, and maintenance of mechanical ventilation systems are known [18]. On a different topic, the possibility to combine the Passive house standard with patrimonial preservation in historical buildings has to be demonstrated. Finally, the issue of high technicality of passive house construction techniques is also questioning. Air tightness and hydrothermal design of walls for example is beyond the abilities of amateur craftsmanship. This could drastically slow down the spreading of Passive House concepts, since many house refurbishment are made by inhabitants or by badly trained professionals.

Finally, it seems that the cultural dimension is missing in the Passive House approach. Its tenants are working on the idea that all architectural shapes are allowed. It has been said for example that "the difference from a conventional house doesn't have to be recognizable." [19]. Doing so, the Passive House concept excludes itself from architectural and cultural debates and concentrates on technical and constructive parameters. This position may be regrettable but allows a broader diffusion of those highly efficient constructive ways. Also, the inspiring integration of cultural dimensions in the building's design, including the potential use of Passive House principles as part of it, belongs to the architect and remains intact.

3.3. Principle 2: equity

As exposed above, the architectural transcription of this principle is the simultaneous integration of various space and time scales. This is definitely a matter of architecture. Except for large scales considerations like global warming or life cycle assessments, the Passive House concept may seem to be unconcerned.

Yet the view of Passive House as being out of architectural or cultural matters, used some lines before, cannot be used here since Passive House principles impact the way the buildings integrate itself in a neighborhood. Sufficient passive solar gains being necessary to achieve Passive house standards in an economical way, a strict lining up to the sun is recommended as well as sufficient distance to avoid winter shadings between buildings. This obviously challenges existing urban forms, which evolution falls under the scope of architecture.

Also, the Passive House standard, just as zero-energy concepts, focuses on the building scale, while increasing concern rise about sustainable neighborhoods and district scale energy management. The consistency of Passive House standards with building scale recommendations developed in the context of sustainable neighborhoods will have to be analyzed. The optimal management of renewable sources may for example impact buildings peak load management and HVAC design.

3.4. Principle 3: precaution

One way to consider the principle of precaution from an energy point of view on buildings is through the concept of climate resilience. Considering that climates are going to change in the coming decades, newly built buildings should be adapted to those changes.

Coley et al. show that a building which is actually more comfortable than another will probably stay so in new climatic conditions [20]. The integration of summer comfort criterions in the definition of Passive Houses can therefore be considered as an important guarantee for their adequacy in changed climates.

But they also show that the shift of internal temperature in buildings can be linearly related to the shift in external temperature. A simple parameter called amplification coefficient (the gradient of the regression line) is sufficient to characterize the building resilience [20]. An amplification coefficient below 1 indicates an ability to temper climate shift in the building. Design recommendations could be added to the actual definition of passive buildings in order to minimize the amplification coefficient. Further studies are needed to identify key parameters of, but it is suggested by Coley's results and all climatic architecture literacy that a high thermal capacity is of major interest.

Another integration of the precautionary principle can be done through the question of changes in occupancy (flexibility of the building). Spectacular occupation changes are from housing to office or commercial spaces. Those usually imply major refurbishments, including HVAC elements. Less spectacular are variations at the family scale (e.g. a new baby). Those frequent changes should impact the energy management in the building. For example, some spaces should not be heated anymore, or other would ask for higher comfort temperature. Such adaptations are difficult to implement in a passive house, since they are not meant to be equipped with heating or cooling diffusers except fresh air ventilation. Three

consequences of heating through ventilation are that:
1/ heating and cooling powers are strictly limited. Higher temperature requirements may lead to the adjunction of static electric heaters, which are harmful for the primary energy impact of the building;
2/ zonal modulation is not allowed, except by modifying the airflow network equilibrium. This is often beyond the ability of inhabitants;
3/ Short time exceptional heat demand in some room is done by increasing the temperature set point for the all dwelling. .

Precautions at the design stage in order to increase the flexibility of passive houses may be over-sized ventilation networks and well positioned valves and pressure constant fans.

3.5. Principle 4: shared responsibility

The principle of shared responsibility urges both designers and inhabitants to act at their own level in order to handle climate change and energy resources limitation.

The Passive House community of architects and manufacturers act in this way with the wide and quick spreading of a highly energy efficient standard. But the buildings' occupant is almost forgotten in this concept, enabling him to take his own responsibility.

The Passive House concept considers occupants only through standardized internal loads and a comfort level estimation (time above 25°C) [21]. Practically, winter climatic control by the occupant is limited. Often, only the set point temperature can be modified by the inhabitant, since heating supply through ventilation result in thermal uniformity and limited heating power put the occupant of doing night interruption [22].

Such a minimization of the occupants' role is outdated. Developments in thermal comfort

assessment have concluded that thermal sensations, satisfaction and acceptability are all influenced by the match between one's expectations about the indoor climate in a particular context, and what actually exists [23]. Practical consequence is that an a priori assumption of comfort cannot be easily expressed. De Dear showed for example that behavioral, adaptations including interaction abilities with the climate control equipments are of major impact on thermal comfort [24] Norms and guidelines such as Ashrae Standard 55 or EN15251 now propose adaptative comfort models which, although developed mainly for offices spaces, are more relevant than a predetermined temperature limit [25, 26]. Further, the PLEA community agreed in the Plea2009 Manifesto that the occupant should be considered as an inhabitant, actively involved in the climate regulation and comfort level definition [26].

Finally, the Passive house concept does not consider the building area/occupant ratio, internal gains and ventilation rates being linearly related to the floor area. Spatial moderation is thus not encouraged.

3.6. Principle 5: participation

The principle of participation urges all actors in building design, construction and management to work together around a common goal.

The Passive House concept may be praise for having gathered architects together with manufacturers and building contractors.

Certainly many individual Passive House owners are playing an active role in the design and the dissemination of the Passive House concept. They may be praised for that, and for that part they indeed act in accordance with the participation principle.

Table 2: Achievements and failures of the Passive House concept regarding sustainability and energy matters

Principle	Achievements	Lacks	Technical Incompatibilities	Conceptual Incompatibilities
Integration	Primary energy efficiency Life cycle cost assessment Comfort feelings, acceptability and fuel poverty mitigation	CO2 evaluation Embodied energy evaluation	High initial investments Mechanical ventilation health impact Technicality beyond amateur ability Patrimonial preservation	Self exclusion of architectural & cultural debate
Equity				Focus on the building scale only
Precaution	Integration of summer comfort criterion	No climate change resilience evaluation	Limited flexibility at HVAC scale	
Shared responsibility	Meeting of architects and manufacturers	non adaptative summer comfort definition Requirements not expressed relative to the occupants		Inhabitants seen as occupants rather than actors
Participation	Meeting of contractors, architects, and manufacturers	-		-

4. DISCUSSION

Section 3 confronted Passive House actual definition and 5 principles defining sustainable architecture. Next to various achievements, two kinds of failures are identified throughout section 3: The first kind of failures, referred to as “lacks”, results from the incompleteness of the Passive House concept. The evaluation of a climate change resilience factor for example is not integrated in the concept but could be added without modifying it. The second kind of failures is “incompatibilities” between sustainability and the Passive House concept. We may dissociate incompatibilities resulting from conceptual aspects and from practical implementations. The difference holds in whether a change in the way Passive Houses are built may overcome the incompatibilities without changing the actual definition of Passive Houses or not.

An example of practical incompatibility is high investments costs. Since these are connected with passive house technical recommendation, it is not a lack. But it could be handled without impact on the concept, through for example further savings on energy-unrelated aspects. An example of conceptual incompatibility is the occupant's limited role. Only a definition change could modify that.

The classification of various failures between lacks and two kinds of incompatibilities is opened to discussion. Such a classification is proposed in table 2. In order to make Passive buildings more sustainable, various measures may be taken:

1/ At short term, the identified lacks could be handled. It can easily be done thanks to mathematical add-ons in the PHPP certification tool [27]. Namely CO₂ impact can be calculated in Europe based on Gemis databases [28]. Embodied energy calculation can also rely on existing databases [29]. Coupled with the already needed external walls description it would give designers incomplete but illustrative information about this topic. Climate change resilience can be deduced from monthly evaluations as described by Coley et al. [20]. Integration of adaptive comfort criterions in the monthly evaluation of PHPP would be more difficult and require further mathematical development. Regression rules based on dynamic simulations and considering monthly meteorological mean values and variances may be looked for in that purpose. Original PHPP comfort index followed such a method [21]. Finally, it would be easy to express the energy performance in kWh/occupant rather than (or next to) in kWh/m², as long as minimal spatial comfort criterions are developed.

2/ At medium term, the identified technical incompatibilities could be handled. High investments costs may be tackled by alternative economical models like Passive House preferential mortgage rates or energy-unrelated savings; Health impact, high technicality and patrimonial concerns may be challenged by wide diffusion of best practices, illustrative cases studies and practical guidelines; low flexibility may be tackled by over-sizing of ventilation networks and sub-networks design.

3/ At long term, conceptual incompatibilities could be questioned. Those are the highest challenges. For that matter it is not clear whether or not the identified incompatibilities should be handled inside the Passive House definition.

Typically, we may wish to enhance the Passive house definition to include architectural quality – which involves considering subjective criterions – or rather consider that the cultural dimension of architecture should stay outside the objectively determined “Passive House” nature of one building.

The same way, the Passive house definition could be adapted to include the inhabitant. For example, the 15kWh/m² criterion is a priori estimated according to standardized internal gains and inside temperature. This evaluation could be coupled with in situ measurement of energy consumption. This way, inadequate behaviors would be avoided, leading to “Passive Living Places” in place of Passive Houses. But it can be argued that the inhabitant interaction ability may be cultivated through enhanced manual control capacities regardless of the Passive house definition.

Also, the integration of district scale concerns are usually handled with top-down directives from the urban scale impacting individual designs, rather than in a bottom-up way, starting with individual housing projects. If so, district energy concerns are not relevant in the definition of a passive house, but may lead to the definition of passive districts whose requirements on the individual scale complete or overtake passive house requirements.

5. CONCLUSION

This paper briefly summarized de Myttenaere's definition of sustainable architecture and its attendant principles. Their pertinence is illustrated: they allow criticizing current practices and identifying practical and conceptual improvements. The passive house concept consistency with these principles is examined. Although this paper does not claim sufficiency, it shows lacks, technical and conceptual incompatibilities making the passive house current definition and tools too short to create sustainable buildings. Possible adaptations of actual practices and definitions are proposed.

6. REFERENCES

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