Defining Sustainability in Relation to the Renovation of Modern Housing

Peters, Terri

Publication date:
2011

Document Version:
Peer reviewed version

Defining Sustainability in Relation to the Renovation of Modern Housing - Current Definitions and Metrics for Sustainable Housing Renovation

Terri Peters
PhD Fellow
Aarhus Arkitektskolen
Denmark
terri.peters@aarch.dk

Summary

This paper focuses on comparing practice-based and academic definitions and metrics of "sustainability" as they relate to the transformation of Modern housing in Denmark.

Keywords: Sustainability, Renovation, Architecture, Denmark, Modern housing

1. Introduction to the Study

Across Europe, the housing built after WWII and before the 1973 Oil Crisis represents a large proportion of housing still in use today. Current estimates state that nearly half of Europeans live in housing built during this time [1] and these perform poorly relative to new buildings and new building regulations. Architects are undertaking renovations to these buildings in large numbers and this is expected to continue to rise. The renovations are instigated for many reasons, for example change of use, repair, interior modernization and also to increase the building's energy performance and for other reasons of "sustainability" [2]. Buildings are responsible for 40% of energy consumption and 36% of EU Co2 emissions and the EU´s Climate and Energy objectives include a 20% reduction of greenhouse gas emissions by 2020 and a 20% savings of energy by 2020 [3]. With tightening Danish national and EU regulations relating to energy use in buildings, architects must focus on other parameters as well as energy use because there is more to designing sustainable building than energy savings. In the building industry, there is an increasing focus in building engineering approaches relating to "low energy buildings" and architectural approaches to "sustainability".

2. Background to the Study and Study Context

Despite the increasing focus on low energy buildings and sustainability, the definitions of key terms in these areas are unclear. According to "Low Energy Buildings in Europe: Current State of Play, Definitions and Best Practice" low energy buildings are known under different names across Europe. "A survey carried out in 2008 by the Concerted Action supporting EPBD identified 17 different terms in use to describe such buildings used across Europe, among which the terms low energy house, high-performance house, passive house/Passivhaus, zero carbon house, zero energy house, energy savings house, energy positive house, 3-litre house etc. In the relevant literature additional terms such as ultra-low energy house can be found. Finally, concepts that take into account more parameters than energy demand again use special terms such as eco-building or green building" [4]. With regard to sustainability, which encompasses ideas including and beyond energy use, the definition is even more broadly defined. Terms such as sustainable architecture,

ecological architecture, green architecture, smart architecture, eco-architecture, environmentally friendly architecture, bioclimatic architecture and others, are gaining popularity but there is no clear understanding in the profession as to what these terms actually mean and how to measure them.

This paper focuses on architectural approaches to sustainable building, rather than engineering or other ways of approaching sustainable building. This study is part of a PhD project that aims to develop an insightful, researched, and general view of the complex issue of architectural approaches to sustainable building transformation in Denmark. This study was undertaken to document and analyze the way that architects define and measure sustainability in Denmark.

3. Method and Approach

3.1 Study Aims and Challenges

While there are hundreds of books, conferences, and journals on the subject of sustainable buildings, both new build and renovations, there is no clear definition of sustainable architecture, or agreed metrics. This study aims to understand and reflect on ideas of sustainability in architecture, towards new metrics and definitions that can be applied to architecture, in particular to renovations.

This paper does not suggest that there is a need for global or EU definition for sustainable architecture, as the point of architecture is to design for specific clients, performance goals and cultural, geographic and economic contexts. Strict definitions do not guarantee desired results and architectural performance depends greatly on how buildings are used, not only how they are designed. For example, building maintenance, client behaviour and occupant behaviour greatly impact the performance of a building. Despite the complexity of the problem, the answer for architects should not be to avoid the difficult task of creating ways of understanding and approaching sustainability in architecture, or to avoid creating or using metrics for sustainability.

This study aims to create results that can be useful to both academic research in this area and architects in practice. Architects can benefit from knowing what is currently being designed and built, what strategies were used and when in the design process, and how successfully they were used. This information needs to be continually researched, compiled and analysed so that architects can make the best decisions for clients and society especially now that there is the knowledge that sustainable building decisions are imperative.

3.2 Study Parameters

Energy use is easy to measure in comparison to other less quantifiable sustainability criteria. But architects must look at more than just energy use to design sustainable new buildings and renovations. Other criteria such as climatic conditions, design quality, materials, user comfort, embodied energy, lifecycle, client requirements, costs, consumption and maintenance are important parameters. Sustainable buildings need sustainable users, and the creation of architecture is more than just building. There are various ways to understand and define sustainable architecture and in this context it is necessary to consider architecture beyond buildings. Aaron Betsky´s definition of architecture encompasses all of the things around building: “Architecture is everything that is about building. It is how we think about building, how we draw buildings, how we organize buildings, how buildings present themselves…buildings are buildings; architecture is something different.” [5].

3.3 Data Collected During the Study

Data collected includes definitions of sustainability from outside of the profession, as well as in architectural literature. Definitions used in the context of architectural practice were also studied. The definitions from selected key texts were compared. A survey of Danish architects was undertaken and responses from twelve Danish architectural practices were compared [6]. The survey asked offices to rank their interest in sustainability from one to five, how they define sustainability,

if they have an office policy on sustainability, how they assess sustainability on building projects, if they rank energy as the most important parameter of sustainability, how they rank their interest in building transformation from one to five, and what they view as key issues relating to sustainability and renovation. It is interesting to note that there were no two responses that were the same and each office was able to articulate their view of sustainability and none ranked it below 4 in importance. None cited a general, reliable way of measuring sustainability across all of their building projects.

4. Discussion of Results and Conclusions

4.1 Defining Sustainability in Architectural Literature

A commonly used and agreed upon definition of “sustainability” in key architectural texts is known as the Brundtland Commission definition which states that “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs" [7].

Noted architect Ken Yeang argues that sustainability is “exemplified” in this Brundtland definition [8] and architect and educator Colin Porteous cites the Brundtland Commission and their work as having “helped to maintain an ecological dimension in the sights of architects and other building enablers” [9]. Peer reviewed, academic sources relating specifically to architecture also cite the Brundtland definition of sustainability in architecture [10] [11]. As the only definition that is consistently quoted and used in architecture, there appears to be an understanding amongst architects that we have a duty of care to future generations and should be focusing on improving social and political concerns at the same time as caring for the environment. These ideas are not even mentioned in either building regulations (including Danish building regulations) or standard assessment methods such as the American system Leadership in Energy and Environmental Design (LEED) [12] or the British system BREEAM [13].

Through misuse of the word, “sustainability” can become a mere buzz-word. This can trigger cynicism amongst architects in this important issue” [14]. Ken Yeang argues that “we need not only to first define and understand what constitutes green design, but also to understand its premises for it would be counter productive for the designer to leap into green design without understanding and agreeing to such basic principles as connectedness” [15]. In practice the world’s poor and understanding the limitations of the environment are not necessarily considered in sustainable design and it seems clear that architects need to either start implementing the meaning of the Brundtland definition in their designs, or come up with another agreed upon definition of sustainability.

4.1.1 Defining Sustainability Specifically in a Danish Context

This seems also to reflect the Danish context. According to Gram-Hanssen and Jensen in “Ecological Modernization of Sustainable Buildings: A Danish Perspective”, there is no clearly defined understanding of sustainable architecture. “The many different procedures used in practice can be seen as a way to establish a “story line” that unites different actors on what is sustainability. For that reason, the authors cannot (yet) see in Denmark signs of a uniform perception of what is a sustainable building” [16].

Another important researcher, Claus Bech-Danielsen, identifies three generations of sustainable buildings in Denmark, with three different players leading the movements: grassroots citizens in the 1970s, engineers and researchers in the 1980s and architects in the 1990s [17]. He draws on his experience at the Danish Building Research Institute over the past fifteen years when he identifies these and also his ideas that environmental efforts focus on behavioural changes, technical

development or architectural design. With regard to architectural design he suggests that the architectural form can reveal the environmental effort (giving the example of rooms designed to maximize daylight) and place-based design. "A sustainable concept cannot be regarded as a fixed guideline that can be repeated again and again" [18].

Jensen and Gram-Hanssen note that in a Danish context, the most important regulation relating to sustainability is the Building Regulations, which have had energy savings as their main theme since 1982 [19]. With regard to sustainable renovation in Denmark, they argue that to be a "sustainable" renovation, it is considered that the ambition for the renovation must exceed the minimum Building Regulations. Since it is energy that is what is easily measured and understood, it is therefore a general understanding that a sustainable renovation must have an energy savings greater than the building regulations. But of course these are assessed at design stage, not after a building has been functioning for some time, and as Jensen and Gram-Hanssen note, this is an ambition not necessarily a reality. Demonstration projects about energy renovation such as the renovations at Albertslund, Denmark, largely define sustainable renovation as being about energy use.

In recent years, a new way of thinking about sustainability is emerging. Michael Lauring sees marked changes in the way that Danish architects are engaging with sustainable ideas since the 1990s. When Bech-Danielsen identifies the three generations of sustainable buildings in Denmark, with the three different players leading the movements, he stops short of commenting on the decade that follows, or anticipating which players will lead sustainability into the 2010s and 2020s. Lauring notes "In the Summer of 2009 most Danish architectural offices seem to have gone green", citing journals, magazines, exhibitions, web pages and conferences dedicated to sustainable building [20]. In coming to an understanding of how sustainability is defined in a Danish context, and how it could be used in the future, Lauring traces Danish economic and political ideas and resulting architectural approaches from the 1970s. Lauring uses the example of Tinggaden housing (1978) by Vandkunsten as an example of a low and dense housing block with aspirations of energy savings and low energy design that actually fulfilled some social and aesthetic goals but did not perform better than the minimum standards. He characterizes the 1980s as being focused on "energetic city life rather than fossil fuels" and as rejecting ideas of ecology and rural design. He argues that the1990s were influenced by the Brundtland Report in 1987 and new leadership in the Danish Ministry of the Environment. Lauring notes that the 1995 Danish Building Code, which took into consideration better insulating windows and doors, the movement of the percentage of windows and doors from 15% to 20% greatly impacted architecture [21]. More power was given to architectural design, because an alternative way of calculating energy was introduced, so that there were no restrictions on the amount of windows as long as the calculated heat consumption did not exceed the limit. Buildings in Denmark looked very different after the 1995 change in regulations, with glazed curtain walls but often with unfortunate indoor air quality issues and cooling demands. Danish building regulations played a large role in helping architects come to define and measure sustainability.

4.1.2 Danish Architects Defining Sustainability – What Are Current Definitions in Practice?

It is difficult to know how architects in Denmark define sustainability because architects do not normally share research between offices or even within offices on various building projects. A survey was undertaken to find some ideas of how Danish offices view sustainability and transformation. In the Questionnnaire, of the survey results where architects were asked to rank the importance of sustainability in their practice, and to describe their office policy or understanding of sustainability, each response was different. BIG was the only office that defined sustainability in a way that relates in some way to the Brundtland definition, relating to shared resources. BIG´s response is "As architects we have an enormous influence on how our cities are shaped and our buildings perform and thereby we carry a responsibility to make sure that we utilize our limited resources without sacrificing a high quality of life which everyone has the right to." Polyform Arkitekter is the only office that specifically cites ecology and lifecycle in their definition of sustainability. All twelve offices rated sustainability as either a five or four rating out of five. Ag5 made an addi-

tional note on their survey that sustainability should be a part of good design, the only office to link architectural quality directly to sustainability. “Addressing “sustainability” issues can also lead to cool designs. Let’s just call it responsible designing.”

In response to the question: “Should energy savings or energy use be the most important parameter of “sustainability” in a building?”, all of the architects who responded to the Questionnaire were reluctant to say that energy savings is the most important parameter above all else. Six offices cited it as “important” but only one said the most important over all else. In fact, Anders Lonka, partner at Adept Architects argues “The most important part is the holistic thinking. Energy is the easy part.” Schmidt Hammer Lassen Architects (SHL) argues that “energy saving is an important parameter, but it is also important to look at how the building contributes to the local environment, the longevity of the building and the use of materials, and how the materials are produced.” Marc Wilson, partner at Ag5 argues that “energy costs are predicted to continue rising. Therefore addressing the running costs of a building in the design phase is extremely important. However as sustainability also covers People and Planet, social sustainability – how the building will be occupied over time, how it might shape social relationships within it, and how the building itself has been constructed and is to be maintained are also of utmost relevance. A highly insulated, air tight, uninspiring space might be energy efficient but damn ugly or socially destructive.”

From this limited survey of twelve offices, it would seem that architects in Denmark are not equating sustainability with energy use. The approach to sustainability is different to definitions in academic literature, and different to the quantifiable engineering approach which focuses on measurable aspects such as energy use. From this survey, it is clear that each office has a different definition and cites different things that matter about ideas of sustainability. The majority of offices explain that their definition of sustainability depends on the project, and that there is no universal definition, or therefore, no way of measuring sustainability.

4.3 Current Metrics Used by Architects To Assess Sustainability – International and Danish Context

As noted in the literature and in responses by the offices, environmental performance or energy efficiency cannot be thought of as equivalent to “sustainability”, although they are often used interchangeably in part because energy can be measured more easily than other parameters of sustainability. Many aspects of sustainability cannot be measured in a straightforward way, such as the contribution of a building to its context and neighbourhood, cultural quality, user satisfaction with the building, value for money, lifecycle, impact on future generations, beauty, and other parameters. This is not to say that these parameters need to be measured, this is certainly not part of an architect’s typical work, but just that some aspects are easier to measure than others, which is why they end up being evaluated and perhaps given too much emphasis.

For example, energy use is used as a metric in building regulations and voluntary assessment programs such as BREEAM and LEED. Seven of the respondents in the survey mentioned using BREEAM. BREEAM was established in 1990 and is the world's foremost environmental assessment method and rating system for buildings, with 200,000 buildings with certified BREEAM assessment ratings and over a million registered for assessment [22]. According to BREEAM´s website, it is “the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance”. In a presentation available on the BREEAM website, the criteria for assessment are listed as, with unequal weighting, management, energy, water, land use and ecology, transport, materials, health and wellbeing, waste, and pollution [23]. These criteria claim to relate to “sustainable design” but the criteria are in contrast to the accepted definition of sustainability and sustainable development in architecture.

According to the responses to the Questionnaire, none of the offices use one method of assessing sustainability consistently across all projects. In their survey response, BIG explains that “certification systems are an important evaluative endorsement of a project’s sustainable profile but they all

have their strengths and weaknesses." BIG uses LEED, BREEAM, Green Star, DGNB and Passive House certifications among others but they "use these certification systems as a starting point and always seek to create continual feedback loops which feedback the energy which is produced into the project as often as we can." Four respondents, Public Arkitektur, Polyform, Site AS, and Nobel Architects, replied that they do not ever use any of the standardized assessment systems such as BREEAM, LEED or others. This is somewhat surprising, because the four offices all scored sustainability as being very high in their priorities, but yet they have not got a way to clearly define or measure sustainability. This is an issue because if they cannot communicate their sustainability intentions or measure their results, even at design stage, let alone once the building is complete, they may not be getting the sustainable design results that they intend.

CF Møller and Henning Lassen responded that they use various International assessment systems. Partner Julian Weyer at CF Møller explains that "We have until now used a few standardized environmental assessment (including Passivhouse and BREEAM), but our strategy is to educate our employees both as DGNB Consultants and auditors (Danish assessment method, adopted from Germany) and also Cradle to Cradle consultants, so that it is easier to implement Life Cycle Analysis in our projects in the future. As architects we need to know much more about materials, their lifecycle, their influence on the environment and LCC /total costs." Signe Kongebro, an Architect and Sustainability Manager at Henning Lassen explains " It depends, we are very international and have to deliver all kinds of buildings in relation to national and international assessment tools. We are doing LEED, BREEAM, DGNB, and normal EU standards on energy performance (2010, 2015 and 2020 in Denmark) Passivhouse, Future Built etc."

4.4 Defining and Measuring Sustainability in Relation to Architectural Renovation

Renovation is, in general, a more "sustainable" strategy than demolishing and creating new building, as defined in the Brundtland definition. Renovation and customizing buildings to meet current needs could be done in such a way as to allow future generations to follow a similar approach. In contrast, if society adopts a strategy of tearing down and rebuilding architecture, future generations will not necessarily be able to adopt this approach due to the limitations of resources and the reality that growth cannot be sustained indefinitely. Building new architecture using fossil fuels and creating buildings that depend on fossil fuels is no longer considered an option that our future generations will necessarily have. Demolishing poorly performing multi-family housing in Denmark is not a reasonable solution because of the slow rate of building renewal. 75% of the buildings that will be in use in 2040 already exist today [24]. Renovation is a strategy that can often be undertaken in such a way as to minimize disruption. In Denmark, it is estimated that in the future, 80% of the architectural work will involve transformations and renovations to existing buildings [25].

Major renovations are defined in the EU Directive on Energy Performance in Buildings as based on financial cost [26]. The Directive states that major renovations are "cases such as those where the total cost of the renovation related to the building shell and/or energy installations such as heating, hot water supply, air-conditioning, ventilation and lighting is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated, or those where more than 25 % of the building shell undergoes renovation".

Standardization tools through voluntary agreements and norms relating to sustainable buildings include BREEAM, LEED, Cradle to Cradle, Living Building, Building Environmental Assessment Tool (BEAT), Green Diploma, Green Accounting, Greenbuild Point System, DGNB, but these are all primarily for new building and do not specifically address renovation. BREEAM is soon to launch BREEAM Domestic Refurbishment in Summer 2011. BREEAM Domestic Refurbishment is a new program that has been developed as a standard to address the needs of the existing housing stock [27]. The second most used international system is LEED, which also has provision for refurbishment. LEED includes major renovations in its standard assessment system. On their website, LEED defines a major renovation as one which "involves major HVAC renovation, significant envelope modifications, and major interior rehabilitation." It also defines it as "Con-

struction work that is extensive enough such that normal building operations cannot be performed while the work is in progress, and/or a new certificate of occupancy is required." A separate initiative is LEED-EB for existing buildings [28]. The first version of LEED EB was established in 2004 to address buildings' overall and daily facility management issues. The new program is not dramatically different but does shift the focus from design to facilities management and building maintenance. EB registration can be sought at any point in the lifecycle of a building, unlike new constructions that must incorporate LEED from the design and construction phase. The system prioritizes energy efficiency and CO2 reductions.

In the EU, there are standards relating to calculating the performance of a building. The European Energy Performance of Buildings Directive states which criteria should be taken into account but does not give weightings, or specify how to calculate the values [29]. The Directive sets forth that the following areas should be considered relating to building performance: thermal characteristics of the building, heating installation and hot water supply, air-conditioning installation, ventilation, position and orientation of buildings including outdoor climate, passive solar systems and solar protection, natural ventilation, and indoor climate conditions. The Directive also states that the positive aspects of renewable energy such as active solar, combined heat and power systems and natural lighting should be taken into account. The buildings are separated by type, in relation to performance, indicating that the Directive recognizes that buildings for various uses perform differently, are built and used in a different way so the expectations need to change. The Directive does not make mention of the difference in performance expectations between renovation and new build.

In response to the Questionnaire question "In relation to transformation or renovation rather than new building, what are the most important "sustainability" aspects that should be considered?" each office had a different response. There is no consensus amongst Danish offices relating to transformation and only a few offices rated architectural renovation highly as being important to their work. All offices responded that when designing a renovation, there are some special considerations needed when designing in a sustainable way. For example, Svendborg Architects and Adept Architects cited increased pressure to consider contextual qualities. Site As responded that architects must consider the building over its lifecycle "The issues that architects normally deal with are the more expensive parts – supplementary insulation, new windows and the outer "frame", which normally "comes last" on the priority list because the investment and payback time are much bigger and longer – but of course important parameters to deal with." SHL argue that the most important issues are "possibly the historical heritage of the building mass that is being transformed, and the possibility to energize a neighbourhood by transforming the use of an existing building. Here the building has a potential of becoming a generator for new life in a local context." BIG´s response looks to a responsibility to future users and renovation as a way of living, with an idea of designing for future renovations. BIG argue that it is important to consider "the future users of the building as well as general public who must accept it, use it, adapt to it, alter it to their own needs."

5. Further Research and Implications

Currently there are many EU and national targets relating to sustainable building and increased pressure on architects to be aware of sustainable ideas and metrics. Sustainability is not well defined or measured in architecture, at least by designers, and this is a problem. Sustainability it is also not well understood by users, and further work should be undertaken in this area.

On-going European standardization work considering the sustainability in building construction currently does not have much discussion in key architectural texts regarding sustainability and is not cited by architects in Denmark when surveyed about how they measure sustainability. Sustainability can and must be considered by designers, but due to the complex nature of design, it is difficult to implement, measure, define, compare and communicate.

Increasingly as more architects use Building Information Modelling and other digital tools, there are more opportunities for architects to communicate sustainability and analyze their designs. New

advances in environmental performance analysis tools such as the software Ecotect [30] are allowing architectural designers to predict a building's environmental performance and carry out simple calculations. For example, Danish office SHL is one of many offices undertaking Ecotect analysis as a design tool relating to sustainability [31]. While this type of environmental analysis is typically undertaken by engineers or other consultants, using Ecotect or similar tools, this analysis can be done within the architectural design process allowing it to impact and provide performance feedback to the designer as the design emerges. This analysis work can be carried out on both new and existing buildings, however it is recognized that it may be more complex when analyzing a building that is already built.

While research has shown that major energy savings can be achieved in housing built between 1961-1972 in Denmark [32], further studies need to be undertaken to see how architectural approaches, beyond energy savings towards more holistic, architectural parameters such as reconfiguring space, light, and other parameters can be achieved. Standardized assessment methods such as BREEAM and LEED measure design intentions but future work could compare design intentions and post occupancy data to see if designs are performing as predicted. Further study could also involve comparison of emerging, smaller assessment systems to see how they serve sustainability and renovation.

6. References

[1] EU 2005, Commission on Research and the Environment, Restate Project, 2005

[2] PETERS, T, "The State of Modern Renovation in Denmark: Current Architectural Approaches to the Sustainable Transformation of Post-War Housing" in *Architecture and Sustainable Development, Proceedings of PLEA 2011*, Louvain-la-Neuve, Belgium (July 2011) In Press.

[3] EU 2008, Climate and Energy Package, European Commission, 2008.

[4] EU 2009, "Low Energy Buildings in Europe: Current State of Play, Definitions and Best Practice", European Commission Directorate General for Energy and Transport, Directorate D, 2009, pp.

[5] BETSKY, A, *"Out There. Architecture Beyond Building: 11th International Architecture Exhibition La Biennale di Venezia",* Marsilio, New York, 2008, pp. 19-20.

[6] PETERS, T, "Sustainability Questionnaire with Danish Architects", Email Questionnaire, 2011, Not Published.

[7] WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, *"Our Common Future"*, Oxford University Press, 1987, Chapter 2, Section 1

[8] YEANG, K, *The Green Skyscraper*, Prestel Verlag, Munich, 1999, pp.33

[9] PORTEOUS, C, *"The New Eco-Architecture, Alternatives From The Modern Movement",* Spon Press, London and New York, 2002, pp.91.

[10] FOX, D. "An Overarching Framework for Sustainability" in *Built Environment*, vol 35, no3, pp. 302.

[11] CANIZARO, V, TANZER, K, "Introduction to Sustainability" in Journal of Architectural Education, vol 60, issue 4, pp 4

[12] LEED http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988 (June 2011)

[13] BREEAM http://www.breeam.org/page.jsp?id=66 (June 2011)

[14] BUCHANAN, P, *"Invitation to the Dance: Sustainability and the Expanded Realm of Design"* in William S Saunders Ed, "Nature, Landscape and Building for Sustainability", University of Minnesota Press, 2008, pp115.

[15] YEANG, K, *The Green Skyscraper*, Prestel Verlag, Munich, 1999, pp.32

[16] JENSEN J, GRAM-HANSSEN K, "Ecological Modernization of Sustainable Buildings: A Danish Perspective" in *Building Research and Information,* Vol 36, no 2, 2008, pp.154.

[17] BECH-DANIELSEN, C, "Three Types of Environmental Efforts – Behavioural Changes, Technical Development, Architectural Design," in *Architecture, Energy, Climate, Nordic Journal of Architectural Research*, Vol 1/ 2, 2010.

[18] BECH-DANIELSEN, C, "Three Types of Environmental Efforts – behavioural Changes, Technical Development, Architectural Design," in *Architecture, Energy, Climate, Nordic Journal of Architectural Research*, Vol 1/ 2, 2010, pp.79

[19] JENSEN J, GRAM-HANSSEN K, “Ecological Modernization of Sustainable Buildings: A Danish Perspective” in *Building Research and Information,* Vol 36, no 2, 2008, pp.148.
[20] LAURING M, “From Ecological Houses to Sustainable Cities, Architectural Minds” in *Nordic Journal of Architectural Research,* vol 22, Nr 1 / 2 2010.
[21] LAURING M, “From Ecological Houses to Sustainable Cities, Architectural Minds” in *Nordic Journal of Architectural Research,* vol 22, Nr 1 / 2 2010, pp. 51.
[22] BREEAM http://www.breeam.org/page.jsp?id=66 (June 2011)
[23] HALEWOOD, J, “Sustainability Through Planning” Building Research Establishment, 2009. http://www.breeam.org/filelibrary/BREEAM_Presentation_300310.pdf, June 2011.
[24] JØRGENSEN, M, “Sustainable Housing-Strategies for Existing and New Buildigns Based on 25 Years of Experiences and Visions From Denmark” Working Paper June 2010
[25] Danish Ministry of Culture “Denmark´s Architectural Policy”, 2007, pp.36
[26] EU 2002, Directive 2002/91/EC EU Directive on Energy Performance in Buildings, 2002.
[27] BREEAM Domestic Refurbishment http://www.breeam.org/page.jsp?id=228 (June 2011)
[28] LEED EB http://www.usgbc.org/DisplayPage.aspx?CMSPageID=221 (June 2011)
[29] EU 2010 Directive 2010/31 EU European Energy Performance of Buildings Directive, Official Journal of the European Union, 2010.
[30] Ecotect is a software owned by Autodesk. http://www.usa.autodesk.com/adsk/servlet/pc/index?id=12602821&siteID=123112 (June 2011)
[31] SHL Architects, Denmark http://shl.dk/eng/#/home/forskning-udvikling/bim-og-baeredygtighed (June 2011)
[32] BECHBECH-DANIELSEN, C, “Three Types of Environmental Efforts – behavioural Changes, Technical Development, Architectural Design,” in *Architecture, Energy, Climate, Nordic Journal of Architectural Research*, Vol 1/ 2, 2010, pp.78