

Measuring sustainable homes - a Mixed Methods approach

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ABSTRACT:

The paper studies the *Active House vision* and the *Active House Specification* work-in-progress to identify what parameters to measure when measuring sustainable homes of the future. The approach is based on a Mixed Methods research strategy where measurements are related to both quantitative and qualitative aspects in relation to the categories Energy, Indoor climate and Environment. The *what to measure* part of the paper results in a matrix that lists the measurement parameters. On basis of the measurement parameters a set of methods are compiled into a matrix that defines *how to measure* regarding quantitative and qualitative aspects. These methods imply Logging and data handling in Excel, Luminance mapping, Cultural Probes, Semi-structured Interviews, Observation, Self-experience studies and photo registration. The paper presents two matrices on *what* and *how* to measure sustainable homes. The paper is concluded with the assumption that exploring seven experimental sustainable homes will result in knowledge and learning to develop a holistic assessment method for evaluation sustainable homes of the future.

CONFERENCE THEME: On Measurement

KEYWORDS: Measuring, sustainable, homes, Mixed Methods

I. INTRODUCTION

Focus on development of sustainable architecture is at an ever high. This has resulted in eagerness to prove the performance of buildings resulting in an increase of rules, evaluation criteria and legislation bringing the tendency of gradually overlooking qualitative aspects while focusing on the quantitative and immediately measurable aspects (Birgisdottir 2010). The tendencies bear witness to a paradigm shift in the ways of considering and studying sustainable living and sustainable homes – a tendency indicated by several recent research projects (e.g. Marsh et al 2010, Entwistle 2010, Brunsgaard 2011). According to Willars and Lynch (2010) the technical means only account for about 20 percent of solving the challenges, whereas occupants' behaviour and lifestyle can account for at about 80 percent. This underlines the importance of not ignoring the architectural and qualitative aspects related to experience, well-being and health and appoints to an approach based on occupants' needs and experiences.

With the new strategic initiative *Active House vision* attention is brought to a holistic approach to considering and developing sustainable homes of the future (Sloth 2010). The initiative is based on collaboration between the building industries, product companies and research institutions and carries the objective to create knowledge that develops holistic sustainable architectural solutions of the future.

The *Active House vision* has resulted in the development of a full scale experimental lab consisting of seven sustainable homes. This project makes it possible to measure these seven experiments through exploratory research in contemporary issues related to the paradigm shift providing possibility of qualitative estimates for developing sustainable homes.

The main objective of the work is to design *a method for holistic evaluation of sustainable homes of the future*. The inclination to establish a holistic assessment method is to provide for a more balanced consideration when learning how to design and develop buildings of the future. Quantitative aspects typically represent the physical and technical – whereas qualitative aspects typically represent the social, psychological and philosophical environments surrounding us.

Based on systematic research the compilation of an evaluation method, that can substantiate and demonstrate a range of sustainable aspects, should lead to the composition of evidence supporting the need to consider buildings from a holistic perspective. Evidence can influence political debate and decision-making and thereby push for implementation of *both quantitative and qualitative* aspects in future strategies, evaluation models and legislation.

This paper addresses the problem of *what and how* we shall measure sustainable homes to extract knowledge with which to aim for a holistic approach of assessment.

2. WHAT TO MEASURE IN SUSTAINABLE HOMES?

The purpose of the paper is to identify *what to measure* in order to compile data and information through measurement. Data and information is a necessity in order to analyze and identify *what parameters* are central to measure and evaluate. This implies the need for identification of *what methods* to use for measuring quantitative and qualitative aspects of sustainable homes. Through this paper we seek to verify what to measure through formulating the hypothesis that: *Through studies of the Active House vision and its coherent design parameters we can identify what to measure through quantitative and qualitative aspects.*

Identification of what to measure will lead to the problem of *how to measure* the parameters. This paper attempts to verify the hypothesis that: *By compilation of methods from natural science and artistic and humanistic disciplines it is possible to design a frame on how to measure quantities and qualities in sustainable homes.*

To approach verification of the hypotheses this paper will study state-of-the-art research projects that work with measuring sustainable houses. The projects take a Mixed Methods perspective on working with interdisciplinary set ups and in cross disciplinary fields in order to identify and measure quantitative and/or qualitative aspects (Bryman 2006).

Social science and anthropology explore social and behavioral environments through methods that build on empirical and bodily experiences and observations. The purpose is to identify and explore acknowledged and unacknowledged needs and desires. Methods include for instance observation, interviews and cultural probes. The recently conducted research project *Minimum Configuration Home Automation (MCHA)* about user driven innovation for developing minimum configuration products for home automation, partly rely on methods from anthropological science (MCHA 2009). Observation, semi-structured interviews and scenario studies have uncovered behavioral patterns in the occupants' everyday habits that proved to have great impact on environmental considerations. The research showed that non-verbalized and inherent habits carry a great responsibility for the 'hidden' energy consumption (Entwistle 2010). The habits were central to uncover to implement that knowledge into developing new projects based on the needs of the occupants.

Qualitative and quantitative research methods are also used in another recently conducted Danish research project regarding the *Comfort Houses in Vejle*, Denmark (Brunsgaard 2011). Ten passive houses and their occupants are subjects to measurements. Semi-structured Interviews (Kvale 2009) was used to systematically uncover the occupants' everyday lives and experience in the low-energy house. Simultaneously interviewing the occupants, measurements on energy consumption and indoor climate conditions was conducted. The project shows that occupant behavior in a low-energy house carry a considerable impact on energy consumption. (Brunsgaard et al 2010)

2.1 ACTIVE HOUSEVISION

The sustainable homes that compile the experimental setup for the project are developed from the Active House vision – a vision of:

(...) buildings that create healthier and more comfortable lives for their occupants without negative impact on the climate – moving us towards a cleaner, healthier and safer world. (Sloth 2010)

The vision defines three central categories: *Energy, Indoor climate and Environment*. *Energy - Contributes positively to the energy balance of the building*. An Active House is energy efficient and all energy needed is supplied by renewable energy sources integrated in the building or from the nearby collective energy system and electricity grid. *Indoor climate - Creates a healthier and more comfortable life for the occupants*. An Active House creates healthier and more comfortable indoor conditions for the occupants and the building ensures a generous supply of daylight and fresh air. Materials used have a positive impact on comfort and indoor climate. *Environment - Has a positive impact on the environment*. An Active House interacts positively with the environment by means of an optimized relationship with the local context, focused use of resources, and on its overall environmental impact throughout its life cycle.

An integrated intelligent controlling system constantly monitors and adjusts the indoor climate in accordance with occupants' needs and pre-set comfort demands. The *Active House vision* attempts to achieve balance between the environment, house and occupants (Sloth 2010).

2.2 ACTIVE HOUSE SPECIFICATIONS

The work of establishing the *Active House vision* has led to a *work-in-progress Active House Specification*. The purpose of formulating a specification is to make the vision approachable and designing-tools available. This supports moving further towards the vision. (Eriksen et al 2011)

The specification state a number of parameters belonging to quantitative and qualitative fields. In keeping with the vision it is structured by the three categories *Energy, Indoor climate and Environment*, also stating that:

An Active House is evaluated on the basis of the interaction between energy consumption, indoor climate conditions and impact on the environment.

The parameters are listed in *Table 1* under each of the categories and will form the basis of what to measure.

Energy

The category implies the groupings *Energy Design, Natural Design Solutions and Renewable Energy*. There seem to be a gap in elaboration of the quantitative and qualitative categories as the latter is hardly elaborated on. Only *design* and *comfort* are stated as parameters in the qualitative category and readings into the further definitions refer to the indoor climate category. Is it possible to state more elaborated qualitative parameters within *energy*? An approach to identifying qualitative aspects could be to relate to the values, occupants ascribe to energy; consciousness of using energy, contributing to reduction of global warming, awareness of consumption, and attitude towards producing energy.

Indoor climate

The category implies the groupings *Light, Thermal environment, Indoor air quality and Acoustics*. This category appears to be the furthest elaborated with very specific groups and units. The category is quite approachable regarding both quantitative and qualitative aspects as the problems rely on a bodily encounter – one of physical nature and one of experiential nature. It might be problematic that the very specific parameters could call for very specific measurement methods.

Environment

The category implies the groupings *Resources and emission and Characteristics and culture*. The parameters elaborated from only one perspective each making it difficult to see through the holistic approach to the category. The real-life-scaled project carries good odds of resulting in knowledge that can further elaborate the categories due to the contextual preconditions and its geographic extend.

The differences in degree of description and elaboration of the parameters clearly signal the *work-in-progress* stage of the work. However, the stated parameters will form the basis for *what to measure* in this *initial* part of the process of measuring with implied development.

	Energy	Indoor Climate	Environment (surroundings)
QUANTITATIVE	<p><i>Energy design/Type of energy:</i></p> <ul style="list-style-type: none"> • Space heating • Water heating • Ventilation • Cooling and air conditioning • Electricity for tech. installations • Electricity for lightning • Electricity for appliances <p><i>Natural design solutions:</i></p> <ul style="list-style-type: none"> • Passive solar energy • Daylight utilisation • Natural ventilation • Shading during cooling season • Integrated solutions • User behaviour <p><i>Renewable energy:</i></p> <ul style="list-style-type: none"> • Energy demand • Energy supply • Source of renewable energy 	<p><i>Light:</i></p> <ul style="list-style-type: none"> • Daylight • Direct sunlight availability • Surface reflectance <p><i>Thermal environment:</i></p> <ul style="list-style-type: none"> • Maximum operative temperature • Minimum operative temperature • Adjustability (individual control) <p><i>Indoor air quality:</i></p> <ul style="list-style-type: none"> • Air change • Minimum air change <p><i>Acoustics:</i></p> <ul style="list-style-type: none"> • Limit value for inside system noise 	<p><i>Resources and emission:</i></p> <ul style="list-style-type: none"> • Re-use of materials • Minimized use of virgin non-renewable materials • Minimized use of non-renewable fuel resources • Minimize life-cycle emissions of greenhouse gasses <p><i>Characteristics and culture:</i></p> <ul style="list-style-type: none"> • To be defined in future process
QUALITATIVE	<p><i>Energy design:</i></p> <ul style="list-style-type: none"> • Design • Comfort <p><i>Natural design solutions:</i></p> <ul style="list-style-type: none"> • Design • Comfort <p><i>Renewable energy:</i></p> <ul style="list-style-type: none"> • Design 	<p><i>Light:</i></p> <ul style="list-style-type: none"> • View out • Visual privacy • Visual comfort • Individual control • Dark bedrooms at night <p><i>Thermal environment:</i></p> <ul style="list-style-type: none"> • An intuitive human interface • Draught • Natural ventilation paths <p><i>Indoor air quality:</i></p> <ul style="list-style-type: none"> • Individual control • Low-emitting building materials <p><i>Acoustics:</i></p> <ul style="list-style-type: none"> • Acoustic privacy and quietness 	<p><i>Resources and emission:</i></p> <ul style="list-style-type: none"> • To be defined in future process <p><i>Characteristics and culture:</i></p> <ul style="list-style-type: none"> • Regional building typology • Regional functional tradition • Potentials and constrains in local climate • Regional materials • Harmoniously fit in landscape • Impact on street- and landscapes • EIA • Preservation of existing values • Ecological quality of the site • Risks by climate changes

Table 1: What Parameters Matrix: The categories Energy, Indoor climate and Environment in respectively the quantitative and qualitative approach. Source: (Authors’ production based on the Active House Specification (Eriksen et al 2011))



Home for Life, 2009,
Lystrup, Denmark
New single-family house
190m²
Picture: Adam Mørk



Solar Aktivhaus, 2009
Kraig, Austria
New single-family house
150m²
Picture: Gitte Gylling



Haus der Zukunft, 2009
Regensburg, Germany
New single-family house
175 m²
Picture: Gitte Gylling



Licht Aktivhaus, 2010
Hamburg, Austria
Renovated double house
More information later...
Picture: VELUX



Sunlighthouse, 2010
Pressbaum, Austria
New single-family house
Picture: Adam Mørk



Carbon Lighthomes,
Rothwell,
United Kingdom
New double house
Picture: VELUX



Maison Air et Lumière,
Varrières-le-Buisson,
France
New single-family house
Picture: VELUX

Figure 1: Seven experimental houses designed and built according to the Active House vision. Source: Authors design.

2.3. EXPERIMENTAL SETUP

To investigate if the proposed measurement parameters are legitimate and to explore errors or absence of aspects we will measure these parameters in a full scale experiment of seven sustainable homes. The seven experimental houses are designed and constructed according to the *Active House vision* as single-family-houses of which one is a renovation project and the remaining are newly built. The houses are geographically located across Europe, with two houses in respectively Germany and Austria, while one house is built in respectively Denmark, France and Britain. This geographic extent provides an interesting basis for studies on energy optimization and importance of place and location to the experience of each house, as well as to the strengths, weaknesses and comparability of houses. Each house has distinctive characters, as they are built, taking into account local, cultural and climatic conditions and with different teams of architects, engineers and contractors. The overall perspective focuses on combining an aesthetic energy-design, high comfort and good indoor climate - while resulting in minimal environmental impacts (Hansen 2010).

When the houses are built and adjusted, families move in for a one year period to test and experience living in and with the houses. First three houses will be tested to the measurement parameters and outcomes will be analyzed. The analysis will be evaluated to analyze whether the parameters provide us with a holistic illustration of the homes and to analyze what can be enhanced regarding parameters, approach and methods. Subsequent, measurements of the remaining four homes will test and revise the model to verify it. Each house will be treated as a case study in an embedded multiple-case design (Yin 2009).

The objective is to test if the measurement parameters can help provide the required answers to the questions and help verify the stated hypotheses.

3. HOW TO MEASURE SUSTAINABLE HOMES?

To be able to measure the identified parameters in the seven experimental, sustainable homes an identification of *how to measure* these is required. Studies of state-of-the-art research projects' use of methods from natural sciences and artistic and social sciences will inspire and support choice and compilation of methods.

How do we measure a house by its ability to improve life to its occupants? As the sustainable homes are designed from a holistic perspective measuring will similarly be approached from a cross scientific and Mixed Methods perspective, by introducing both methods from natural sciences and artistic and humanistic disciplines. Qualitative and quantitative research is often presented as two fundamentally different paradigms through which we study the social world. Through a Mixed Methods Research strategy quantitative and qualitative data are brought together to provide for comprehensive collection

and analysis corresponding to holistic hybrid view on sustainability and measuring (Bryman 2006).

Mixed Methods Research (...) an approach to professional research that combines the collection and analysis of quantitative and qualitative data. (Creswell 2009)

The Mixed Methods strategy is carried out as sequential practices where research into quantitative data is followed by research applying qualitative methods to the data. The approach can also be performed vice versa and as an iterative method. For instance measurements on quantitative data can reveal fluctuation, and to explain or explore this, qualitative methods such as interviews or observations can identify details or tendencies in e.g. user behaviour (Creswell 2009).

Both quantitative and qualitative data are considered to represent aspects of the relations between occupant, house and environment, which will also be reflected in the choice of methods to study these.

3.1. MEASURING QUANTITATIVE DATA

The intelligent controlling system implemented in the design of the homes is appropriate to use for logging data. The system monitors weather and indoor climate to adjust the house to the occupants' needs. Meters are placed on the system that can log and extract data on energy consumption and production, related to respectively heating and electricity, on weather and physical and behavioral indoor climate. Manual measurements on daylight can support investigations on the indoor climate light parameters, which are the most widely elaborated in the specification and daylight appear as a focal aspect in the *Active House vision* (Hansen 2010)(Osterhaus 2010)(Førland-Larsen 2009).

3.2. MEASURING QUALITATIVE DATA

Studies of the MCHA and Comfort Houses projects show that several qualitative methods can be used for studying the relations between environment, home and occupant, as e.g. observation studies, interviews or scenario-observation studies. This leads to wondering, if a triangulation of methods can support a more holistic perspective on measuring qualitative aspects?

In the studied research projects that treat experiences related to sustainable living, there seem to appear three perspectives to filtering these experiences; a private, an inter-relational and a professional (Søndergaard and Entwistle 2009) (Brunsgaard 2011). Inspired by this three-way perspective and a triangulation of methods a three-parted structure is suggested to build the qualitative research setup on.

Occupants' experiences

How can we measure occupants' experience of living in the house when we are not present? Differences between the occupants' acknowledged and unacknowledged needs and experiences of living in and with the houses are a central offset for measuring qualitative aspects. The occupants' experiences imply perspective on living in the house, why this method attempts to document experiences through the occupant's perspective. User based exploration focus on how the occupant experience life in a sustainable home and interrelations and inter-influences between occupant, house and environment have an effect on perceptions and feelings with regards to living in an intelligent and sustainable house. Registration of user experiences is based on *Cultural Probe* method. This imply that the occupant is set the task of registering data from experiences of living in the house through photos (digital camera), a log book for noting immediate thoughts (physical note book), and a diary (electronic template) (Bryman 2008) (Hastrup 2003).

Interviews

Interview is a frequently used method to gather data. The method appears in several research projects as the user perspective is gaining importance (Brunsgaard 2011) (Entwistle 2010). A qualitative interview can be based on several approaches. Inspired from the MCHA and Comfort Houses projects the *Semi-structured Life-world Interview* will be used; a method appropriate for extracting knowledge from and understanding the life-world of the interviewee (Kvale 2009). The flow of a

Semi-structured Interview creates possibilities of sudden new questions to explore appeared subjects of interest or to navigate away from such if these are off key. New insight and knowledge might appear from unexpected sides that might come to be relevant to the research. The face to face interviews will be done in the sustainable home, establishing a safe setting. An appropriately tailored interview-guide forms the overall framework for the interview situation consisting of questions and sub questions relating to different themes (Kvale 2009). The method help create knowledge about the experiences the occupant is able to verbalize. Also, the conversation about the occupant's everyday experiences of living in the house might result in new recognitions to the occupant. (Kvale 2009)

Self experience studies

The experience studies based on architectural theory and phenomenology are central when dealing with the hybrids between bodily and special experience. The MCHA and Comfort Houses projects does not deeply deal with this approach though considering the research approaches from more divisible perspectives. Professional knowledge about architecture is considered central to connect the different methods. First-hand empirical field study experiences can provide for an enhanced possibility of connecting the dots between occupants' behavior and statements related to the technical functioning of the house. The experience registrations are based on architectural methods, phenomenology and sensing approach, inspired by Juhani Pallasmaa (2005, 2007), Steen Eiler-Rasmussen (1989), Louis Kahn (Lobell 2008), Dean Hawkes (2008) and Peter Zumthor (2006). Registrations will be compiled in descriptive and narrative texts supported by photos.

4. RESULTS

Below, the results of studies in *how to measure* are presented in a matrix. The methods are presented in relation to the categories to undergo research with the intent that the proposed methods can support finding answers to the measurement parameters. This concluding matrix should be understood as framing the proposed methods in relation to investigating the identified measurement parameters. This matrix further relates to measuring the first round of sustainable homes and thereby reflects its initial stage.

Quantitative measurements are listed as reasonably specific and are expectedly plain sailing. Qualitative measurement parameters and methods appear more indistinct and blended and expectedly it will be challenging to relate to a specific category due to an experience that experience is complex to classify.

5. DISCUSSION

5.1. ON THE ISSUE OF MEASURING

When looking into the concept of measuring in relation to buildings and architecture a lot seems to rely on quantitative means. Are the qualitative aspects of a building not considered as important to prove as the quantitative ones? Or is it simply not possible to put a formula to quality?

Qualitative aspects can immediately appear quite intangible since they rely on feelings and experiences rather than numbers. The line of thought appoints to the tangible difference inherited in respectively the quantitative and the qualitative aspects of sustainable architecture and thereby it appoints to the still stubborn persistently existing barrier between engineering and architecture disciplines.

“I only wish that the first really worthwhile discovery of science would be that it recognized that the unmeasurable is what they're really fighting to understand, and that the measurable is only the servant of the unmeasurable; that everything that man makes must be fundamentally unmeasurable.” – Louis Kahn

In the above quotation by Louis Kahn seem to capture the essence of the tangibility of the quantative and qualitative. Opposed to the conventional upbringing within sustainable architecture he points to the unmeasurable – qualitative – as the fundamental aspect. Is Kahn right in his statement? Would the quantitative aspects loose their justification without their dependence on qualitative aspects? Hopefully, the studies can bring us closer to answering these wonderings.

	Energy	Indoor Climate	Environment (surroundings)
QUANTITATIVE	<p>Meters are placed on energy consuming and producing devices. Data are logged as mean hourly values.</p> <p>Logging:</p> <p>Heating consumption:</p> <ul style="list-style-type: none"> Space heating (kWh/m²/mth) Water heating (kWh/m²/mth) <p>Electricity consumption:</p> <ul style="list-style-type: none"> Ventilation (kWh/m²/mth) Cooling/air con. (kWh/m²/mth) Electricity for technical installations, lightning, appliances (kWh/m²/mth) <p>Natural design solutions:</p> <ul style="list-style-type: none"> Passive solar energy: Indirect evaluation as by energy savings Daylight utilisation: Lux + electricity Natural ventilation: Indirect eval. Shading during cooling season integrated solutions measured by logging data in awning position. User behaviour measured through collection of super steering of system and presence data <p>Renewable energy:</p> <ul style="list-style-type: none"> Heating production (kWh/m²/mth) Electricity production (kWh/m²/mth) 	<p>House is separated into zones (rooms/areas) constantly measured. Meters placed on walls 1.6 m above floor in shadow. Data are logged as mean hourly values</p> <p>Light:</p> <ul style="list-style-type: none"> Lux data are logged (lx) TimeLapse Luminance mapping/pictures () <p>Thermal environment:</p> <ul style="list-style-type: none"> Temperature data are logged (°C) <p>Indoor air quality:</p> <ul style="list-style-type: none"> CO₂ data are logged as mean hourly values (ppm) Relative Humidity data are logged as mean hourly values (%) <p>Acoustics:</p> <ul style="list-style-type: none"> Observation of the acoustic environment will help determine whether measurements of the acoustic environment in and around the house are required 	<p>Logging weather data – meters are placed on roof top constantly measuring. Data are logged as mean hourly values.</p> <p>Weather:</p> <ul style="list-style-type: none"> Outdoor temperature (°C) Outdoor lux (lx) Rain (1/0) Wind speed (m/s) <p>Resources and emission:</p> <ul style="list-style-type: none"> Registration Evaluation through comparison to calculation <p>Characteristics and culture:</p> <ul style="list-style-type: none"> Indirect evaluation through quantitative measurements and description.
QUALITATIVE	<p>Energy design:</p> <ul style="list-style-type: none"> Occupant experiences/Cultural Probes Semi-structured Interviews Self-experience studies <p>Natural design solutions:</p> <ul style="list-style-type: none"> Occupant experiences/Cultural Probes Semi-structured Interviews Self-experience studies <p>Renewable energy:</p> <ul style="list-style-type: none"> Occupant experience/Cultural Probe Semi-structured Interviews Self-experience studies 	<p>Light:</p> <ul style="list-style-type: none"> Occupant experiences/Cultural Probes Semi-structured Interviews Self-experience studies TimeLapse studies Luminance photos/mapping Light narratives <p>Thermal environment, Indoor air quality and Acoustics:</p> <ul style="list-style-type: none"> Occupant experiences/Cultural Probes Semi-structured Interviews Self-experience studies 	<p>Resources and emission:</p> <ul style="list-style-type: none"> Occupant experiences/Cultural Probes Semi-structured Interviews Self-experience studies <p>Characteristics and culture:</p> <ul style="list-style-type: none"> Registered through photo registration Description Occupant experiences/Cultural Probes Semi-structured Interviews Self-experience studies

Table 2: What Methods Matrix (first draft): Matrix of *what* quantitative and qualitative *methods* to use for data collection related to each of the categories Energy, Indoor climate and Environment.
Source: (Authors production based on a compilation of the *Active House Specification* (Eriksen et al 2011))

5.2. ON WHAT TO MEASURE

The listed measurement parameters seem quite un-done – are they elaborated enough within the three categories to result in a holistic illustration and rightful fulfillment of the ambitious *Active House vision*?

Is it possible to state more elaborated qualitative parameters within *energy* and why does the descriptions of the parameters refer to the indoor climate category? Are there no qualities in energy?

The initial test-period of the experimental houses is presumed to indicate if, how and which proposed methods can answer to the stated measurement parameter. This will influence the further process revision of whether the measurement parameters are sufficiently accurate to answer the *Active House vision*.

The three measurement categories Energy, Indoor Climate and Environment and their listed parameters obviously have their restrictions at this stage of the *work-in-progress*. It would justify all of the categories to be further explored and elaborated in this attempt to establish a specification. This project will hopefully yield to defining the singular categories and parameters.

Measuring the sustainable homes will hopefully result in answers to some of the questions, providing for specifying the parameters within the three categories.

5.3. CHALLENGES TO THE EXPERIMENTAL SETUP

There are big challenges in this measuring setup. The experimental houses are designed and constructed by different companies, with different teams of architects, engineers, entrepreneurs and project managers, in different countries, different climate and different legal regulation and standards. The house designs, building traditions and materials are different, the habit of living and the people are different. These cultural aspects must stand in the background for the central aspects regarding environment – the ability to adaptation to climate and surroundings and the occupants' experiences of living in and with the sustainable houses. These aspects can help identify how we can make comparison across. This makes it possible to demonstrate differences and coincidences in occupants' wishes and requirements to a sustainable home in accordance with place.

5.4. ON HOW TO MEASURE

The proposed methods matrix suggests a lot of different methods through the Mixed Methods research strategy, but can the generous use of methods and scientific directions course for confusion rather than clarity in the explorations? Could the intent to research the different aspects of sustainable homes by triangulation course for blurred results or contrary results? It might. In that case, it is central to keep focus on the holistic purpose of the explorations. We are not searching for single rights or wrongs but rather for inspiring and interesting tendencies to support our hypothesis in qualified ways. Here, the professionalism and discernment of the researcher must be considered the right tool for determining the answers.

The study proposes methods to intercept qualitative aspects and set off to explore whether these methods are any good for the job?

5.5. ON RESULTS

In order to extract knowledge to implement in the further process the measurements must be analyzed properly and according to the idea of focusing on a holistic approach and the interplay between quantitative and qualitative aspects. What are more important – quantitative or qualitative aspects of the houses? If it is possible to make such a distinction is very relevant to the discussion of the need for a holistic approach.

5.6. ON ANALYSES

How do we treat and analyze data and information in order to be able to answer to the questions? The various methods and approaches calls for various analysis approaches. The data will be gathered in NVivo (qualitative data analysis software) (Lewins and Silver 2007)) and analyzed through an inductive approach to explore options in the data. Deductive and inductive analysis approaches will both be relevant to detect the worth of the data (Hastrup 2003).

The case study research (Yin 2009) approach to the setup for exploration enable for comparable studies in the analysis phases of the project. By using the same methods for data collection comparability studies will have similar premises and studies can be possible across e.g. different themes or typologies. The setup enables numerous permutations providing for uncovering both expected and unexpected areas of the explorations. Further strategies for data analysis will be uncovered in the succeeding stages of the project.

5.7. VALIDITY, RELIABILITY AND GENERALIZABILITY

This research project focus on sustainable homes spread across five European countries. The results of the three initial case studies in respectively Denmark, Austria and Germany will indicate whether this geographic extend hold any kind of generalizability.

It is our belief, that a vision of successful development of sustainable homes, as of sustainable architecture in general requires a more holistic approach regarding all phases of building, from

design phase to operation phase. Focus on holistic, inter-disciplinary design processes would make the preconditions for successful holistic assessment greater.

This initial proposal for systematically exploring sustainable homes cannot be considered a final answer to the issues, but rather an attempt to prove the validity of the hypotheses. Hopefully, this way of systemized method for gathering data will prove its worth. Very different methods and approaches are introduced for exploring different areas of the problem and discovering whether these support or undermine each other will be a key to deciding further development for the matrix.

6. CONCLUSION

The paper studies the *Active House vision* and the *Active House Specification work-in-progress* to identify what parameters to measure related to both quantitative and qualitative aspects in relation to the categories Energy, Indoor climate and Environment. On basis of the measurement parameters a set of methods are compiled into a matrix that defines what to measure regarding quantitative and qualitative aspects.

The conclusion is must evaluate the buildings on their preconditions – their design parameters and visions for the individual building to identify whether the design parameters are good enough. In order to answer to our questions we must analyze a combination of quantitative and qualitative data.

7. ACKNOWLEDGEMENTS

This paper is the second paper in the PhD project *A Method for Holistic Evaluation of Sustainable Buildings of the Future* where quantitative and qualitative measurements of seven buildings in five European countries - built according to the Active House vision - will contour the setup for development of a method for holistic evaluation of sustainable homes.

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