INTELLIGENT ENERGY CONSUMPTION IN LOW ENERGY HOUSING

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ABSTRACT
BR10 requires that all new residential constructions should be built as low energy housing. In order to meet these requirements residential buildings must be equipped with far more complex technology, than conventional housing. This, for example, could be a combination of mechanical balanced ventilation, natural ventilation, heat pumps, solar heating, solar cells or automatic sunscreens.

The users' needs and wishes for the energy consumption (extent and quality), and thereby the interaction between consumer and building, installations and electrical consuming equipment, is vital for reaching the energy- and emission goals.
The project's focus is energy efficiency in residential housing by controlling the interaction between technology and behaviour. The project is looking into all of the significant energy consuming applications, such as heating, ventilation, lighting, household, entertainment, IT etc.

The main part of the project has been the interaction with the users of the house. Different scenarios have been tested by the family living in the house. The family has through its daily living tested if the building, the installations and the utilities have been functioning according to plan – what have been good and what have been bad?

KEYWORDS
Energy performance, indoor environment, comfort, hybrid ventilation, intelligent controlling

INTRODUCTION

EnergyFlexHouse in Taastrup, is a high-tech laboratory for development, testing and demonstrating total innovative energysolutions for the building sector. The construction consists of two almost identical buildings, from which the one – EnergyFlexHouse Family (EFHfamily) – is Denmark's first energy neutral residential home. The home is supplied with energyefficient systems and sustainable energy facilities, which produce the energy, used both by the family who lives inside the house but also for an electrical car used for transportation by the family.

The two buildings are equipped with extensive data logging equipment (more than 500 measuring points all together), which gives a unique opportunity to monitor and study, cause and effect. In October 2009 the first test family moved in to EFHFamily and in December 2011, the fifth family moved out. The families live in the house for 3 to 6 months at a time depending on different practicalities. The families take part in the activities, focusing on the interaction between technology, users, controls, energy services and energy consumption.

The energy neutral home is supplied with the technology used in an average residential home. Although everything is new – putting the newest technology to a test – constructions, installations, kitchen appliances, IT etc.

EFHfamily gives a rare opportunity to develop, test and document the energy- and user-related advantages of simple or more complex control concepts and systems for energy services, primarily focusing on indoor climate.

The global challenges regarding energy supply and significant reduction of the CO2 level, must be accomplished by energy efficiency and usage of sustainable energy. 35-40% of the energy consumption is used in the buildings for indoor climate, hot water and other appliances, which demands energy in accordance with the buildings usage.

Experience from newly constructed low energy housing has so far shown that the interaction between the user and the technology has not been working properly. Mainly because the users are not taught how to use the technology in the houses correct. As a consequence the houses use more energy than calculated, but also the indoor climate is challenged by overheating during the summer and low temperatures during winter.

The technological challenges are therefore to:

- develop cost- and energy-efficient technology
- mastering the dynamic interaction between consumption and supply
- finally, mastering the interaction between user and the energy consuming technologies – building, installations and equipment.

This project focuses on the last and important part of the challenges which has "intelligent" controlling of the energy services as its focus.

The energy- and user-related advantages of simple or more complex controlling concepts and systems for energy services have been tested and documented during the project. .
This has been done with focus on, that the controlling solution can manage the comfort level in the house as efficient and energy optimized as possible. All the while the users demand and need for information and control, of the comfort level and energy consumption has to be accommodated.

A central part of the project has therefore been the interaction with the users. Different scenarios and processes have been tested in practice. The family has through its daily living tested how the building, the installations and the equipment have been working. What have been good – what have been bad?

The questions have been many, for instance:
How is the building being used, and what is the resulting energy consumption? Can the family master the technical installations to get a good indoor climate? Is intelligent control an advantage – or is it just an annoyance? Which information concerning energy consumption and energy supply is the family interested in? Can we develop a manageable interface to make it simpler and interesting to monitor energy consumption? Can an interactive interface affect the family's behaviour and energy consumption?

For this project there has been developed automatic controlling of the mechanical ventilation, natural ventilation, heating, and sunscreens, so that these subsystems could be connected in random order. With this platform as a starting point, there has been developed 4 control strategies:

a. A **basic control –** A simple control, which the three following controls, is based on.
b. An **indoor optimized control**, which insures that the indoor climate fulfil category I of DS/EN 15251
c. An **energy optimized control** which ensures that the house is managed energy efficient according to the guidelines in Bygningsreglementet 2010
d. A **user-defined control**, which makes the users able to make manually individual changes to ventilation, sunscreens and heating.

The difference between the **basic control** and the more advanced control is the following:

- Dividing the house into zones
  In the more advanced controls, the house has 5 zones instead of just 1 zone.

- Temperature set points (heating and cooling) changes during the day and according to the season. The temperature is registered in each zone, so each zone has the possibility of having different temperature set points and settings for natural ventilation and sunscreens.

- Variation in opening area of automatic windows.
  In the **basic control** it is only possible to open the windows 0 % or 100%. In the advanced controls any opening area is possible.

- Temperature regulation with hysteresis
  The hysteresis (range) prevents the windows, sunscreens and heat pumps from opening/going on and off all the time. The value changes during the day and according to the season.

- Automatic control of the bypass.
  The automatic control can contribute to a better indoor climate, so it does not get too hot, along with an energy saving in transition periods in which the bypass is not yet activated.

- Use of motion detectors to determine if the family is home or not.

The four controlling strategies are fitted to EnergyFlexHouse (EFH) at Danish Technology Institute (DTI) and the strategies were tested by a family living in the house.

For the **user defined control** and for choosing strategies the family was given a tablet, with a related application

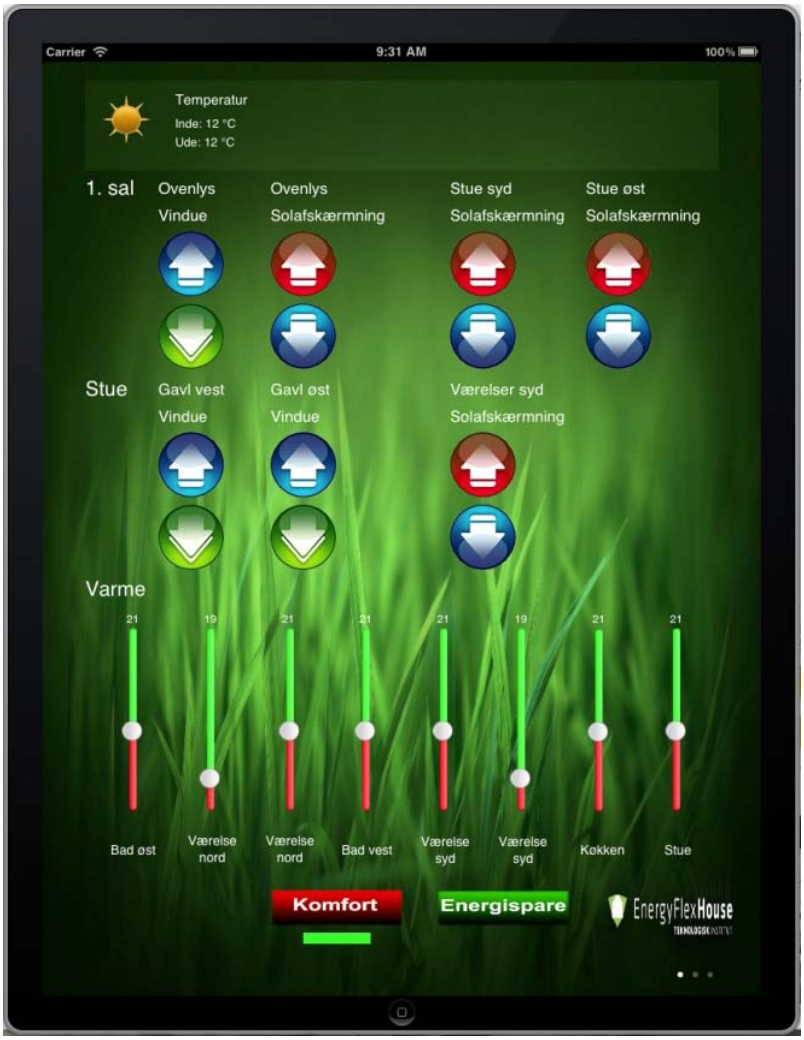

Figure 1 - Tablet for controlling strategies

CONCLUSION

The tests show that it is one thing to design and implement energy optimized solutions and systems and it is an entirely different thing to get the users to use them correctly in their daily living. If the users cannot handle the systems, e.g. because they are too complicated or too time demanding, creative ideas and thoughts behind the energy efficient solutions and systems will not do any good. This also concerns the effect of promoting the awareness of the consequences of the users' actions and subconscious behavioural patterns.

The tests with the 4 controlling strategies in cooperation with the family in EFH, show that it is not possible to develop a satisfying controlling strategy without involving the users. The users will not be satisfied with the indoor climate, if they do not have influence on the controls. This should be taken into context with that energy efficient controlling requires as little user influence as possible, in order to realize the expected energy efficiency.

The optimal control is characterized by its ability to adapt user demands along with resulting in a change in user behaviour adapting to the control.

The project also shows that there is a substantial barrier in getting products from different manufactures to communicate. Problems are partly technical, partly responsibilities related, in that it can be difficult to place the responsibility in any operational problems, manufactures are also hesitant to provide technical specifications.

Based on the concept, which is developed through cooperation between the residents, the involved companies and DTI, a prototype for the advanced controls has been developed and tested by the family living in EnergyFlexHouse.

Experiments with the 3 advanced controlling strategies, "optimized indoor climate", "optimized energy consumption" and "user controlled", have been performed over a period of 4 months.

If you only focus on the potential energy saving on the ventilation, the energy consumption has been reduced by 83 %, comparing a situation of constant mechanical ventilation to a situation with similar outdoor conditions, but with hybrid ventilation, controlled by the developed strategies.

The family expressed general satisfaction with the indoor climate no matter which strategy was chosen.

The family was surprised that their heating consumption was nearly 30% higher using the user controlled strategy and admitted that the energy optimized strategy definitely was acceptable, especially considering the consequences.

The project has shown that it is of great significance for the energy consumption in low energy housing, that the indoor climate is precisely controlled along with demands for the indoor climate is fulfilled. It is also of high importance that the installations are engaged in the right order according to weather conditions. The project shows that, an intelligent controlling, giving the users certain degrees of freedom, has a decisive significance on the energy saving potential in low energy housing.

This has to be seen in perspective of that the significance of the user behaviour, is relatively larger for low energy housing than for conventional construction.

The test family in EnergyFlexHouse has given unique opportunities for mapping the effect of the changes in both systems and products, among others the subjective user evaluations of the physical and controlling actions have given a valuable knowledge on the subject. The fact to include the end user this way – in the real environment on an average day – can ensure that the solutions developed is getting impact on the market and delivering the wanted energy savings.

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