Model Home 2020 project *i*
CarbonLight Homes

"Improving building performance without limiting the occupants"

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Executive Summary
With increased impetus in developing zero carbon building solutions, the one thing that cannot be legislated for is the activities and lifestyles of people.
It is therefore imperative that an holistic view of future building design should include integrated technology that improves performance of buildings whilst balancing lifestyles of occupants and therefore be robust with regards to the 'human factor'.
The VELUX CarbonLight Homes experiment aims to show what can be achieved by using an intelligent building management system (BMS) to provide a balanced and comfortable indoor climate. The project is one of 6 Model Homes completed by VELUX around Europe and challenges issues such as site orientation (it is built east/west), renewable energy (no photovoltaics) and construction methods (using a combination of materials and techniques).

1.0 Introduction

Sustainability, energy efficiency and renewable technology will be major drivers in the future direction of the UK construction industry, which is partly about reducing carbon emissions and dependency on fossil fuels, and partly about developing a workable infrastructure for future low energy building solutions.
However, in the desire to achieve low/zero carbon building solutions the quality of the indoor environment - which has a direct effect on our health and well being - is generally overlooked.
In the EU today, we spend 90% of our time indoors, consuming over 40% of the total energy use. In addition, up to 30% of the building stock does not contribute to, nor provide a healthy indoor climate. Therefore, looking into a future perspective of how we construct and renovate buildings, it is necessary to consider climate change, resource supply and human health whilst ensuring that improvements in building performance do not restrict the activities and lifestyles of occupants.

2.0 The experiment

"You never change things by fighting the existing reality.
To change something, build a new model that makes the existing model obsolete."
Buckminster Fuller – engineer

The philosophy of the UK project, the "CarbonLight Homes" ***ii***, is about using today's technology to create comfortable, sustainable indoor environments that improve the quality of life for the people within.
The homes have already become a benchmark for future housing design in the local area, having highlighted the benefits for families and communities by minimising energy usage and promoting respect for the environment. Ultimately, the homes help generate a sense of community and of responsibility, the concept of which is

applicable to all buildings.
The UK experiment consists of a pair of semi-detached houses (3 & 4 bed) to reflect the typical UK family home.

3.0 Challenging convention

The future of construction is facing serious challenges such as resource supply, energy efficiency and unhealthy buildings to name but three. But the real challenge facing us is twofold – the energy challenge and the liveability challenge. To address this, it is important to look at habits and historical development of sustainable solutions and challenge the methods and perceptions that shape the low carbon building solutions of today.

4.0 Daylight

Daylight has been used for centuries as the primary source of lighting for building interiors and the unique variability in intensity, colour and direction of natural light has a huge influence on both the thermal and visual environments.
It is well known that direct exposure to daylight provides many health, well being and performance benefits and yet the design of daylight into buildings is still not given adequate consideration.
In 2001, it was discovered that there is an additional light receptor in the eye which has raised awareness of the potential positive influence of non-visual elements of daylight such as photobiological effects and circadian rhythms. Consequently, it has been recognised that we not only need ways of measuring light, but assessing the impact of light.

5.0 Sunscreening

Most buildings rely on the reaction of occupants to activate blinds and screens, which quite often results in too much overheating before action is taken, or if the building is vacant, then no solar shading will be in place at critical times. Individual perception of what is comfortable can also affect judgement of the person operating sunscreen devices and cause unwelcome discomfort to others.
By using a BMS to control the sunscreening, this removes the need for occupants to respond to the changing environment and the system can be designed to interpret the occupant's preferences from available data and balance the internal comfort levels accordingly.

6.0 Indoor air quality

Windows not only provide daylight, but also provide fresh air. By strategically placing windows at high level, a stack effect is created to draw fresh air in and force stale air out which helps with cooling and freshening the internal environment to maintain good air quality and thermal comfort. Ventilation also has important psychological aspects, which can be summarized as "creating a link to nature" (the outdoor environment). ***iii***
The natural ventilation in the CarbonLight Homes is controlled not only on the internal temperature, but on the concentration of CO_2 and the relative humidity. In warm periods when the CO_2 exceeds a predefined set point, windows are opened automatically. In cold periods, the natural ventilation strategy is maintained, but with support from a mechanical ventilation system with heat recovery (MVHR) which, between them, continuously adjust the ventilation rate to ensure that the predefined CO_2 concentration level is maintained.

7.0 Thermal comfort

Thermal comfort can be defined as "that condition of mind which expresses satisfaction with the thermal environment" and is influenced by 6 parameters:

1. Air temperature
2. Radiant temperature
3. Relative humidity
4. Air velocity
5. Clothing level
6. Activity level

Thermal comfort is achieved when these 6 parameters are in balance. ***Ix***
The CarbonLight Homes uses the BMS to assist in achieving this balance. We will also be testing an additional setting whereby if the outside temperature goes above 26°C, then the windows will close and the external awning blinds will come down to seal and protect the inside space, whether the homes are occupied or not.
It is important therefore, to design in as much flexibility into the use of the systems as possible and the approach of the CarbonLight Homes was to make every room a separate zone so that the spaces can be adjusted to suit every persons own preference using a full BMS with adequate individual overrides.

8.0 Building Management Systems

Most BMS are designed to respond to the specific needs of spaces (rather than specific needs of occupants), mainly relating to internal temperature and often including humidity and glare. But if a BMS can be designed to balance the way people live, rather than dictate how they live, then this will overcome the need for a 'one size fits all' strategy and will provide ultimate flexibility in the management of the building services. The system should also allow adequate manual overrides, as individual control is important for creating a satisfactory indoor environment.

9.0 Integration

It is important that any services, systems, installations etc, should be adequately integrated to ensure compatibility and functionality within a BMS as well as ease of use by the occupants. Without integration, systems will work independently, will be difficult to understand due to multiple user interfaces, will increase maintenance costs, have no flexibility and no centralised data analysis.
The CarbonLight Homes uses the BMS to control all building services, using the solar thermal collectors as the primary source of heat with an air source heat pump (ASHP) as a supporting measure all year round. The solar thermal and ASHP heat up a thermal store which provides for both domestic hot water and space heating.
The other and equally important aspect of integration is to ensure that the effectiveness of the design with regards to energy efficiency, indoor climate and impact on the environment promotes architectural quality, comfort, health and well being, all of which represent the true value of the building. ***iv***

10.0 Energy performance

The CarbonLight Homes are designed so that use of fossil fuels for energy is reduced to a minimum. Consequently, the decision was taken to be all electric on the basis that it is not possible to de-carbonise natural gas and that gas supplies are a finite and dwindling resource.
In addition to the energy choice, the energy strategy had to ensure compliance with:

- Current and future building regulations
- Code for sustainable homes

- Latest government definition of 'zero carbon'

And this was achieved by:

- 'U' value of 0.11 W/m²°C for all walls, floor and roof.
- Air permeability through the structure of less than 3m³/h.m².
- Triple glazed windows to east elevation for improved thermal protection and double glazed windows to west elevation for improved solar gain.
- High levels of glazing for improved natural daylight.
- Hot water and space heating using solar thermal collectors, ASHP and MVHR
- Natural ventilation strategy all year round with no mechanical cooling.
- LED lighting throughout.
- Automated window operation and blind control to reduce solar gain, prevent glare and reduce internal CO2 levels.

Predicted energy consumption:

Heating - kWh/m2/y	57.60
Hot water - kWh/m2/y	17.00
Installations heat loss - kWh/m2/y	4.28
Fans, pumps, standby and loss electricity - kWh/m2/y	4.08
Electricity demand for Heat Pump - kWh/m2/y	14.60
Lighting - kWh/m2/y	4.45
Household - kWh/m2/y	8.80
SUM - kWh/m2/y	***110.81***

Predicted energy production:

Solar Collectors – total kWh/m2/y	36.80
Heat Pump - kWh/m2/y	50.34
PV - kWh/m2/y	0.00
SUM - kWh/m2/y	***87.14***

11.0 Monitoring

The testing and monitoring of the homes will be part of a VELUX initiative where all six of the Model Home projects around Europe will provide data to the industry.
The monitoring will be split into two sections:

- The quantitative data will be taken from the numerous sensors around the house to measure the performance of the building, but also to measure the performance of the people.
- The qualitative data will be in the form of interviews and questionnaires to find out how the family feel about living in a low carbon home and in some respects to measure how their perceptions change during the course of the monitoring period.

12.0 Learnings so far

What we have learned so far shows that there is a distinct gap between theory and practice. The challenge is to close this gap in order to qualify theory and thereby future practice and to enable ourselves to build houses based on qualified theory that meet the requirements for user well-being.
We have also learned that the success of a sustainable building relies on the people who build it and the people who manage the start-up and optimisation process.

13.0 Summary and conclusion

The importance of daylight and fresh air in the design of new buildings should not be underestimated and the CarbonLight Homes project shows that these elements are critical in supporting the need to provide healthy indoor environments, as well as improving the energy performance and reducing the energy need of buildings.
'Health' is defined by the World Health Organisation as being a state of complete physical, mental and social well being and not merely the absence of disease and infirmity ***v***.
VELUX Company Ltd commissioned a report in 2010 which concluded that the current approach to housing design overlooks elements that are central to promoting well being. These include sunlight (daylight), natural ventilation and radiant heating.***vi***
Building Management Systems can play a crucial part in achieving this balance between energy efficiency, livability and good health and ensures that an individual's perception of what is a healthy environment is not detrimental to other users of the building and indeed to themselves.
By developing a BMS that can automatically adjust parameters to suit the differing lifestyle of families and building users, this substantially reduces the problems associated with the 'one size fits all' approach and will not only support the lifestyles of occupants, but will enhance the performance of the building and make it an altogether more attractive place to live and work.

14.0 References

i *VELUX Model Home 2020 project, viewed 07 November 2012: http://www.velux.com/Sustainable_living/Model_Home_2020*

ii *VELUX GB, CarbonLight Homes project, viewed 07 November 2012: http://www.velux.co.uk/aboutvelux/modelhome2020/carbonlighthomes*

iii *VELUX, Daylight, Energy and Indoor Climate basic Book, 2010*

iv *Active House principles, viewed 06 November 2012: http://activehouse.info/*

v *World Health Organisation, Healthy workplaces: a model for action, 2010*

vi *Hobday R, Designing Houses for Health – A Review, 2010*