Energy neutral house – the Danish House+ concept

Poul Erik Pedersen, Project Manager
The Danish Electricity Saving Trust
Denmark
pepe@elsparefonden.dk

Keywords

energy-neutral, House+, intelligent home, user-friendly, zero-emission house

Abstract

An international project contest is running from February 2009 until June 2009. 44 innovative teams expressed an interest in the pre-qualification to participate in the project contest. In January 2009, 5 teams were selected to participate in the project contest.

The project contest nominates the best conceptual House+ project. The House+ concept (called Bolig+ in Danish) is developed in cooperation with many different parties in the building sector. The House+ is an attractive house – beautiful, functional and inspiring. The House+ is very energy efficient and it is energy neutral (year-to-year), which means that it produces the same amount of energy as it consumes.

The House+ dogmas[1] are:

- energy neutral on an annual basis (Low energy class 1 - min. 50% better than the demand in the Danish Building Regulations (BR), 2008)
- intelligent and user-friendly
- flexible – in use and over time
- pleasant and healthy indoor climate
- adaptable to local surroundings.

An international contest (project contest) is running during spring 2009. A jury will evaluate the proposals according to the House+ dogmas. The winning House+ projects (category: Block of flats – other categories expected to follow) will be published as "freeware" on the Internet.

The project competition process has included team-formation workshops, team pre-qualification and special team-member workshops to ensure innovative use of well-known technology solutions.

The winning project will be built in 2010-2011 in Aalborg, Jutland of a high quality, technically, functionally, aesthetically and environmentally.

A comprehensive programme for measuring and evaluating the indoor climate and the energy consumption will be implemented in the flats. Measurements will be performed with measuring devices communicating through an open and wireless standard, which means that installation of sensors and data collection will be very simple and affordable. The measuring and evaluation results from the House+ buildings will be promoted widely and the public will be invited to visit the houses.

The Residential House+ initiative is expected to highlight the next generation of residential houses.

Results will be published as freeware on the Internet.

Introduction and background

The need for a stable energy supply in the EU, CO_2 reduction efforts and the global climate challenge have been implemented in EU-directives, climate strategies, national action plans for the energy sector, and parallel initiatives for reduction of energy consumption and greenhouse gases. Energy efficiency in

1. House + dogmas is the title of the original project. The word 'dogma' is used here to denote a set of incontrovertible principles which were laid down at the start of the project.

Figure 1. House+ logo in Danish.

Figure 2. Architecture and energy. The Danish Building Research Institute (2006)

building is in focus both at a national level, at an EU level and at a global level. Lately the proposal by the EU Commission for a strategy for climate and energy politics has set a target including a 20% reduction of energy consumption in 2020. A major part of this reduction will be realised through energy efficiency in buildings.

In respect of new buildings, major improvements have been made in national building regulations, and a number of initiatives, such as low energy buildings ("Passiv Haus") and energy neutral buildings influence the development year by year.

The development of new buildings is important for two reasons: firstly, the development is both a cultural and technical challenge; secondly, the targets, results and experiences from new buildings are used in action plans and policies for energy efficiency in existing buildings.

The energy neutrality in House+ should be viewed in this context.

The Residential House+ concept is developed in cooperation with many different parties in the building sector in Denmark. The concept development started at an Energy Camp including representatives from many relevant parties and the process – defining the content and details – took place in 2006. The House+ dogmas are (Bolig+, 2009):

- energy neutral on an annual basis (Low energy class 1 – min. 50% better than the requirement in the Danish Building Regulations (BR), 2008)
- intelligent and user-friendly
- flexible – in use and over time
- pleasant and healthy indoor climate
- adaptable to local surroundings

It is very important that a House+ is both an attractive house – beautiful, functional and inspiring – and very energy efficient. The House+ is energy neutral (on an annual basis), which means that it produces the same amount of energy as it consumes. Furthermore it is Low energy class 1 – i.e. min. 50% better than the minimum requirements in the DK building regulations 2008 (Note: Based on calculations without adding the energy-production from the house itself, e.g. electricity from solar cells etc.).

Overall general demands for House+ project

The House+ concept includes the five dogmas implemented in an architectural, functional and comprehensive design fitting into the local context, in keeping with local infrastructure, climate, geology, topography and ecology. At the same time the concept includes five overall demands:

- Building of high architectural quality, including design, function and materials
- Realistic and sturdy designs and solutions based on current practice
- A reasonable total-economy including implementation, operation and decommissioning
- Operational reliability and long life for systems, installations and constructions
- Simple and well-arranged interplay/symbiosis between constructions and installations (and end-user) thereby minimising the energy consumption.

The House+ dogmas

DOGMA 1: ENERGY NEUTRAL

Annually, an energy neutral building does not use more energy from the outside than it returns. The returned energy has to be of the same, or of a higher quality than the energy that is used (e.g. electricity supplied to the grid as compensation for purchased heat) and it should also have at least the same relevance (the building can not receive heat during winter and return it during summer).

In accordance with the Danish Energy Regulations and matching calculations, electricity is as a principle regarded to be 2½ times more valuable than other types of energy consumed or produced in the building.

Figure 3. Arkitema (2006), The Ecological Council.

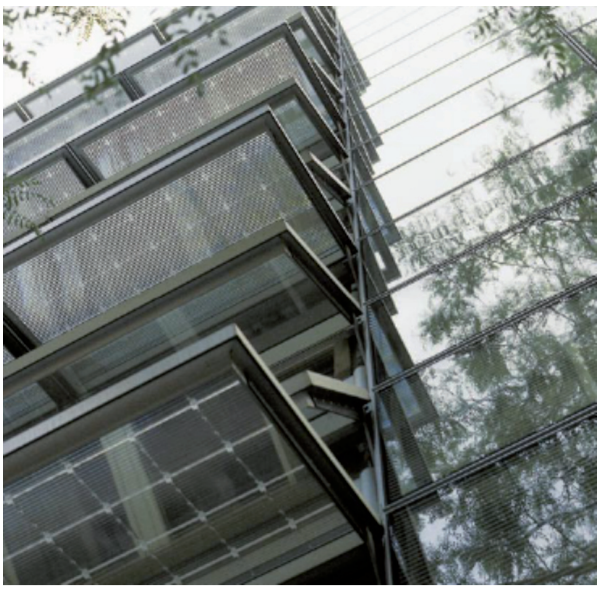

Figure 4. Architecture and energy. Rie Øhlenschlæger (2006)

Electricity produced using smaller PV-systems (< 6 kW) can be delivered to the electricity network in Denmark, at the same price as the received electricity. If the "exported" production exceeds the "imported" electricity the difference has unfortunately no value. For larger PV-systems/plants a special agreement will be developed between the PV-owner and the energy company.

Energy neutrality can be assured through the design of the building, constructions and installations, including the utilisation of solar energy. The requirement in regard to energy neutrality includes that each building must fulfil the energy framework for low energy buildings, class 1, as determined by the calculation program Be06, however not including possible electricity production in connection with the building, e.g. from solar cells.

Energy neutrality can apply to:

Buildings without a common local energy system:
The individual buildings observe the definition of energy neutrality. The individual buildings observe the upper limits for low energy class 1 buildings.

Buildings with common local energy system:
The buildings including common energy systems observe the definition of energy neutrality. The individual buildings observe the upper limit for low energy class 1 buildings.

Energy neutrality is documented via Be06 and the House+ toolkit by compiling an energy balance that month to month in a normal year shows:

- The monthly energy consumption divided into space heating, DHW and electricity.
- Energy received from the outside: from the local grid (electricity, district heating or gas) or as oil or biomass (e.g. wood, biofuels or biomass pellets).
- Energy that is returned to the local grid.

DOGMA 2: INTELLIGENT AND USER-FRIENDLY
A House+ dwelling is equipped with systems that via control, measurements and demand management contribute to both energy neutrality and to increasing the utility value of the dwelling.

For example, electric lighting only needs to be on when natural daylight is insufficient and when users are present. The same conditions apply to a number of other "energy services" – heat and indoor climate and electricity consuming equipment, e.g. PCs, TVs, radios etc.

In addition, a number of services interact – e.g. by switching off/limiting unnecessary artificial light combined with optimum use of solar shading it is possible to reduce the need for ventilation and at the same time obtain an improved indoor climate by avoiding excess heating. Optimised, intelligent use of the services can give reduced energy consumption and an improved indoor climate.

Simple and continuous feedback about energy consumption and energy production to the users of the individual dwellings combined with control via an interactive user interface can contribute to: improved user patterns, more appropriate control of heating and ventilation systems, and improved use of flexible components in the thermal envelope. In short – improved interplay between buildings, installations and users.

In addition to energy related functions the systems can fulfil other objectives such as local control, entertainment and communication.

When the conditions in relation to energy tariffs and control of electricity consumption in the long term are in place, the systems can be equipped with an "Energy trader" that to a certain extent is able to control the electricity consumption and sale according to fluctuating electricity prices. The "Energy trader" offers a possible financial advantage and can also be an asset in connection with the visualisation of energy users. The system can form part of intelligent control and monitoring of a dwelling, however, in principle this is not necessary in order to obtain energy neutrality as it does not by itself result in reduced energy consumption.

Well-documented combinations of known solutions are important. As far as possible the systems have to utilise open standards (plug-and–play compatible) with expansion possibilities and wireless communication preferred.

It will be possible to upload the collected data to the server of the Danish Electricity Saving Trust (The Danish Electricity Saving Trust, 2008).

DOGMA 3: FLEXIBLE – IN USE AND OVER TIME

This includes flexibility of use, flexibility in terms of renovation and flexibility for adapting to different climatic conditions during the year.

The House+ should be the physical framework relating to the possibilities afforded to various family structures – e.g. the traditional family, etc. Flexibility means that the house can be adjusted to new conditions, e.g. the number of occupants, young families, families with grown-up children, the elderly and less mobile, etc.

The flexible climatic shield can be replaced in line with wear and tear and due to the fact that new technology provides new opportunities for more energy-optimised solutions. All components with a lifetime shorter than the building itself are easily replaceable in a House+. The basic constructions in a House+ have a long lifetime and are made from sturdy materials.

The climatic shield in a House+ is dynamic and varies during the year. The design of a flexible climatic shield is very closely linked to decisions regarding energy consumption, utilisation of the house and habits of the occupants.

The agents can be dynamic facades, windows with shutters, sunshades, double-facades, flexible utilisation of the rooms, replaceable components of the building, flexibility in utilisation of the installations (electricity, heating, water supply etc.).

DOGMA 4: PLEASANT AND HEALTHY INDOOR CLIMATE

This includes: Indoor air quality, daylight quality, thermal conditions and noise.

Building materials must not liberate gases, solid polluting particles or ionising radiation, which can result in an unsatisfactory and unhealthy indoor climate conditions. Indoor air humidity has to be kept at a reasonable level. The daylight conditions in a House+ need to assure good and sufficient natural light during most of the daylight hours. Draughts etc. should not occur, and uncomfortable temperatures should be avoided. Noise intrusion from external sources and internal noise are minimised in a House+.

DOGMA 5: ADAPTABLE TO LOCAL SURROUNDINGS

A House+ is tailored to local conditions, e.g. public and private energy supply, local drainage, etc., sun and wind conditions, noise, air quality, surroundings and scenery. A House+ is low energy class 1 and has no compulsory energy supply.

A House+ building is situated, designed and shaped so that the local microclimatic conditions at the house are optimised. The daily experiences both inside and outside the house are very important.

Proof of energy neutrality

The proof of the performance of the buildings and installations (including renewable energy) is provided through input data and calculation results using the official and latest version of the Danish calculation tool Be06, while the proof of fulfilling the overall requirements for energy neutrality is provided using the House+ toolkit. Be06 is the official Danish tool for proving that a new building meets the requirements in the Danish Building Regulations (hereinafter BR) in terms of energy performance. Compliance with BR requirements is a necessity to obtain a building permit. Be06 also calculates compliance with the two low-energy classes defined in BR.

The House+ toolkit is an Excel tool used for verifying and calculating the energy neutrality of a building, month by month and on a yearly basis.

Energy neutrality can be achieved through low energy class 1 buildings including thermal solar energy and photo-voltaics, glasshouses, flexible components (shutters, seasonal insulation, etc.), and temperature zoning.

LOW ENERGY CLASS 1

The total energy consumed when providing heating, ventilation, cooling (real and virtual), and domestic hot water in a low energy buildings is defined in BR95 (addendum 12) and BR-S 98 (addendum 9). The total energy consumption in a low energy class 1 building must not exceed:

$$35 + \frac{1100}{A} \quad kWh/m^2 \ per\ year$$

where A is the heated gross floor area of the building.

Each House+ building must meet the low energy class 1 requirement without production of electricity.

OVER-HEATING PENALTY

If the indoor temperature is calculated (per Be06) as exceeding 26°C, an over-heating penalty will be calculated as the amount of electricity needed to remove the excess heat by a mechanical cooling system having a COP of 2. The electricity consumption for this virtual cooling system is, as all other consumption of electricity, multiplied by factor 2.5 before it is added to the calculated total energy consumption.

VENTILATION

Ventilation is one element where House+ deviates from the minimum requirements laid down in BR. In House+ it will be permissible to use ventilation according to requirement as long as the indoor air quality and the moisture content are monitored and shown to be of sufficient quality, thereby presenting no health risks or encouraging reduced indoor air quality in terms of odours or mould accumulations.

Ventilation as required by BR will often require zoning of the ventilation system to ensure the greatest possible efficiency, although this may have some impact on the layout of the ventilation system.

AIR TIGHTNESS

The minimum requirement in BR is that the building does not have an uncontrolled air change of more than 1.5 litres per m² heated gross area at a pressure difference of 50 Pascal.

The actual building will be subject to a blower door test when it is finished to prove its air tightness. Both over- and under-pressure situations will be tested. The air tightness demand must be fulfilled by the mean value for the two tests.

DOMESTIC HOT WATER

Domestic hot water (DHW) is included in the total energy consumption of the building.

The total DHW consumption must be in the range from 15 to 60 m³ per dwelling per year. The consumption of domestic hot water is determined to be 45 litres per person per day. This equates to approximately 3500 kWh/year for a family of four persons.

USE OF ELECTRICITY – LIGHTING AND APPLIANCES

The electricity consumption for each house/flat is limited to:

520 kWh (basic consumption) +
335 kWh/person + 1.6 kWh/m²

This equals approximately 2100 kWh/year for a one family House+ of 150 m² with a family of four.

This relatively low consumption is obtained through (existing) energy efficient equipment combined with reasonable end-user patterns. The 2100 kWh covers: washing, dishwashing, combined refrigerator and freezer, cooking, light, IT, multimedia, TV and recording, and various smaller appliances.

For flats the limit for electricity consumption is set to 1700 kWh/year.

International project contest

An international contest (project contest) is running during spring 2009.

44 innovative teams expressed an interest in the pre-qualification to participate in the project competition. In January 2009, 5 teams were selected to participate in the project contest.

A jury will evaluate the proposals according to the House+ dogmas.

The project competition process has included team-formation workshops, team pre-qualification and special team-member workshops to ensure innovative use of well-known technology solutions.

The winning House+ projects (category: Block of flats – other categories expected to follow) will be published as "freeware" on the Internet.

The winning project will be built in 2010-2011 in Aalborg, Jutland of a high quality, technically, functionally, aesthetically and environmentally.

A comprehensive programme for measuring and evaluating the indoor climate and the energy consumption will be implemented in the flats.

Measurements will be performed with measuring devices communicating through an open and wireless standard, which means that installation of sensors and data collection will be very simple and affordable.

The measuring and evaluation results from the House+ buildings will be promoted widely and the public will be invited to visit the houses.

The Residential House+ initiative is expected to highlight the next generation of residential houses.

References

Bolig+ (2009): *Visionen om den energineutrale bolig*. www.boligplus.org (first accessed 13.01.2009).

The Danish Electricity Saving Trust (2008): *Min Bolig*. www.elsparefonden.dk/minbolig (first accessed 13.01.2009)

Acknowledgements:

Many warm thanks to the whole House+ group consisting of representatives from many different groups in the building sector in Denmark.