SE's new Passive- and Plus Energy HQ and the Certification Process

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Abstract

This paper describes the overall design ideas, installation and energy consumption of the Plus Energy HQ for SE (Syd Energi) in Esbjerg. It also pays special attention to certification related issues and the quality control that accompanies the certification of a large Passive House office building.

The design aims to meet the ambitious goals for this 11.000 m2 (heated floor area) office building: The building should fulfill the International Passive House criteria and be a Plus Energy House. The "plus" energy balance includes the energy requirement for the building operation during a year. The energy for operation of the plug loads (computers, printers, etc.) as well as servers is not included in the balance. To reach the positive energy balance, approximately 1,950 m² PV cells are mounted on the roof.

The design is heavily influenced by the Integrated Energy Design (IED) process, where design premises and energy goals were identified from the very start, and the design team (contractor, architect and engineer) has collaborated intensely from the earliest stages of the project.

The goal was to create a building which in itself is a crucial parameter in not only lowering the building's overall energy demand, but interact optimally with the building systems to move the energy consumption from peak periods to off-peak periods. Key features are the use of Thermally Active Building Systems (TABS), large buffers installed in the heating and domestic hot water system and an innovative heating- and cooling plant.

The building's large server room is also cooled by an innovative cooling system allowing the supply temperature of the chilled water to be as high as 18 °C. The return temperature (28 °C) is high enough to be directly transferred to the fluid in the concrete slab, to be used for space heating. The heating and cooling demand of the building, as well as the cooling demand of the server, is covered by an innovative chiller system, custom designed to make the most effective use of free cooling, geothermal heating and cooling and heat recovery from the server room.

The Passive House certification process has provided External Quality Assurance to the energy calculations and the quality on site. Due to the scale of the project, the process of submitting necessary studies and documentation needed to be systemized and an official record of the communication had to be generated. The certification process was divided into a number of intermediate checks to improve risk management and ensure a secure basis for the planned performance targets.

Keywords:

Passive House
Plus Energy House
Integrated Energy Design (IED)
Passive House Certification
Thermal Active Building System (TABS)
Concrete Core Activation (CCA)
Server room
Hot Aisle Containment System (HACS)

SE's New HQ

SE is Denmark's third largest supplier of electricity created by merger in April 2006 as a regional energy company. It covers an area over 7,000 km2 from the river Skjern in the north to the Danish / German border in the south and serves approx. 256,000 households in the region. Besides the core business of producing, distributing and trading in energy, the business includes communication (internet, TV) and climate and energy consulting. The company's vision is to create a more sustainable community by supporting the conversion to a greener energy system and by an aggressive roll-out of digital infrastructure. As a part of this, the company wants to lead the way as a role model by strengthening its own sustainability with a new HQ. The new HQ must be visible and innovative in relation to take responsibility for the development of the energy sector.

In June 2011, after a competition with 5 teams, SE chose Hoffmann A/S (the Danish branch of Veidekke AS) together with its partners GPP Architects, Esbensen Consulting Engineers (energy and installations), Sloth Møller Consulting Engineers (structural) and Thing and Wainø (landscape) for the construction of the new HQ in Esbjerg. SE's assessment highlighted that "A beautiful architecture and a pioneering mix of energy solutions was given high priority in the selection of this competitive proposals".

The new HQ will be a landmark with its organic shape and special scenic location. At the same time it will be a beacon for low-energy buildings and the use of alternative energy sources.

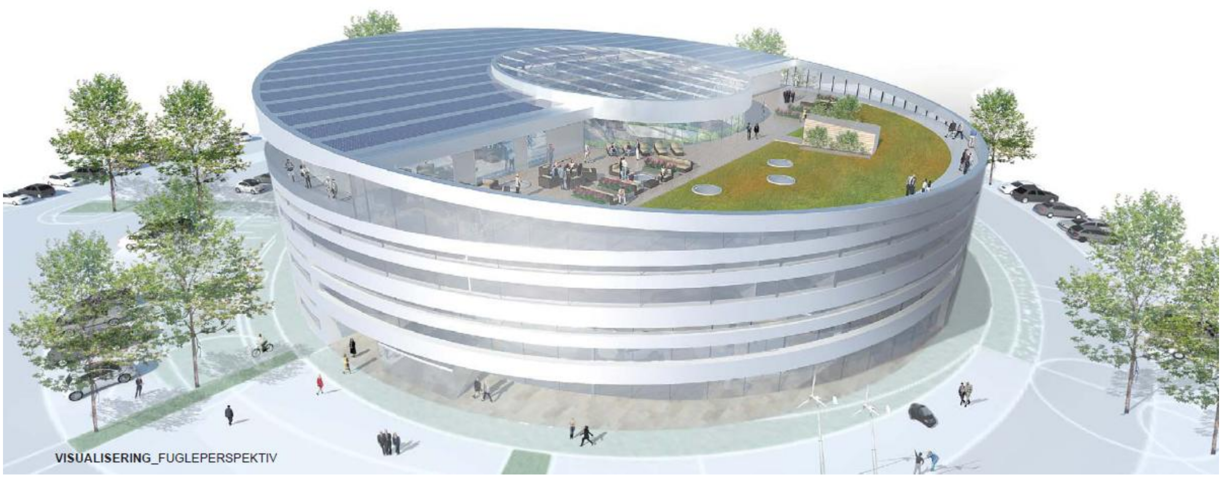

Figure 1: SE's new HQ in Esbjerg, Denmark

One of the design team's particular goals was that the new HQ should address the issues of balancing supply and demand found in any modern electricity system. This is the case for especially Denmark that generates the equivalent of about 19% of its electricity demand with wind turbines. On large scale Denmark manages to keep the electricity systems balanced due to having the benefit of its particular neighbors and their electricity mix. Norway and Sweden effectively act as Denmark's "electricity storage batteries". Norwegian and Swedish hydropower can rapidly be turned up and down and Norway's lakes effectively "store" some portion of Danish wind power [01].

The goal was to create a building which in itself is a crucial parameter in not only lowering the building's overall energy demand, but interact optimally with the building systems to move the energy consumption from peak periods to off-peak periods. Key features being the use of Thermally Active Building Systems (TABS), large buffers installed in the heating and domestic hot water system and an innovative heating- and cooling plant.

The building shall be certified as Passive House and, after the installation of approximately 1,950 m² PV cells, become the largest Plus Energy House in Denmark. The "plus" energy balance includes the energy requirement for the building operation during a year. The energy for operation of the plug loads (computers, printers, etc.) as well as servers are not included in the balance.

Design Process

For the new HQ the design team aimed to create a building where the proposed energy solutions to the greatest possible extent were integrated in the building's overall architectural expression, both externally and internally, and where the design contributes to presenting a business where the focus is on minimizing energy consumption.

To reach this goal the design team applied Integrated Energy Design (IED) as method and process from the earliest stages of the competition. To use IED effectively, following activities were included in the design process [02]:

- Select a multi-disciplinary design team from day one, who are skilled in energy/environmental issues and are motivated for close cooperation and openness.
- Analyze the boundary conditions of the project and the client's needs and demands and formulate a set of specific goals for the project.
- Arrange a kick-off workshop to make sure that all team members have a common understanding of the design task.
- Facilitate close cooperation between the architect, engineers and relevant experts
- Make a Quality Assurance Programme and a Quality Control Plan to follow-ups throughout the project.
- Motivate and educate construction workers and apply appropriate quality tests.
- Make a user manual for operation and maintenance of the building.

The right design premises and goals were identified early within the competition. The team tried to make use of all the passive qualities of the building deriving from the architectural choices in order to create the best possible indoor climate using only the building itself. To do so, design sketches of shapes, volumes, orientations and facade designs were analyzed and simulated with respect to energy consumption, thermal comfort and daylight availability. Hereafter the building was completed by adding installations at a minimum extent, so the building is only supplied with the necessary lighting, air conditioning, heating and cooling.

The ambitious goals for the project combined with a very tight time schedule required collaboration within the design team to be optimal during the entire project. A joint project office “Fælles tegnestue” was established at Hoffmann in Aarhus. During the design phase the project office was permanently manned by ten persons; two project managers from Hoffman, three architects and five engineers. Additional 6 work places were available for specialists and subcontractors called in as needed. Subcontractors for the technical installation were also selected early in the design stage to strengthen the design team further and to minimize changes late in the main design stage.

As with all projects, a Quality Assurance Programme is set up by Hoffmann for the design and build phase. However in the case of a Passive House certification, the project is subjected to an external independent control, checking that the building project would meet the passive house criteria, performed by Passivhus.dk (contracted by the building owner).

By using the methods from IED it was possible for the contractor, architect and engineer to cooperate on the building design, so decisions regarding architecture and technical installations were made in a systematic process. The final result is a better indoor climate, fewer visible installations, a lower energy consumption, sensible running costs and not least a better cooperation in the design team.

Unique features of the building

Daylight vs. Overheating

As part of the high standards for indoor environment, SE required that all workplaces in the new HQ would have a local daylight factor of at least 2% (not merely an average of 2% in the entire room). The high daylight factor will, besides providing increased visual comfort, significantly reduce the energy requirement for artificial lighting, but simultaneously increase the risk of overheating.

As the building is located close to the sea in an area with high wind speeds, it was evaluated that only fixed external solar shading would be an option (not controllable). As this would reduce the daylight levels within the room, the choice was made to use internal solar shading despite the reduced shading efficiency – being mainly a glare protection.

Due to the use of internal solar shading combined with a highly insulated and tight building, the facade design was crucial, with respect to glazing area and placement, to maintain an optimal thermal and visual indoor climate while minimizing heat loss and excessive solar gains. Daylight and thermal simulations have been used to optimize the design resulting in a band of high placed windows to provide natural light deep into the rooms, while a lower band provides the view. The lowered (open) ceiling is “pulled back” to be able to increase the height of the upper window band, and the façade thickness between the lower and upper window was minimized to maximize daylight penetration deep into the room. Glazing has been chosen to satisfy the daylight requirements, while having a very low U- and g-value (LT: 62%, g: 0,34, U: 0,50).

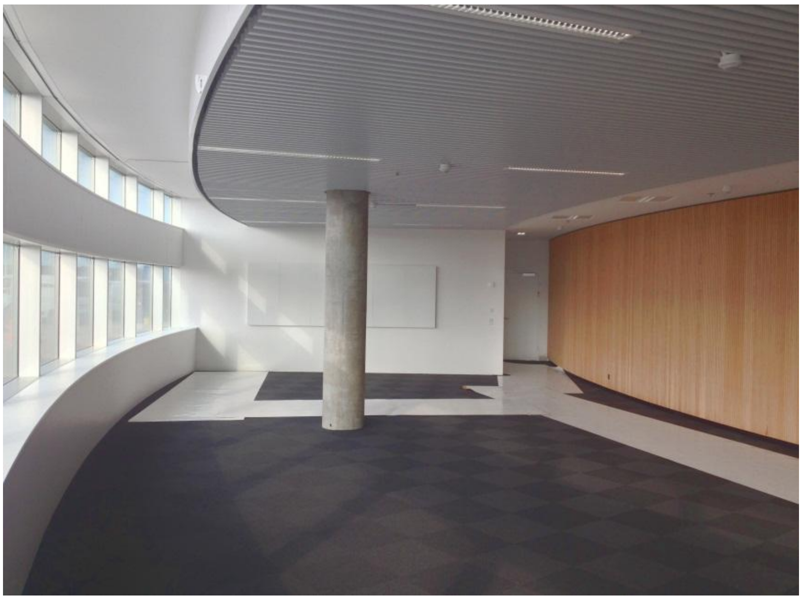

Figure 2: Optimized daylight levels due to high placed windows

Thermally Active Building System

A key element in lowering and moving energy consumption from peak periods to off-peak periods is the use of a Thermally Active Building System (TABS). The mass of the building slab provides "inertia" against temperature fluctuations, effectively "flatting out" temperature fluctuations throughout the day caused by internal and external heat loads. This self-regulating effect of thermal mass is further increased by cooling or heating the concrete slab through an integrated piping system within the slab. Water is pumped through these pipes and heat and cold emission take place through the ceiling. In this way a space is continuously heated up or cooled down.

Being a Passive House, the new HQ is by definition well insulated with only a limited capacity needed for heating up and cooling down. As a result of this and because of the large heating/cooling surface of the concrete slab, the temperature difference between the air in the room and the surface of the ceiling only needs to be small in order to meet the real heating or cooling need.

The entire building consists of approximately 280 thermally active prefabricated elements. The TABS are grouped in 3 main-zones based on orientation and internal heat loads. The supply water temperature of each these 3 zones is shifted individually based on local weather predictions as well as measurements of the past days. The water temperature will normally be controlled between 16ºC and 26ºC. In between shifting from heating to cooling and vice-versa a dead-zone is implemented. The TABS in each main-zone are furthermore grouped per room/zone. Each room is fitted with temperature sensors and on/off valves providing individual setpoint control for each space. Since TABS react slowly, only day-to-day room temperature compensation is promising - an instant correction cannot be achieved with TABS.

Figure 3: Thermally Active Airdeck elements at SE HQ.

Server room

According to the estimates of the building programme the servers would consume 1.231.000 kWh/a (140 kW average, 200 kW peak), or 4-5 times as much primary energy as the operation of the rest of the building. This had to be addressed before anything else.

A task force was formed including key personnel from the IT-department, SE’s director in response of the building project and external specialists on energy efficiency and IT.

It was found that the assumed 1.231.000 kWh/a was based on rough extrapolations to number of server racks. In order to make more relevant estimates, it was necessary for SE to agree internally, what should be the capabilities for extension.

Measure the immediate consumption

The existing server rooms’ electricity consumption was measured twice. It revealed an average power uptake of 28 kW (May 13 to May 17 2011) for the whole server room with an average of 400 W per physical server and very small daily and weekly variation.

The little variation and the high minimum power meant that the number of physical servers had to be reduced as much as possible.

The general electricity meters for the server room also revealed that the average electricity consumption from 2006 to 2011 had been 27,5 kW or practically the same as measured in May. This is contrary to the common assumption that the electricity consumption would be ever increasing.

Virtualization and concentrating IT-load

SE was already running a number of servers “virtually”, meaning that they run within a “shell”, a program on a physical machine. It was decided to make as many servers as possible run this way.

The virtual servers are running on a set of servers, not just on one machine. The usual setup is to have all servers running and distribute the IT-load evenly.

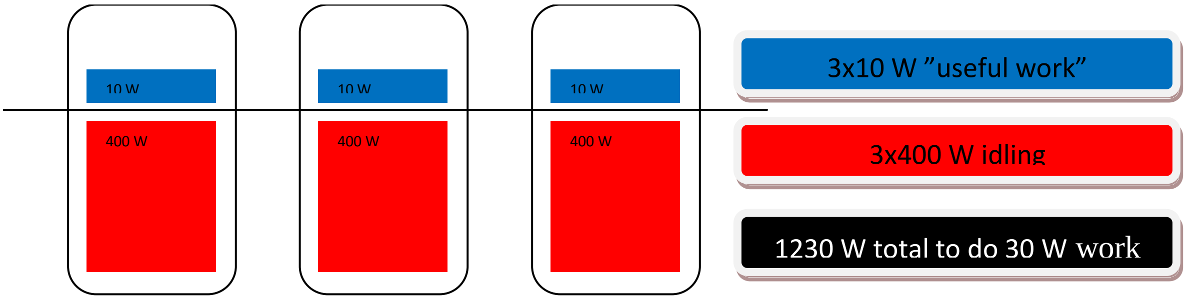

Figure 4: IT load distributed

It was decided to configure the system to allow a maximum load of 80% on each physical machine and set the rest of the physical servers stand-by automatically.

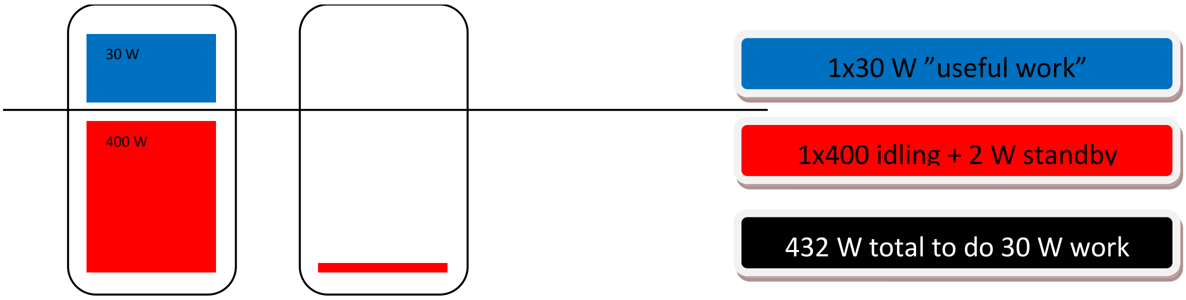

Figure 5: IT load concentrated on fewer physical machines

It was decided to keep a few applications running on dedicated physical servers. Still the combination of virtualization and concentrating the IT load on fewer machines was estimated to reduce the power uptake from 28 kW to 13-20 kW saving 150-250.000 DKK/a.

Guideline for energy efficient equipment

Finally the IT-department wrote an internal policy on buying only energy-efficient equipment.

New Design criteria

During the design phase, it was decided by the client to design the cooling of the server room to 41 kW of heat load in order to accommodate for 16 kW extra physical machines and other equipment from the start of the operation, which should be possible to increase to 85 kW. The actual load during start of the operation turned out to be approximately 60 kW.

The design criteria furthermore stated that the cooling system for the server room should be as energy efficient as possible, with references to the energy efficient data centres of Google and Facebook.

Innovative cooling system with optimized heat recovery

With these ambitious goals set for the server room, the engineers within the design team were given an extra challenge – at a stage where most of the design already had been finalized.

The server room needed to be located in the basement of the HQ. This meant that "direct free cooling" could not be adopted, as it would require a significant supply of fresh air for the server room, with no space for additional air handling units.

It was found that the most energy efficient solution would be to use "indirect free cooling" with over-dimensioned cooling units allowing for a much higher water supply temperature. The system was finally designed and tested with a water supply temperature of 18ºC allowing for a much greater use of "free cooling" compared to a conventional system with supply temperatures of 10ºC .

To increase the efficiency of heat recovery a Hot Aisle Containment System (HACS) has been applied within the server room. The efficiency of the HACS is higher compared to Cold Aisle configurations because the hot aisle is capable of maintaining higher temperatures. According to Niemann [03] the temperature in a typical hot aisle environment can be maintained at approximately 38ºC. The net effect of this elevated return temperature to the cooling unit enables better heat exchange across the cooling coil, better utilization of the cooling equipment, and overall higher efficiency. [03].

Due to the HACS's layout and overdimensioned cooling units, the water return temperature of the system is designed and tested at 28ºC providing the possibility of highly efficient heat recovery.

Low Carbon Heating and Cooling System

The heating- and cooling plant is an integral part of the design aimed to move the energy consumption from peak periods to off-peak periods. The system is fitted with two 4.000 liter buffers for heating and domestic hot water (DHW), allowing a major part of the heat to be produced during off-peak hours. The TABS however are by far the biggest energy buffer and with their slow reaction ideally suited to be heated or cooled during off-peak hours.

To minimize the energy consumption of the heating- and cooling plant it is designed to make the most efficient use of free cooling, geothermal heating/cooling and heat recovery from the server room.

Summer:

Both the innovative design of the server room cooling system as well as the use of TABS allow for the use of a high temperature cooling system with chilled water supply temperatures as high as 18ºC. The high supply temperature and that the cooling is produced mainly during night hours, allow a very high percentage of the total cooling demand to be provided by free-cooling (using dry-coolers). The dry-coolers are overdimensioned to allow them to be used with outside temperatures as high as 16ºC.

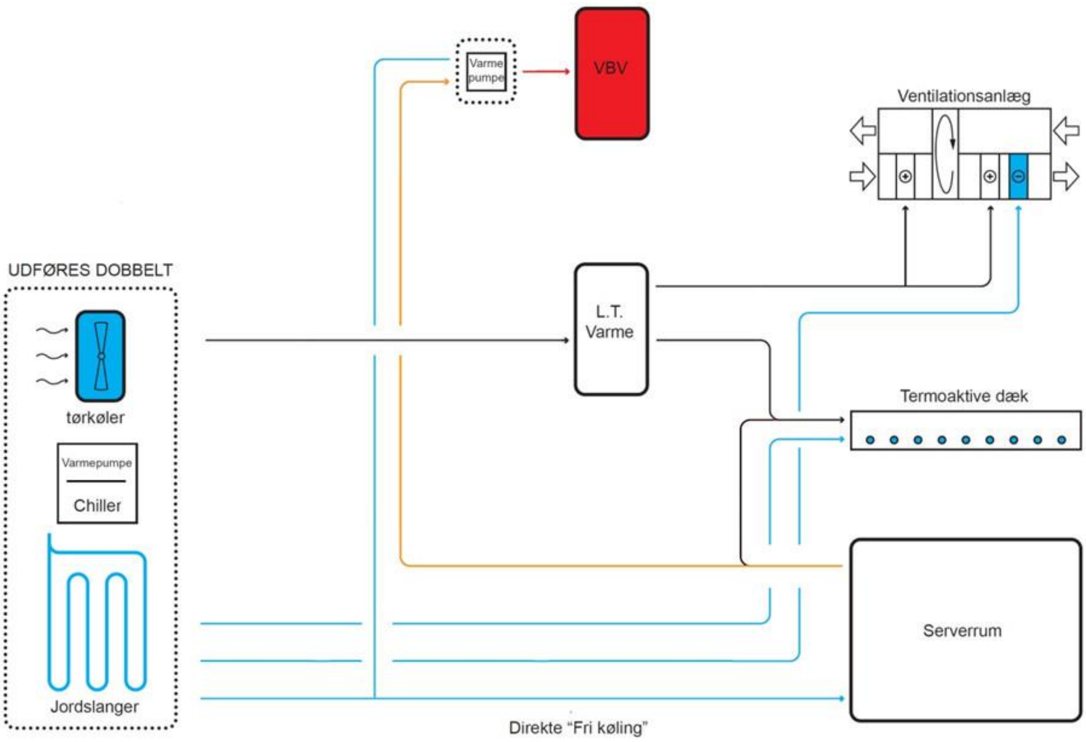

Figure 6: Heating- and cooling plant during summer operation.

When the outside temperature is higher, the system will circulate the chilled water through a 10.000m geothermal piping array, using geothermal cooling. First after the geothermal cooling system no longer can meet the demand, the actual chillers will be used. This is expected to be only a few days annually.

During summer waste heat from the server room is used to produce domestic hot water using a dedicated heat pump. Due to the 4.000 litre DHW buffer this heat pump can run at a low effect, continuously recovering heat from the server room. Due to the high return temperature from the server room this heat pump has a very high COP when producing DHW.

Winter

During winter waste heat from the server room is the primary heat source, backed with the 10.000m geothermal piping array (ground source heat pump). During winter waste heat from the server room is used with following priority:

1. Direct heating of the TABS
2. Domestic Hot Water production via dedicated heat pump

3. Heat source for the heating plant instead of the geothermal piping array.

Due to the high return temperature of the “chilled” water from the server room (28ºC), heat can be transferred directly (via heat exchanger) to supply the TABS with a water temperature of 26ºC.

Hereafter the return water from the server room can be used for DHW production and finally as heat source for the Heat Pumps (Chillers). Also the heating system is fitted with a 4.000 litre buffer to make it possible to use waste heat from the server room as efficient as possible.

After having drawn as much heat possible from the server room, the return water is cooled using 100% free-cooling and circulated back to the server room.

Ventilation

The office areas are ventilated using a demand controlled mechanical ventilation system with heat recovery. Displacement ventilation is used to maximize ventilation efficiency of the system. The atrium is ventilated using a hybrid ventilation system (mechanical ventilation with heat recovery during winter and natural ventilation during summer).

Passive House Certification

The building owner, SE, decided to apply for a Passive House certification in order to have an independent control whether the building would meet the passive house criteria.

To avoid confusion it should be made clear that the authors refer to the internal passive house criteria and certification scheme led by Passivhaus Institut, Darmstadt, Germany.

The focus areas of the Passive House certification are quality in design and construction, energy consumption and indoor climate. These issues are at the same time the most important things to the building owner in terms of costs (quality and indoor climate) and environmental impact (energy consumption in operation being the largest single contributor).

The certification process has a stringent structure:

1. Offer and eventually contract
2. Audit of energy calculation (PHPP) and building design documentation
3. Spot checks on the building site, typically three visits
4. Control of documents from the building process
5. Issuing and handing over the Passive House Certificate

Independence

The certifying authority (Passivhus.dk in this case) is not allowed to do any design on the building project and must be independent from building owner, designers and contractors. Sometimes we, as certifying authority, consciously go very close to this border in order to support these parties as far as possible. Still we happen to deny some projects the final certificate, if not all requirements are met.

In this case Passivhus.dk was involved by the building owner in the competition stage to set clear energy requirements. At this stage it was pointed out that the server room would need special attention.

Design documentation

The building owner already receives a checklist for the documentation which is needed to assess the project with the offer. Ideally this is all forwarded as one package, but in larger projects it is often necessary for the designers to start with a lot of (conservative) assumptions and lock them as the project progresses. More stages means more workload on the certifier and higher costs.

The core of the documentation is the PHPP-calculation of the building's total energy consumption including all office equipment, cooking etc. This tool is used for all Passive House certifications across borders, with local climate data.

Upon receival the certifier checks the material for completeness and checks each part of the calculation and documentation for correctness. Typical issues are:

- Geometry is not correctly entered into the calculation
- Thermal bridges have not been taken into account
- Thermal bridge calculations are not erroneous
- U- and g-value of the window pane is not correct; even the sales personnel of the window manufacturer might not be absolutely aware of the differences between different products
- Value for ventilation heat recovery is too optimistic
- Not all electricity consumption has been taken into account

The certifier comments the material in an Excel-form, which the designers answer.

Quality assurance on site

Passivhus.dk makes spot checks in prefabrication and on the building site. The following are some examples from building sites and prefabrication that we have visited during the last few years.

Figure 7: Foundation, This is the most common spot for low quality in the construction phase of the projects, which Passivhus.dk has visited. Even given perfect working conditions the quality is often terrible.

Figure 8: Left – Poor combination of tape and membrane. The plastic tape stretches during installation incurring tension. Also this membrane showed particularly resistant to the glues of a range of high quality tapes. Right – Poor cellulose insulation. In spite of the technician counting the total amount of cellulose installed into the voids of a roof and the manufacturers written warranty, we saw up to 20cm insulation missing in a 43 cm cavity.

Costs

In the case of SE the total cost for this external quality control paid to Passivhus.dk is around 2 Euro/m2.

In addition the designers and contractors would usually have to document their project more thoroughly than usual. We believe that this leads to a higher quality to the benefit of the building owner, but also the designers and contractors benefit from the “challenge” and might avoid making some severe errors.

Unique issues

The Passive House specific limit to the total primary energy demand is 120 kWh/m2/a. This left little room for the server facility. For domestic buildings this limit may never be exceeded. In non-domestic it may only be exceeded, if it is still proven that everything is optimised “as far as possible”. In this case it directed attention to the expected very high electricity consumption due to the server room.

Despite efforts to motivate and educate construction workers, first spot checks on the building site by Passivhus.dk found that not everything was completely flawless. As a result, Hoffmann upgraded its internal quality assurance during the construction phase by appointing a keen right hand to the building site manager, who would concentrate on this issue.

Project Facts:

Project type: Office building
Status: Ongoing (2011-2013)
Client: Syd Energi Holding A/S
General Contractor: Hoffmann A/S
Architect: GPP Arkitekter
Engineer: Esbensen (installations), Sloth Møller (construction)
Landscaping: Thing & Wainø ApS
Advisor to Syd Energi Holding A/S: Johansson & Kalstrup A/S,
Passive house certification: Passivhus.dk ApS
Contract Amount: Approximately 210.000.000 kr (incl. warehouse)
Size: 11.000 m2 gross office (excl. warehouse)
Address: Vildsundvej 1, 6715 Esbjerg

References:

[01] CEPOS. Wind Energy - the case of Denmark. Copenhagen: The Danish Think tank CEPOS, 2009.
[02] A guide to integrated energy design IED, INTEND project – www.intenddesign.com, 2009
[03] Hot Aisle vs. Cold Aisle Containment, John Niemann, White Paper #135, APC 2008