APRIL 2013

THREE YEAR STATUS GREEN LIGHTHOUSE

Photo: Adam Mørk

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1 Foreword

When the partners behind Green Lighthouse gathered together in December 2007, two years before the UN Climate Conference COP15 in Copenhagen, they had a shared vision: to demonstrate what we in Denmark understand by innovative green building, based on existing technology and of high architectonic quality. The programme for Green Lighthouse was developed to be a beacon for:

- COP15 – as a showcase during the Climate Conference in December 2009
- Public-private collaboration in which the university, the business community, the ministry and municipality worked to transform a shared vision into concrete reality
- A green campus building fired by the ambition to demonstrate that green building concepts need not conflict with architectural and functional values, nor jeopardise a good indoor climate.

Green Lighthouse was built as a demonstration project. The strategic partners behind it are very keen to pass on their experience and share the knowledge gained – what met expectations and what did not – after three years of operation. The key points are given in this report.

Throughout the first three years of the building's life, the partners (the Properties Agency (under the aegis of the Ministry of Climate, Energy and Building), the University of Copenhagen, the Municipality of Copenhagen, VELUX and VELFAC) have enjoyed excellent teamwork with the designers and builders (Christensen & Co and COWI) in the follow-up and management of the great interest shown by visitors from home and abroad. In that connection, our thanks must be given to the daily users of the building, who have had to cope with the high level of traffic this interest has generated.

Over the last three years, we have harvested experience in the technologies used in the building, the handover from consortium to user with the building certifications awarded and, equally important, the contact with the many enthusiastic visitors. All this has equipped us to make a valuable contribution to the development of sustainable building in Denmark.

That a visit to Green Lighthouse in the summer of 2012 inspired the present construction of a similar building in the Chinese province of Nanjing, is just a single, though illustrative, example of how Green Lighthouse, with its modest 950 m^2, has sent ripples around the world from Tagensvej 16 in Copenhagen. We hope that Green Lighthouse will continue to function as a beacon and inspiration for innovative sustainable building.

For the strategic partnership:

Thomas Bjørnholm
Vice Chancellor

University of Copenhagen

Carsten Jarlov
Director

Properties Agency

Anne Skovbro
Director

Municipality of Copenhagen

Michael K. Rasmussen
Director

VELUX Group

This report was jointly prepared by Bjarne Dalgaard (Properties Agency), Jacob Sølling & Tomas Refslund Poulsen (Copenhagen University), Lone Feifer (VELUX) and Niels Varming (COWI).

Other contributors were Marianne Hartz Thomas (Operate) and Reto Hummelshøj, Juliane Münch and Maja Grud Minzari (COWI).

2 Introduction

This document is a collated report on the most important things learned after the first three years' operation of Green Lighthouse.

Photo: Adam Mørk

Green Lighthouse is Denmark's first carbon-neutral public building[1], with the sun as its pivotal point, inspiration and primary source of energy.

It contains 950 m^2 of floor space with a unique energy concept – a combination of solar energy, heat pumps and district heating.

Green Lighthouse is an energy-efficient building of high architectural value. It admits large quantities of daylight, and is filled with fresh air by its natural ventilation system – so it has a healthy indoor climate. At the present time (April 2013), it houses the student service centre of Copenhagen University's Faculty of Natural Sciences and has been the home of Copenhagen Innovation and Entrepreneurship LAB[CIEL][2] since 2011. Green Lighthouse is situated on the University's Nørre Campus at 16 Tagensvej.

The partners behind the building are the Properties Agency (under the aegis of the Ministry of Climate, Energy and Building), the University of Copenhagen, the Municipality of Copenhagen, VELUX and VELFAC.

Green Lighthouse was built by a consortium consisting of Hellerup Byg, Christensen & Co. Arkitekter and COWI.

[1] Assessed in accordance with valid Danish building regulations in 2008 – BR08
[2] http://ciel-lab.dk/

2.1 Summary of measured energy consumption

The measured values of Green Lighthouse energy consumption are 30% under the requirements of the future Building Category 2020. After normalisation[3], the building almost meets these requirements even without the contribution of renewable energy.

In the third year of operation (2012), the building registered a primary energy consumption[4] that was roughly 100% higher than expected. This is the actual consumption ignoring the contribution of renewable energy.

More than half this excess energy consumption can basically be attributed to the fact that the real world differs in many ways from the theoretical norms and predictions that make up energy calculation. One important difference, for example, is that the building has been used considerably more than the 45 hours a week that was included in the standard calculations.

This consumption does not take into account self-production of renewable energy, which is slightly higher than expected

Overall, there is an inexplicable gap of excess consumption of purchased energy of some 9 kWh/m^2 per year, which corresponds to about DKK 5/m^2 a year, or DKK 5,000 for the whole building.

2.2 Building's history

The strategic partnership was established in December 2007 and a number of targets set for the construction. In the following months, the partnership drew up a contract and a schedule for the building and drafted the vision underlying Green Lighthouse.

The mileposts of the project were acknowledged and celebrated as they were passed, from the signing of the architecture competition and partnership agreement in March 2008, selection of the winning team in July 2008, and the first sod turned in October 2008, to the topping-out ceremony in May 2009 and the official opening in December 2009, with GLH acting as a much-visited tangible demonstration at COP 15 of Denmark's expertise in the fields of sustainability and energy-correct building.

Since 2009, the building has housed many happy users from Copenhagen University and later from CIEL.

The building has subsequently been granted two certificates for its level of sustainability. The first was in November 2011, when GLH received documentation that it was a LEED Gold building; the second was in May 2012, when it was awarded the DGNB-dk Bronze medal.

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[3] Normalisation is the process in which deviations from design specifications are corrected for 'normal' or actual conditions.

[4] By BR08, in which electricity is multiplied by 2.5 and district heating by 1.

2.3 Visitors to the building

Even when Green Lighthouse was under construction, it awoke great interest in the building sector, organisations, politicians and the media, in Denmark and abroad. This interest rose markedly after the opening in October 2009 and reached its peak during COP 15 in Copenhagen in December 2009. Meanwhile, in the subsequent three years the building has been regularly visited by a broad spectrum of interested people from senior politicians and decision makers to sector-related companies, public institutions, including municipalities and universities, and students and enthusiasts from home and abroad.

During COP 15, the Mayor of New York, Michael Bloomberg, visited Green Lighthouse.

Michael Christensen, CCO, explains Green Lighthouse to Michael Bloomberg. Photo: Lizette Kabré.

In the following spring, the building was visited by a delegation from China, led by Minister of Commerce Chen Deming. In the wake of the official Chinese visit to Denmark, Green Lighthouse was visited by a series of visits of other Chinese delegations from major cities and regions, including that of Nanjing.

Chen Deming on his visit to Green Lighthouse. Photo: Lizette Kabré.

In April 2010, President Medvedev of Russia also visited Green Lighthouse and declared the next day his intention to build a Green Lighthouse in Russia.

President Medvedev visits Green Lighthouse. Photo: Lizette Kabré.

Interest in the project remained at the same high level until August 2012, when the Prime Minister of South Korea, Kim Hwang-sik, was given a guided tour of Green Lighthouse during his official visit to Denmark.

Kim Hwang-Sik on his guided tour of Green Lighthouse. Photo: Lizette Kabré.

Green Lighthouse has been visited informally by such prominent figures as Nobel laureate Wangari Maathai in July 2011, Denmark's EU Commissioner for Climate Action, former EU Energy Commissioner Andris Piebalgs, current Danish Minister for Climate, Energy and Building, Martin Lidegaard, and Beijing's Vice-Mayor for Building, Chen Gang.

Since the building was opened, countless groups from architecture firms and building companies, municipalities and universities have been given guided tours. At least 10,000 people have been shown round by representatives of the partnership and consortium. In the first three years, the visitor's service has also conducted 250 guided tours for interested members of the general public. In addition, many students, architects and supporters of sustainability have made private visits, so it is estimated that the total number of visitors exceeds 15,000 in the first three years of operation.

The partnership is delighted with the great, continuing interest in Green Lighthouse and has arranged many of these visits as an extension of the close teamwork in the project. Apart from spreading experiences and visions about Green Lighthouse, the numerous delegations have helped create and maintain a network of contacts and the partnership has received feedback and opinions from all over the world.

The huge interest demonstrates that there is a clear and constant need to see and experience ambitious, sustainable buildings concepts become concrete reality. Green Lighthouse has become what it was designed to be − an inspirational beacon for ambitious and visionary sustainable building.

2.4 Green Lighthouse in China

In the summer of 2012, a Chinese delegation led by Nanjing Party Secretary Yang Weize visited Denmark. As part of the sustainability study trip, the delegation visited Green Lighthouse. Mr Yang showed great interest in the building. One result of the visit was that COWI initiated negotiations in the late summer of 2012 with Nanjing High Tech Zone, a Business Development District in Nanjing, for the construction of an exhibition and information centre inspired by the Danish building. The contract was signed in the autumn and, together with the Chinese architect firm Archiland International, COWI has spent the last six months designing the building and developing the energy concept.

The building in Nanjing differs from its Danish counterpart in many ways.

- It is situated in a region with a completely different climate, which places different demands on indoor climate control and the energy concept.
- Nanjing Lighthouse is an exhibition and information centre that is open seven days a week.
- The building is five times larger than the Danish building.
- The building is in a park area and designed as an integral element of that park.

The building is planned to meet Danish BR2020 energy requirements. Building is expected to begin in the summer of 2013 and handed over to the owner in 2014.

Architects: Archiland International – Beijing.

Project management and energy concept: COWI – China and Denmark.

Illustration: Archiland International

2.5 Awards and recognitions

Below is a list of the awards and other marks of recognition Green Lighthouse has received.

2.5.1 Awards

Municipality of Copenhagen award for Excellent and Beautiful Buildings in 2010

"There's no great secret to building sustainably. What is special about Green Lighthouse is that it is both carbon-neutral and beautiful to look at and pleasant to spend time in" – Pia Allerslev, Municipality of Copenhagen's Mayor of Culture and Leisure at presentation ceremony.

Confederation of Danish Industries Building Materials Award 2009 for Innovative Collaboration

The Green Lighthouse partners (the Properties Agency (under the aegis of the Ministry of Climate, Energy and Building), the University of Copenhagen, the Municipality of Copenhagen, VELUX and VELFAC) received the award because "*it is the result of superb collaboration across sector boundaries. The partners have succeeded in thinking CO_2-neutrality into the building, with health and comfort at the centre. Energy design and innovative architecture have made it possible to create a building that uses a quarter of the energy of the norm for buildings of today. And it is quite exceptional that they have managed to build it in a year,*" said Confederation of Danish Industries Building Materials Chairman, Mogens Nielsen.

Green Good Design 2010

In 2010, Gsreen Lighthouse also won the GREEN GOOD DESIGN award, selected from thousands of submissions from more than 46 countries. Read more at www.europeanarch.eu

2.5.2 Nominations

Green Lighthouse was also nominated for:

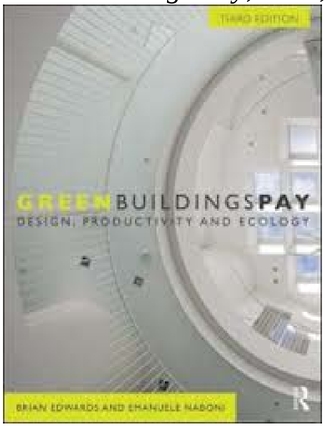
- The Danish Light Award 2010
- Education & Learning category at the World Architecture Festival in Barcelona 2010
- Climate Cup Partnership Award at the World Climate Solutions Conference in 2010

Furthermore, in 2011 the European Commission endorsed the building as an Official Partner in spreading the word about best practice in sustainable energy technology and building alliances.

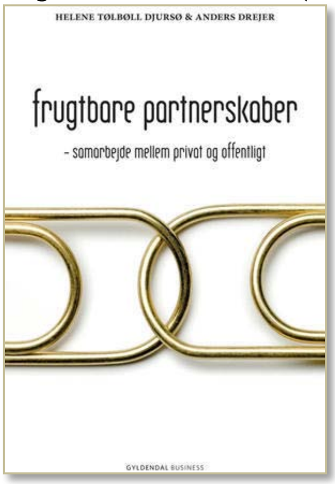
2.5.3 References

During its first three years, Green Lighthouse has been a reference building in numerous publications and exhibitions on sustainable building. Here are a few examples:

› *Green Buildings Pay*, 2012, Routledge



› *Frugtbare Partnerskaber* (Fruitful Partnership*)*, 2011, Gyldendal

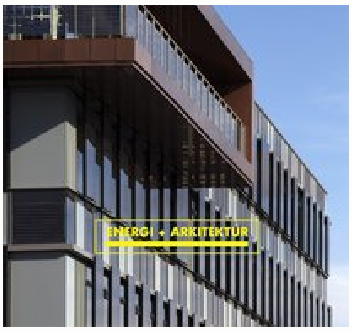


› *Arkitektur og Energi* (Architecture and Energy) – towards a 2020 low-energy strategy, 2011, Statens Byggeforsknings Institut (Danish Building Research Institute)

- *Ny Arkitektur i Hovedstaden* (New Architecture in the Capital), 2011, Dansk Arkitektur Center (Danish Architecture Centre)

- Reference in technical theme of indoor climate, Arkitekten (The Architect)

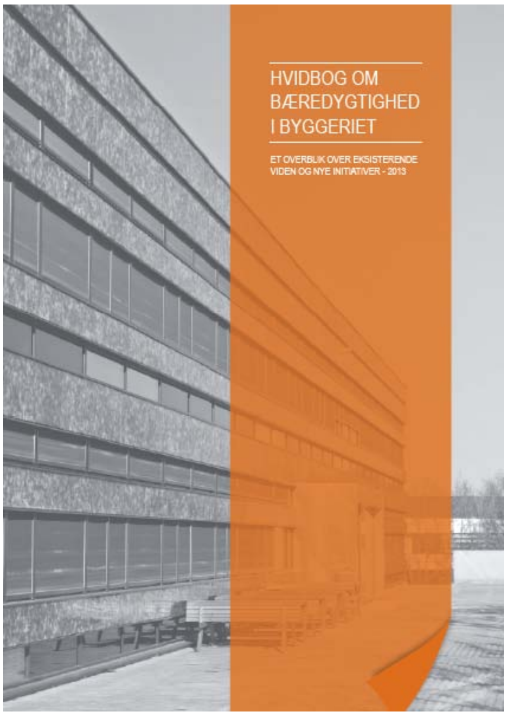
- Energi + Arkitektur, 2011 (Energy + Architecture) Arkitektens Forlag (The Danish Architectural Press)



Energi + Arkitektur

This book presents the best in new Danish energy-oriented architecture focusing on the energy and architectural methods and practises in the integrated design process, which together result in high quality architecture.

- Exhibition New Nordic at Louisiana, 2012, – model, photos and drawings
- Exhibition Ecobuild in London, 2013 – model
- White Book on sustainability in building, 2013



3 Learning points

This section presents some of the learning points the partnership encountered during and after the project. The declared objectives of the Green Lighthouse from the very beginning were to test new possibilities for sustainable building, with low energy, high architectural value and optimal indoor climate. The experience gleaned in the following reflects both aspects that succeeded and aspects that did not meet expectations, and observations made about complexity and initialisation. The project partners are eager to share this experience in the spirit of development that created it, in the hope that it might benefit other buildings.

3.1 Demonstration building

Green Lighthouse was built as a demonstration project whose intentions were to construct a public office building with extraordinarily low energy consumption. It is a complex building in which many technical solutions for reducing its energy consumption were tried and tested. GLH is also a small building and the potential of many of the solutions selected will only be fully met in larger-scale constructions.

Examples of technical challenges:

- Control of the building was carried out by two different systems, with windows and sunscreening operated by one system and heat pumps and mechanical ventilation by the other. This turned out not to be the most suitable arrangement and there were certain problems in coordinating the two systems

- The heating system is more complicated than usual, with parallel operation of solar heating and heat pumps connected to a district heating network, and a system of motorised valves to control water circulation. When irregularities occur, it can be difficult to localise the fault.

Learning point:

- Even with a research project, we should be aware, especially in small buildings, of **not** making the solutions chosen too complex and not testing too many ideas at the same time. During the design and tender process, thought must be given to how fault-finding will be carried out, and attention paid to minimising time needed for running in and error correction.

- Care must be taken in the design phase ensure that requirements for function and energy consumption can be demonstrated by the contractor on handover and during operation. The building contractor should be obliged to include, for example, two years' operation of a delivered building and energy targets should be agreed upon for the operational phase. A thorough handover of future operation is also important.

3.2 Tendering model

GLH was a tendered as a turnkey contract. This form of tender is not particularly suitable for a research building as the turnkey contractor often wishes to move on to the building phase as quickly as possible − even during the development phase. The risk here is that decisions can be made on too loose a basis.

Learning point:
- It is recommended that the project should be put out to tender as a finished project, with the solutions chosen fully considered and the detail design complete. A research building such as GLH is an excellent candidate for public-private innovation, in which private companies can contribute their knowledge in the design phase and prior to tender.

The turnkey contract for GLH included one year's operation and obligated the contractor to follow up on operational figures and deviations. In the course of the first year, running-in procedures identified two specific problems that were critical to energy consumption: half the solar cells were not connected (with the supplier making financial compensation); and a ventilation damper was missing, which led to increased heating consumption and draughts for the user.

Learning point:
- It is recommended that the operation of sustainable projects should be contracted, with precise specifications and prerequisites of measuring parameters.

The BE08 energy consumption calculated in the planning phase is based on a number of assumptions that do not necessarily match the subsequent use of the building.

Learning point:
- Calculation of parameter variations should be made in the planning phase so that sensitivity to factors such as increased temperature, use time and air change can be identified by suitable programs.

Knowledge transfer: It is important that funds should be earmarked for energy optimisation and documentation of actual operation. An associated EUDP project has been of great benefit in this respect. This project also included Viborg Town Hall, whose energy concept is based on experience from Green Lighthouse but used in a building of 20,000 m^2. The same type of district-heating-operated heat pumps were used, though with an effect ten times higher. After servicing of the heat pumps (checks on the vacuum in both chambers), this system now runs as predicted and consumption in Viborg Town Hall is now as calculated. A separate report in this EUDP project will be presented in the summer of 2013.

4 User experiences

Copenhagen Innovation and Entrepreneurship Lab (CIEL) have been occupants of the second floor of Green Lighthouse since 2011 and have four permanent office places and various ‘open’ spaces for student assistants. CIEL also uses the conference rooms for internal and external meetings.

Users are generally satisfied with Green Lighthouse and perceive the building as beautiful, different and innovative. Many CIEL guests are impressed with and interested in the building, which thus also functions as a good ‘icebreaker’.

Users experience Green Lighthouse specifically as a living building that itself ‘administers’ windows, light and heating and so on. According to CIEL staff this is a good arrangement, as it is possible to override the automatic function and control lights, blinds, windows manually, as well as airing out the room by opening the door to the terrace as and when needed.

The users make particular mention of the change of light in the building throughout the day.

The users experience problems in the winter months with the LED lighting going out after relatively short periods with no movement in the room and everybody sitting at their work stations.[5] This flags up the need for adjustments to be made to match the actual use situation.

The building is also sound-sensitive, with noise from events in the building disturbing occupants elsewhere. However, this is a general problem with open buildings and open-plan offices.

[5] Ed.: the second floor was not designed as office space but for informal meetings and get-togethers. This could explain why controls are set as described. Operations has been asked to check the settings on the second floor.

Green Lighthouse is featured as a case in the book *Green Buildings Pay*[6]. User experiences from the building's first year are presented; they correspond closely to user experiences of today:

"*Analysis of the responses found that most employees expressed an interest in working in a sustainable building and enjoyed the results. In general, the building is perceived as beautiful and full of daylight. Many respondents talked about the quality of the indoor environment, mentioning in particular the freshness of the air even during long meetings.*"

"*Air quality and daylight are perceived to be of a very high standard. But noise remains a problem. Employees have adapted to being in a rather public workspace, but find the actual and the visual noise distracting (many visitors). The results confirm the importance of including the users as early as possible in the design and building process, and to actively engaging with their experiences once the building is occupied.*"

"*The rector of the university has expressed satisfaction that the Green Lighthouse has helped fulfil the demanding ambitions behind the campus sustainability plan, which set the target in 2009 of being one of the greenest campuses in Europe. The publicity the project has attracted and the calibre of its visitors has also been an unexpected bonus for the university.*"

Overall then, the conclusions is that users value the building's architecture, innovative design and light, whilst the open space can be a disadvantage in daily life. The users also need to be thoroughly briefed on the inherent possibility of manual operation of the building's technology and that adjustments can be made to suit current activity.

Figure 1: the architect behind Green Lighthouse, Michael Christensen

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[6] (Green Buildings Pay, Brian W. Edwards and Emanuele Naboni; Routledge, 2012)

5 Energy consumption

Green Lighthouse was built as Denmark's first public CO_2-neutral building, based on the current Danish BR08 building regulation. The energy calculation was programmed in accordance with the expected 2020 European energy requirements for public office buildings. Since the building was completed, a voluntary Building Category 2020 has been established for energy consumption in 2020. Green Lighthouse meets the requirements for this category in terms of measured energy consumption. The first three years of measured energy consumption also show that more energy has been used in practice than was assumed in the theoretical calculations.

In 2012, actual user behavioural patterns meant that the building had a primary energy consumption[7] of about 60 kWh/m^2 per year (not including its own production of renewable energy) compared to a theoretical consumption of about 30 kWh/m^2 per year. More than half of this difference is accounted for by the fact that real operation differs in a number of ways from the theoretical standards and norms used in energy calculation by the BE06 program. Most significantly, users have wanted higher temperatures than expected, the heat pumps have not worked quite as expected and building use and air change has been considerably higher than expected. The last two factors can be partially attributed to the many visitors who have been through the building. However, the above figures do not take into account self-production of renewable energy, which is slightly higher than assumed. Overall, there is an inexplicable excess consumption of some purchased primary energy of some 9 kWh/m^2 per year, which corresponds to an annual energy bill that is about DKK 5/m^2 higher, or roughly DKK 5,000 per year more for the building as a whole.

It's rather like the petrol consumption of a car. The ex-factory consumption figure of 22 km/litre is rarely experienced by the average driver; real-life conditions, such as driving behaviour, road and weather conditions, differ from factory test conditions.

Green Lighthouse has a measured consumption that is some 30% lower than Building Category 2020 standards. When this figure is normalised, it comes very close to meeting those standards, even discounting self-production of renewable energy. Green Lighthouse was built as a demonstration building for the 2009 UN Climate Conference COP15 in Copenhagen, with a very sharp focus on energy consumption and renewable energy, without compromising a good indoor climate with masses of daylight and fresh air. The project partners also paid close attention to monitoring the building's actual con-

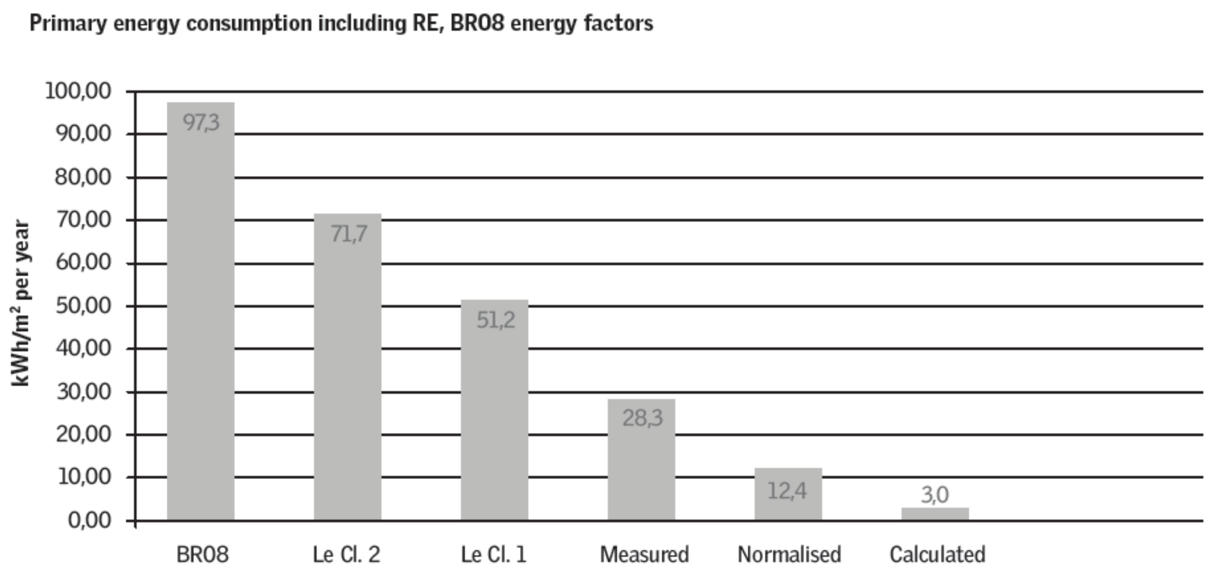
[7] By BR08, in which electricity is multiplied by 2.5 and district heating by 1.

sumption performance in order to optimise the building and evaluate the technical solutions. After analysis of energy figures and user behaviour, Green Lighthouse has been through a continual process of fine-tuning and adjustments. The project's energy consumption, including the combination of heat pumps, solar energy, underground heat storage and district heating were monitored in an EUDP project by a group of people from COWI, BYGST, KU, VELUX and others.

5.1 Measured energy consumption in detail

An exhaustive measurement programme of the entire building has been carried out and a great deal of data has been saved on an hourly basis and continually evaluated throughout the project. As the building has now been in operation for three whole calendar years, plus a small part of 2009, assessment of operation was made in 2012, which can be accepted as the third year of operation.

Green Lighthouse was put to tender at a time when the minimum requirements of building regulations for primary energy consumption was 97.3 kWh/m^2 per year for this category of buildings. At that time, the energy framework for the best low energy class (LE 1) was 51.2 kWh/m^2 per year. The building was measured as being 3 kWh/m^2 per year under standard operational conditions.



The measured energy consumption show a demand of roughly 28.3 kWh/m^2 per year when primary energy factors[8] that were valid at the time of construction.

When this figure is normalised with the assumptions that deviate from those of the energy calculation in BE06, we arrive at an energy consumption of 12.4 kWh/m^2 per year. Normalisation is the process in which corrections are made for the deviations in assumed values compared to 'normal' values. It is described below.

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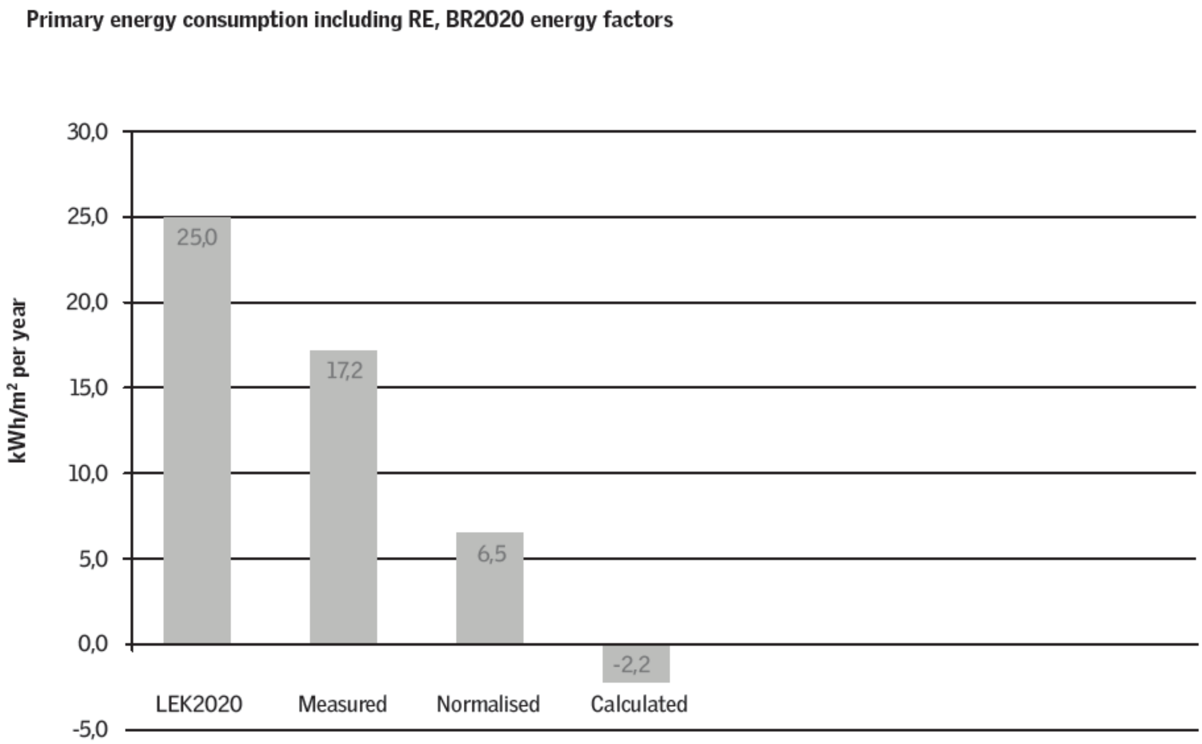
[8] Primary energy factors multiplied by energy consumption allow interpretation of the actual energy consumption used to produce 1 kWh. In BR08, 1 kWh of electricity has a primary energy factor of 2.5; district heating has a primary energy factor of 1.

When the building was constructed, one of the demands was to respect future demands for buildings in 2020. At that time, these demands were not known and guesswork was required. Since then, Building Category 2020 has arrived, defining the requirements that will apply to buildings in 2020. Among other things, there are new primary energy factors that change the results slightly.

Building Category 2020 requires buildings to meet a maximum consumption of 25 kWh/m^2 per year. The measured values correspond to about 17.2 kWh/m^2 per year, which, when normalised as described above, means an energy demand of about 6.4 kWh/m^2 per year. The calculated energy consumption is roughly -2.2 kWh/m^2 per year, which would make it a plus energy building.



Normalisation adjustments are given above. Note that the figures are for energy consumption only – renewable energy is not included.

Corrections were made for:

› Fewer degree days in 2012 than in a normal year, which means that measured heating consumption is less than it should be in a normal year.

› Higher room temperatures. There is a general wish among the users of the building for a room temperature of about 23ºC, which figure has been used in normalisation.

› Extended operation time. There has been a noticeably longer use time than the BE06 standard of 45 hours a week. A normalised value of 60 hours a week has therefor been used. The extended operation time resulted in more hours of use of all the building's installations.

› Increased infiltration. There are more significant changes of air as a result of openings in the facade than expected; mostly due to the handicap door, which is used a great deal, from the swing door and from the terrace door on the second floor. As there is no windcatcher, a chimney-effect is created in the atrium that exacerbates the problem.

A small amount of energy is also being consumed for no apparent reason. But possible explanations are:

- Uneven internal loads. That is, there are periodic high internal loads in certain rooms and very small loads in other rooms. So the need can arise for extra ventilation in a meeting room full of people, at the same time as a need for heating elsewhere in the building. BE10 treats the entire building as a single zone, but that is not how things are in reality.

- Higher use time than the building is normalised for.

- Extra infiltration above and beyond the expected – from opening windows, for example. A value *has* been given to this increased infiltration but with a high level of uncertainty as the infiltration has not been measured.

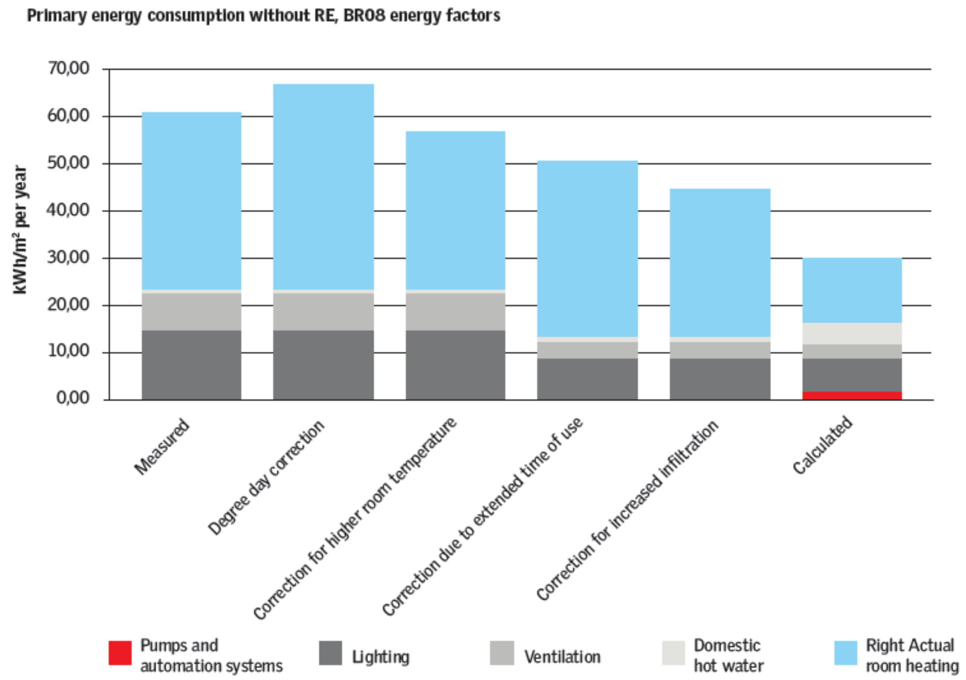
- It is possible that BE10 does not calculate accurately enough to be used in this way in direct comparison with measure data.

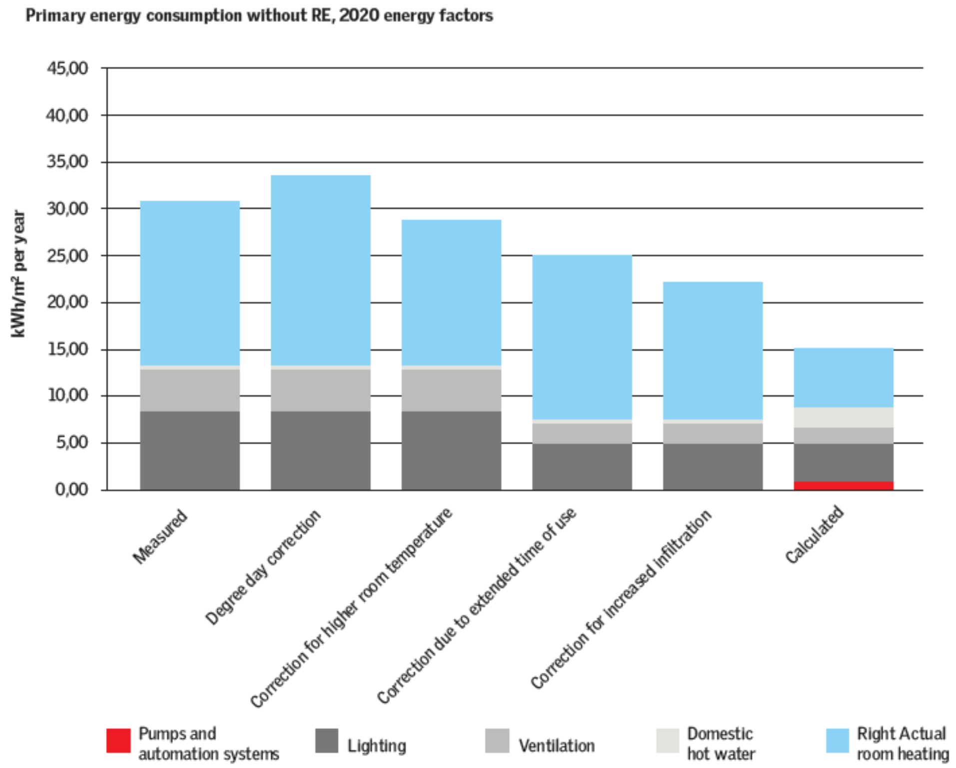
- It is evident from the measuring data that certain meters have episodes of drop-out in which they give the same information for lengthy periods – sometimes for a couple of day. If the control system responds to such signals, this can cause errors. It is also possible that the energy meters are defective.

- There has been a consistently higher lighting level than the 200 lux calculated for.

Discussion will continue as to whether ventilation in the toilets can be set up as an independent system, which will reduce the operation time of the central plant. This is expected to reduce energy consumption for ventilation and heating.

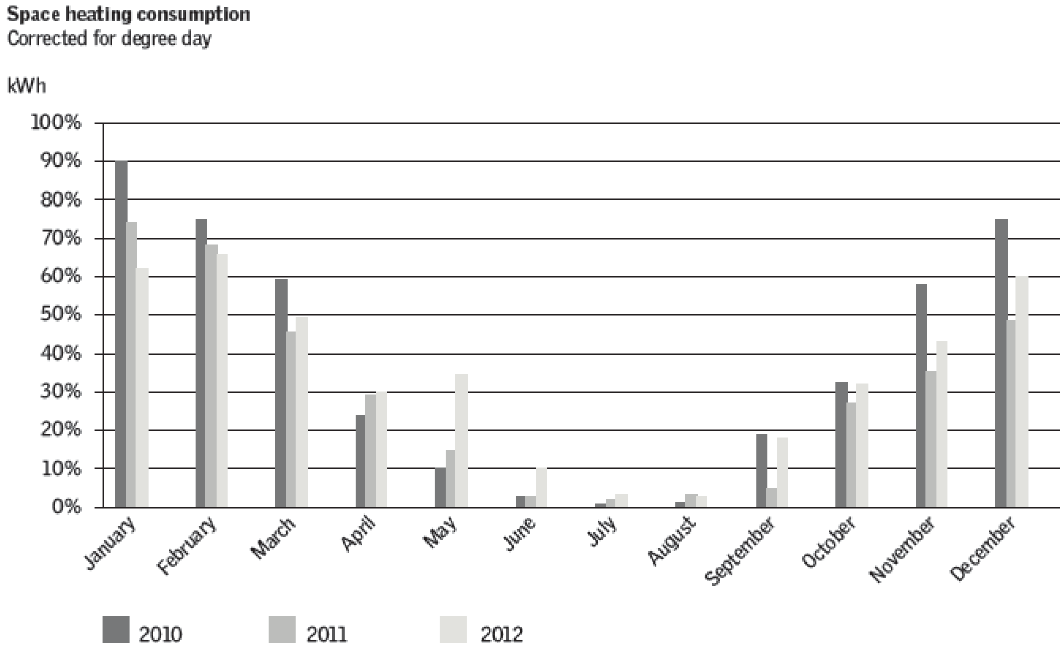
Below, the energy requirements of the building are given in primary energy. Two graphs have been produced using the energy factors in BR08 and Building Category 2020. It is evident that there is an energy requirement that has no explanation. It is primarily heating consumption that is higher than calculated – it accounts for about 16 kWh/m^2 per year with BR08 energy factors and about 10 kWh/m^2 per year with 2020 energy factors.





5.1.1 Space heating consumption

In the figure below, space heating consumption for the first three years is given on a monthly basis. It will be seen that the first year has higher values than the subsequent two – this was the running-in year. It will also be seen that there was higher heating consumption in 2012 than in 2011. In May and June 2012 in particular the measurements appear much higher, with no definite explanation as to why. Extra heating consumption in May, June and September 2012 compared to 2011 amounts to some 4 kWh/m^2 per year and could go some way to explaining the increased energy consumption. Another explanation for this phenomenon could be that new users have moved into the building and use it differently – they use the roof terrace more, for example, which would account for the greater heat loss from the open door.



6 Certifications

Green Lighthouse was the first Danish building to be certificated to one of the major standards in sustainable building.

In 2011, about two years after opening, the building was awarded LEED Gold. Details of LEED certification are given below.

In 2012, GLH went on to receive DGNB Bronze, after taking part during the pilot phase in the Danish certification system DGNB. Details of this certification are also given below.

So Green Lighthouse is also the first building in Denmark to achieve dual certification, with recognition from two international certification organisations.

6.1 DGNB

In the spring of 2012, four certifications and three pre-certifications of pilot projects were carried out by DGNB Denmark. Green Lighthouse was one of these projects.

Figure 2: Presentation of the certification diploma. Photo: DK-GBC copyright

The result of the DGNB certification is seen in Fig. 8. A much higher score is achieved in Environmental Quality, whereas a minimum of one point is given for Economic Quality. The remaining categories have more or less stable values of about 50 %. Site Quality does not count in the overall score.

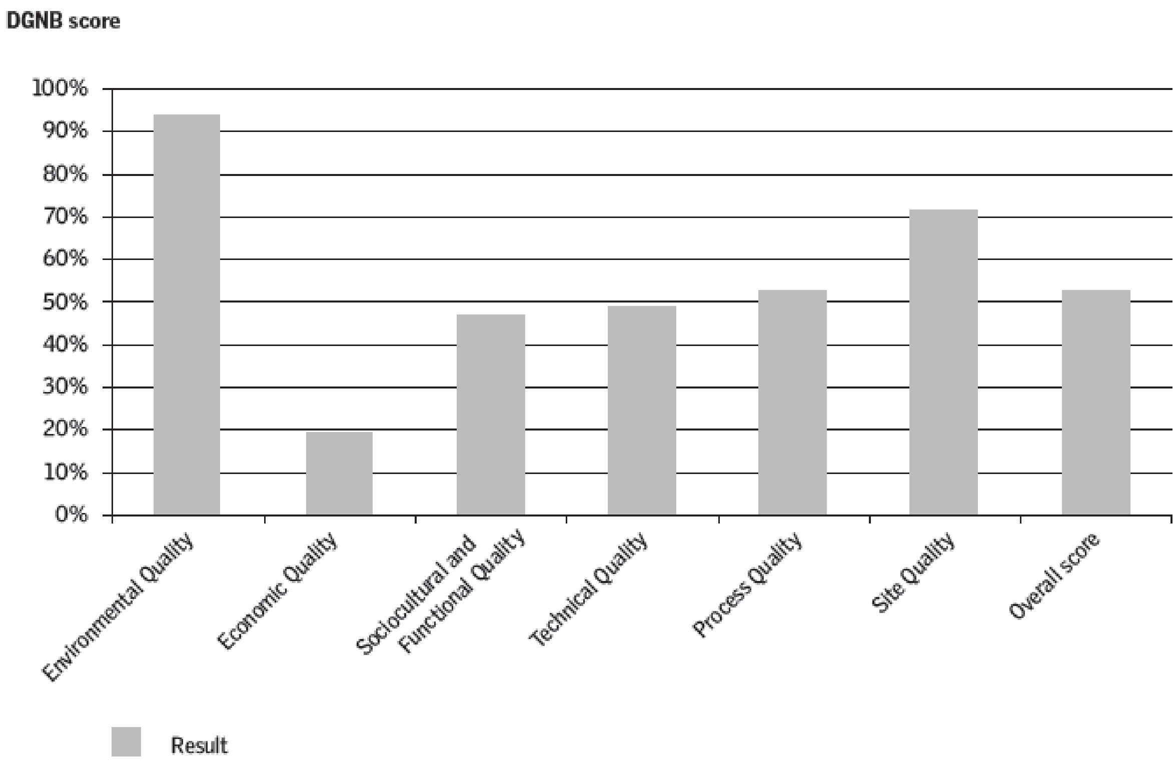


Figure 8: Green Lighthouse's score in DGNB

The environmental quality is high because there has been such sharp on limiting environmental impact. However, throughout the project great efforts have been made to reduce the environmental impact of the operational phase – but environmental impact in both that phase and throughout the entire life cycle achieves a very high score. Figure 3 gives the various LCA[9] values from certification. If environmental impact is reduced by 30% compared to the reference building, then a maximum score is achieved in the LCA analysis. In Global Warming Potential (GWP), which is the CO^2 emissions throughout the building's entire life cycle, then a total saving is achieved of more than double that required to gain maximum points in DGNB. The remaining LCA criteria also achieve a good score, with maximum points in everything except POCP (Photochemical Ozone Creation Potential).

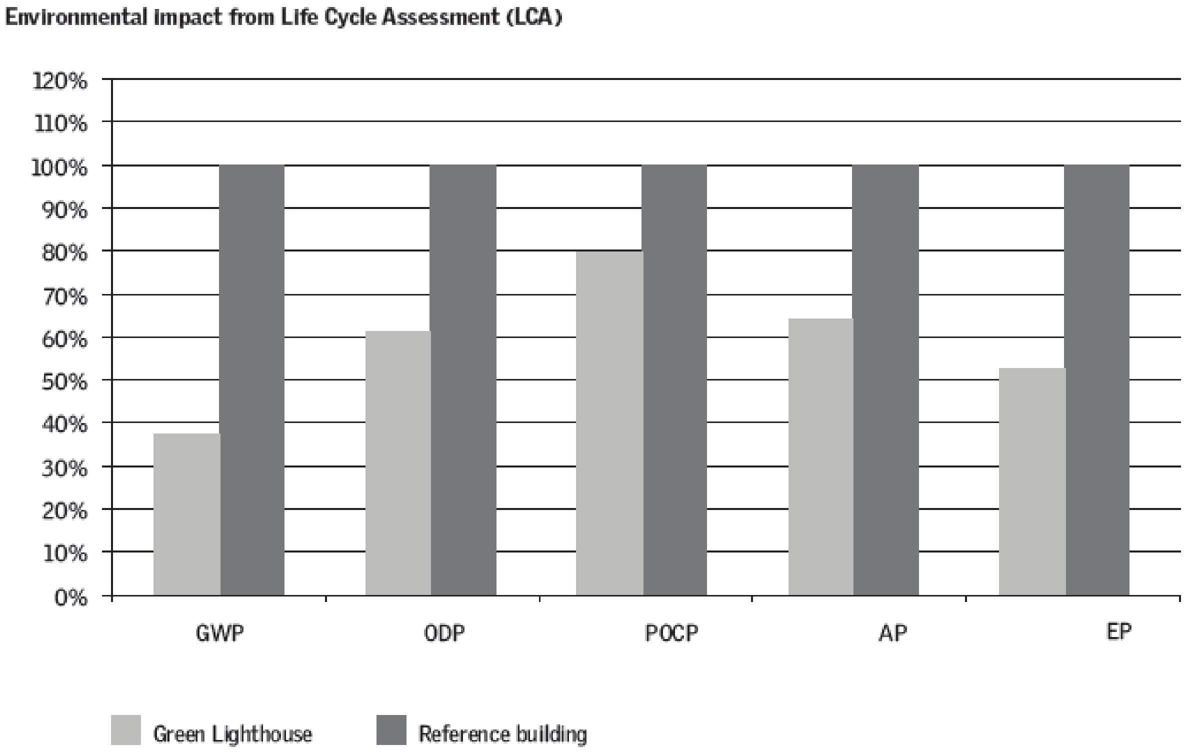


Figure 3: LCA results for Green Lighthouse in DGNB certification

Economic quality gets a minimum score of about 20%. This is mainly due to the high construction costs that means the building can only achieve 10% in the LCC (Life Cycle Cost) analysis, a parameter that scores heavily in economic quality. The essential cause of this is that the building has implemented a large number of demonstration elements in the energy concept, which led to significantly higher costs. As the building is very small, those extra costs play a major role and lead to a building that cost about DKK 39,000 /m^2. The initially high m^2 price is used to calculate all maintenance costs and replacements for a period of 50 years, even though the price of these replacement will fall in the future. Replacements are included in the maintenance, and should be less expensive in 10 years

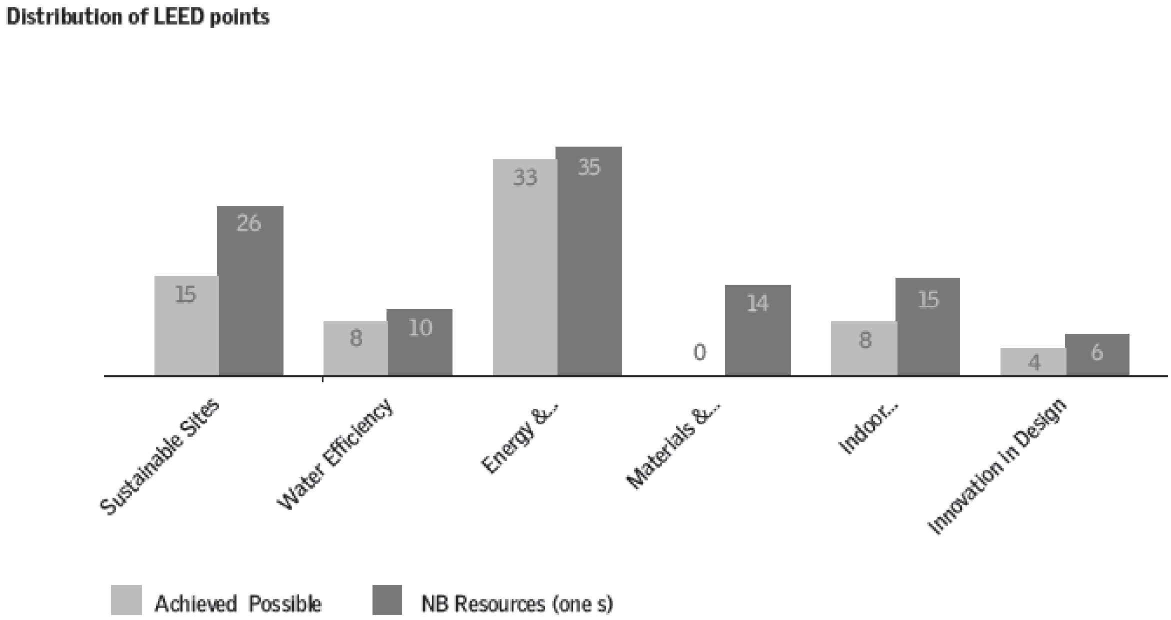
[9] Life Cycle Analysis. A method of analysis used to describe a building's environmental impact throughout its lifetime, including construction and demolition.

In a research building that tests new technologies and techniques to the extent that Green Lighthouse does, building costs will always be high. In subsequent projects with similar solutions, this has not incurred extra building costs of more than 3-5%.

6.2 LEED

Green Lighthouse scored 68 points in LEED certification – 60 is required for Gold and 80 for Platinum.

The figure below shows that the project does extremely well in all categories apart from Materials & Resources. This is because many of the points in this category are impossible to achieve in a newbuild project, but also it has been difficult to document materials in the way LEED requires.



Eight possible points were rejected: no points were awarded for innovation in the use of PCM materials; and none for cycle parking, despite the fact there are many bike parks and changing rooms. The project partners believe these points could and should have been awarded but decided against a drawn-out appeal process. If they had been awarded, Green Lighthouse would have attained 76 points and thereby be very close to Platinum certification.

However, Green Lighthouse was not optimised in the planning and design stages to achieve maximum points in the LEED system, but to meet actual needs.

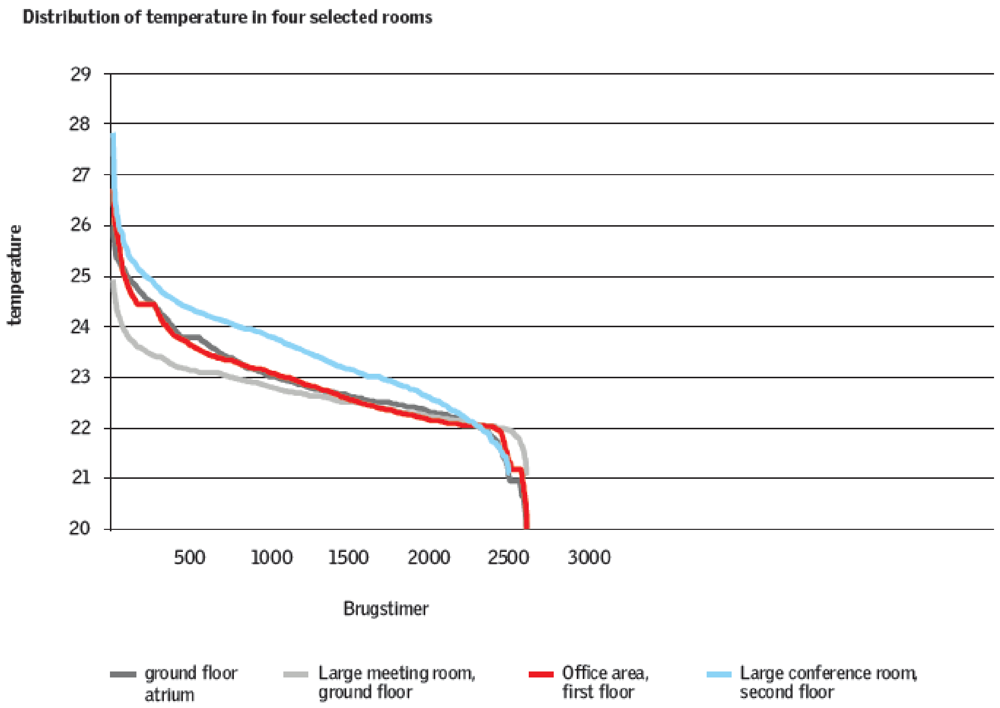
To achieve the final point, Green Lighthouse should install a recharge point for electric cars and buy green electricity for over a two-year period. But not all requirements in LEED make the building more sustainable by Danish standards. American demands differ somewhat from the Danish approach. The partners chose, therefore, not to install the extra features purely to achieve a higher LEED score.

7 Measured indoor climate

Indoor climate is one the factors to be included in the reporting system. It was analysed according to the DS/EN 15251 standard, and is described in the following section. The building was designed to meet a demand for a maximum of 100 hours of use time over 26ºC and 25 hours over 27ºC. The figure below shows how many hours a given temperature was present – for example, it shows that there was a temperature over 25ºC in the large conference room on the second floor for some 300 use hours.

None of the rooms exceeds planned hours over 26ºC. The large conference room on the second floor shows most hours and the large meeting room on the ground floor shows no hours at over 26ºC.

Nor do any of the rooms exceed planned hours over 27ºC. The large conference room on the second floor is the only room to exceed planned hours over 27ºC – and then only by 8 hours.



7.1.1 Temperature

Analyses have been made of the percentage of use time (Monday to Friday from 0800 to 1700) that meets the various indoor climate classes in DS/EN 15251. To be classified as a particular category, at least 95% of the hours must meet the laid-down demands.

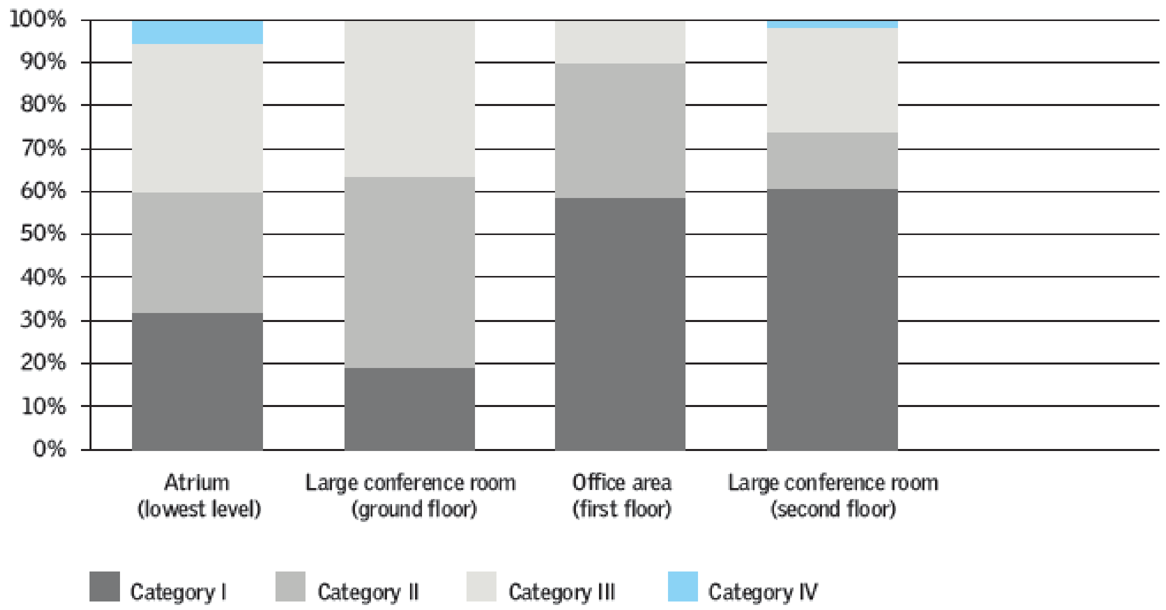
It appears that they are met most closely in summer, when natural ventilation is used. Part of the reason for this is that temperature levels laid down in DS/EN 1521 for winter are lower than desired by Green Lighthouse users. So when they want 23ºC in winter, it is impossible to achieve Class 1, which lies between 21 and 23ºC.

In the summer, demands for the various classes are:

- Class I: 23.5-25.5ºC
- Class II: 23-26ºC
- Class III: 22-27ºC
- Class IV: exceeding Class III

Summer is defined in this analysis as June, July and August.

Indoor climate categories, thermal indoor climate – summer

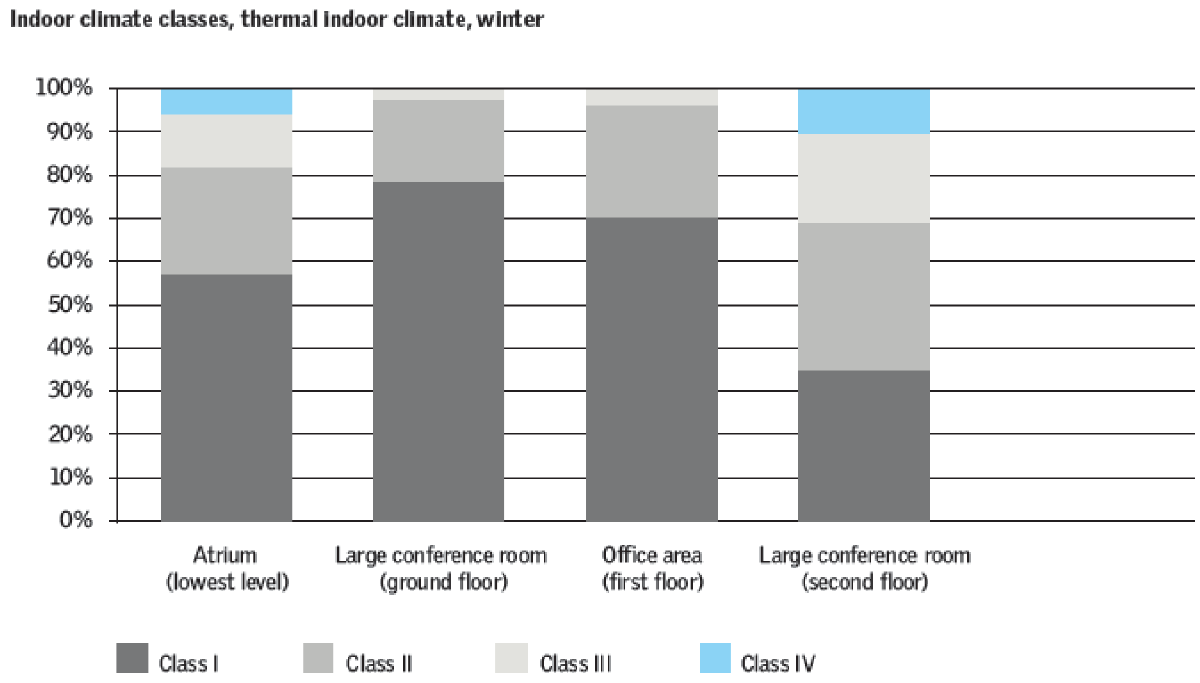


It becomes apparent that all rooms are Class III, which meets the 95% factor.

Demands of the various classes for heating situations are:

- Class I: 21-23ºC
- Class II: 20-24ºC
- Class III: 19-25ºC
- Class IV: exceeding Class III

The heating season is defined in this analysis as all year, except June, July and August.



In winter, the base of the atrium and the conference room on the second floor are Class IV, whilst the large meeting room on the ground floor and the office space on the first floor are Class II.

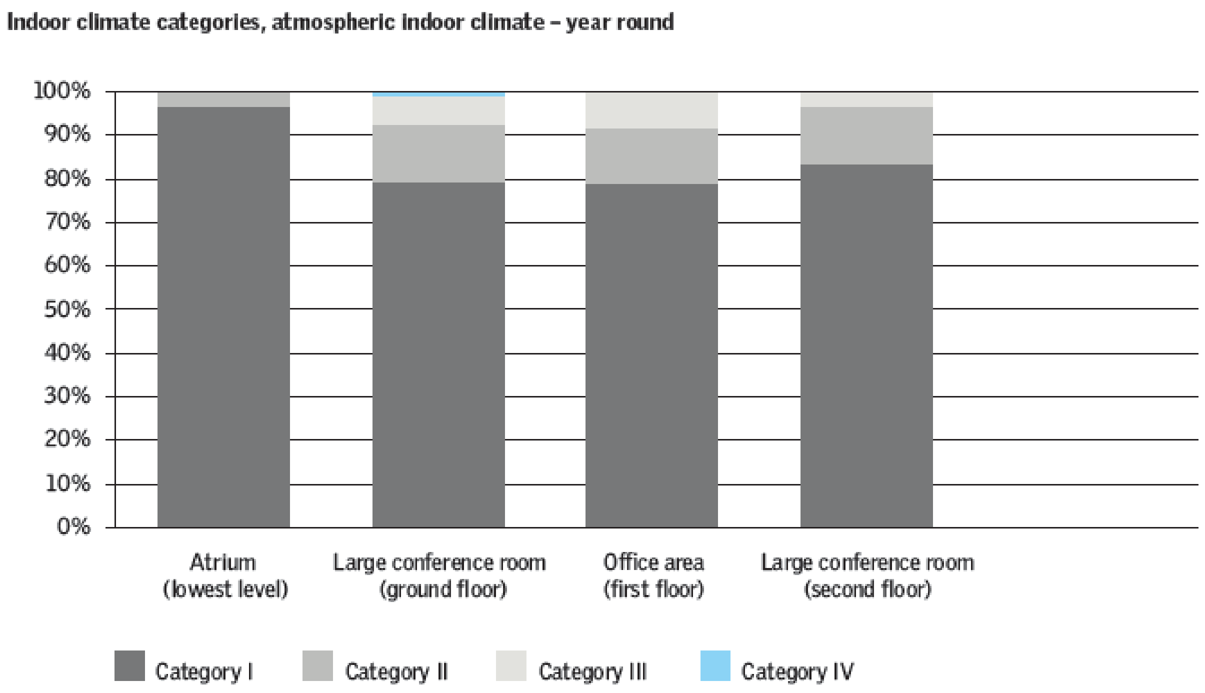
7.1.2 Air quality

Analyses were also made of the air quality through CO_2 measurements to determine indoor climate standards. It must be pointed out, though, that the measurements are extremely suspect and it has been necessary to apply corrections to reach any reasonable result. What is more, there were no specific design parameters for CO_2, so the standard demand for a maximum of 1,000 ppm was applied, which corresponds to Class III.

Demands for the various classes are:

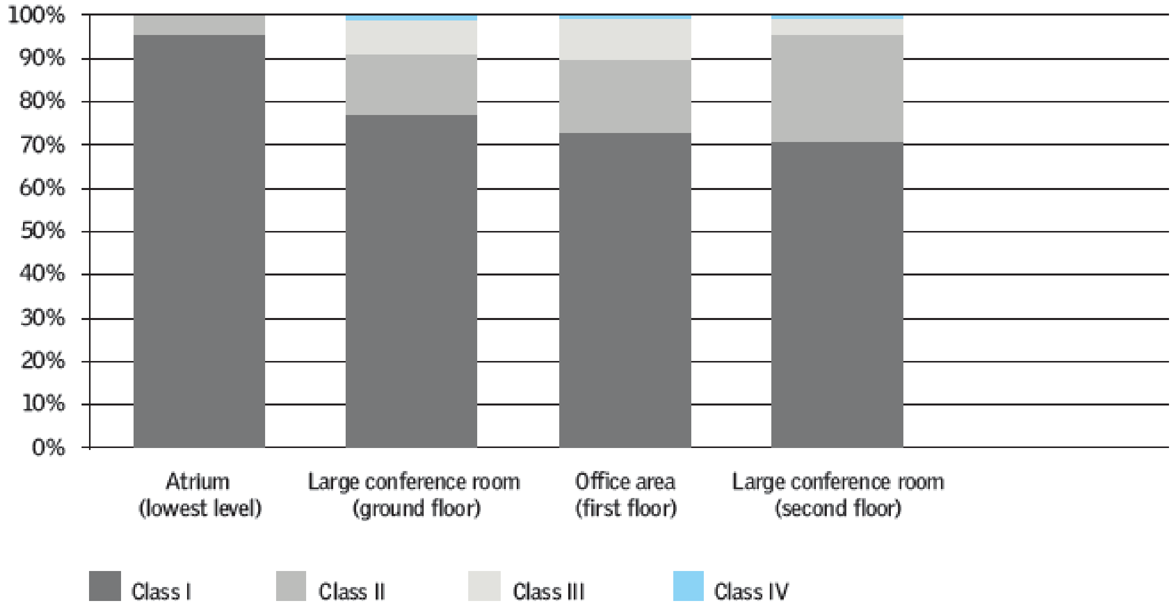
- Class I: Under 750 ppm (parts per million CO^2)
- Class II: Under 900 ppm
- Class III: Under 1,200 ppm
- Class IV: exceeding Class III

A background concentration of 400 ppm was assumed.

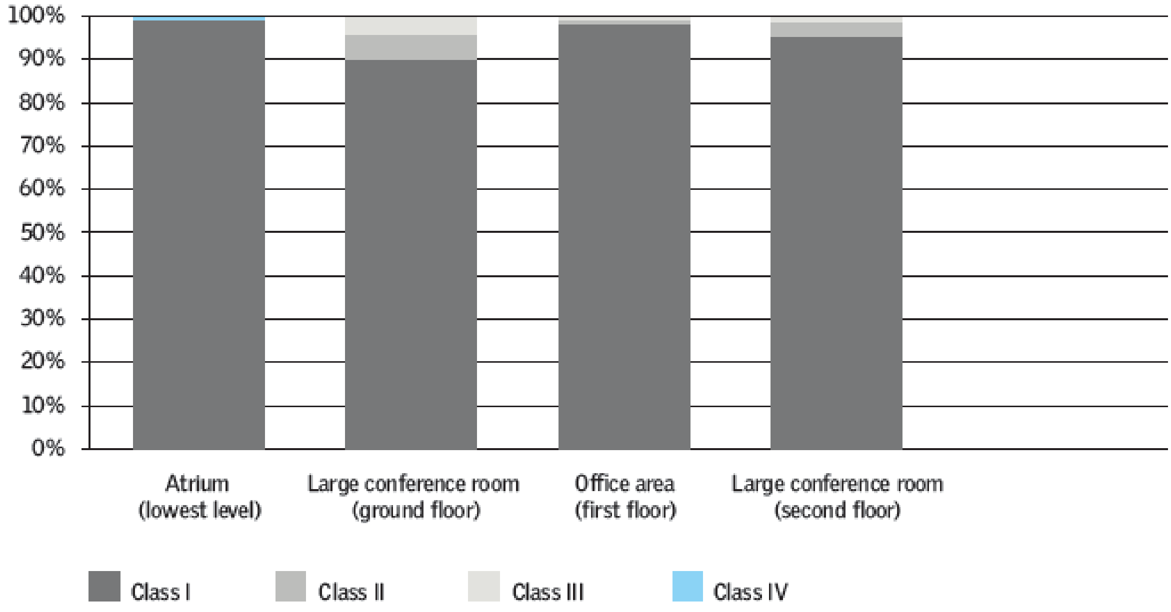


It is evident that the base of the atrium is Class I, the large conference room on the second floor is Class II, and the large meeting room on the ground floor and the office space on the first floor are Class III. The two following graphs also show that there are significantly lower CO_2 levels in summer than in winter, as that is when natural ventilation system is used most.

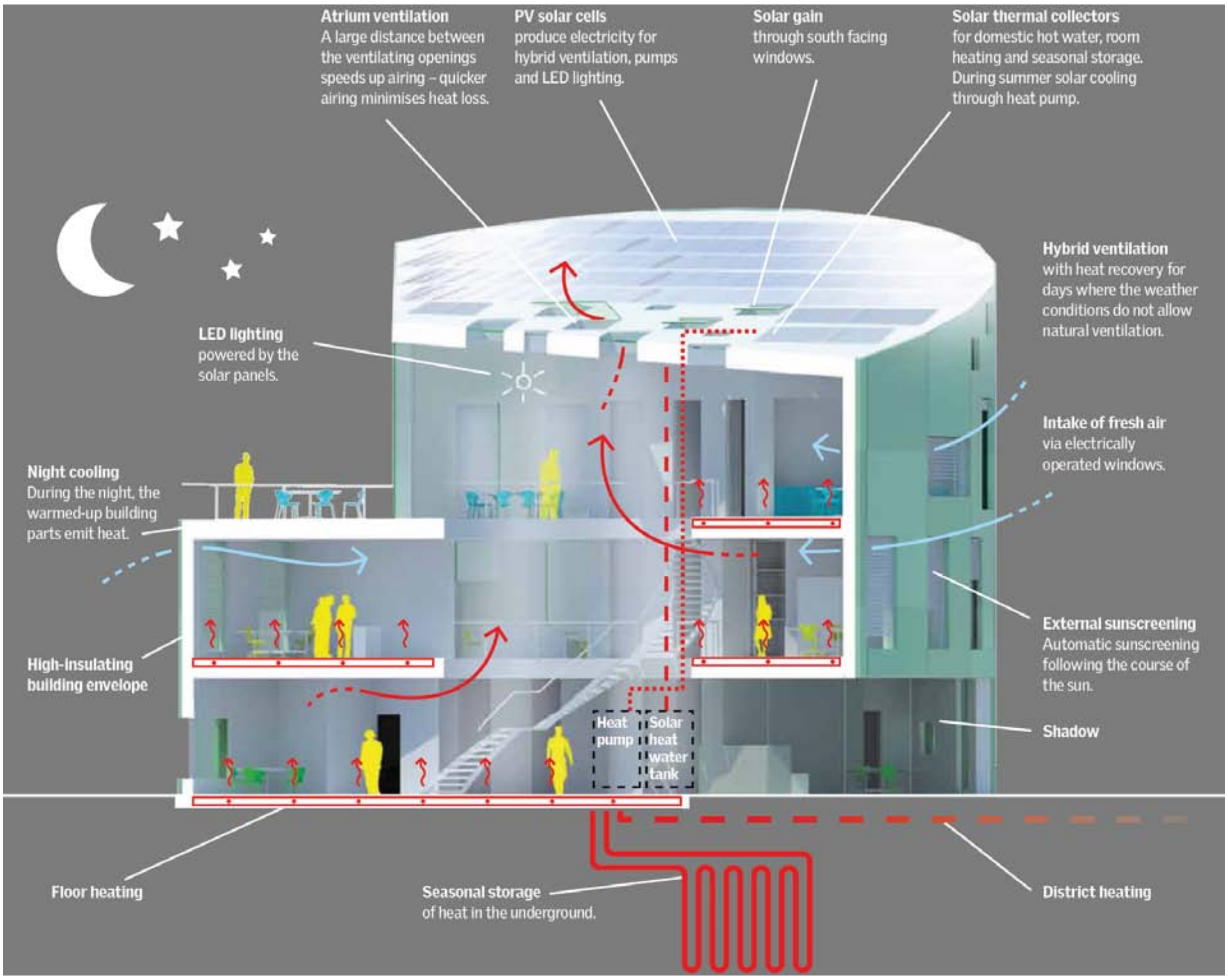
Indoor climate, atmospheric indoor climate, winter



Indoor climate, atmospheric indoor climate, summer



Appendix: energy concept – diagram



8 Appendix: Active House

Active House is a vision of buildings that create healthier and more comfortable lives for their occupants without impacting negatively on the climate – moving us towards a cleaner, healthier and safer world.

The Active House vision defines highly ambitious long-term goals for the future building stock. The purpose of the vision is to unite interested parties based on a balanced and holistic approach to building design and performance, and to facilitate cooperation on such activities as building projects, product development, research initiatives and performance targets that can move us further towards the vision.

The Active House principles propose a target framework for how to design and renovate buildings that contribute positively to human health and well-being by focusing on the indoor and outdoor environment and the use of renewable energy. An Active House is evaluated on the basis of the interaction between energy consumption, indoor climate conditions and impact on the environment.

- Comfort – creates a healthier and more comfortable life
  An Active House creates healthier and more comfortable indoor conditions for the occupants, ensuring a generous supply of daylight and fresh air. Materials used have a neutral impact on comfort and indoor climate.

- Energy – contributes positively to the energy balance of the building
  An Active House is energy efficient. All energy needed is supplied by renewable energy sources integrated in the building or from the nearby collective energy system and electricity grid.

- Environment – has a positive impact on the environment
  An Active House interacts positively with the environment through an optimised relationship with the local context, focused use of resources, and its overall environmental impact throughout its life cycle.

Source: Activehouse.info

Figure 9 shows Green Lighthouse performance by measured and calculated indicators in accordance with Active House categories – 1 = calculated, 2 = measured