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*Published in:*
Conference proceedings

*Publication date:*
2009

*Document Version*
Publisher's PDF, also known as Version of record

# Innovative retrofit to improve energy efficiency in public buildings

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## Keywords

Public buildings, energy savings, retrofit innovation, eco-buildings, $CO_2$ reduction, EU project, high performance

## Abstract

The BRITA in PuBs project within the EU Eco-Buildings programme started in 2004 and finished in spring 2008. The project aimed to increase the market penetration of innovative and effective retrofit solutions to improve energy efficiency and to implement renewable energy technologies.

A group of demonstration public buildings in the participating European regions (North, Central, South and East) were retrofitted. These public buildings can be used as drivers to heighten awareness and raise society's level of awareness of energy conservation. Secondly, the research work packages of the project include socio-economic research such as the identification of financing strategies, assessment of design guidelines and development of an internet-based knowledge tool for retrofit measures and case studies.

In this paper two demonstration projects are reported. The energy savings, the $CO_2$ savings and the economy of the Danish demonstration project, an old factory constructed in the 1930s and converted to a cultural centre, are described. Furthermore the constructions, the installations, the solar photovoltaic and solar thermal and the building management systems are reported.

The Norwegian demonstration project concerns the Borgen Community Centre located in a suburban area in Asker close to Oslo, the capital of Norway. The Borgen School was built in 1970 and retrofitted and converted in 2005 to Borgen Community Centre, a place for the whole neighbourhood. The main building, which is part of the BRITA project, contains a secondary school and facilities for health-care services and leisure-time arrangements. The energy-saving measures and the energy consumption are described.

The demonstration projects proved that introduction of the right concepts for energy saving measures and renewable energy integration into a renovation project can bring the resulting building up to an energy standard that is considerably higher than that required by the current national building regulations at a reasonable cost and payback time.

## Introduction

The first main pillar of the BRITA in PuBs project is the exemplary retrofit of 8 demonstration public buildings in the 4 participating European regions. The general aim of the retrofits is to reduce the primary energy demand for heating, ventilation, cooling and domestic hot water by factor 2 and at the same time improve the user satisfaction by also factor 2. The second pillar is research work, containing socio-economic research including an overview of various incentives, review of retrofit measures and case studies, assessment of existing and development of new design guidelines, and quality control checklists to secure a good long-term performance of building and systems. The third pillar is dissemination, containing the project's website, an e-learning module on ecobuilding, blackboard information sheets, architectural student courses, and facility manager training courses arranged in four of the demonstration buildings. The research and demonstration work is published to different target groups by means of numerous seminars and articles. BRITA in PuBs also participates in a joint dissemination activity undertaken by the four concurrently running Eco-Buildings projects within EU frame programme 6.

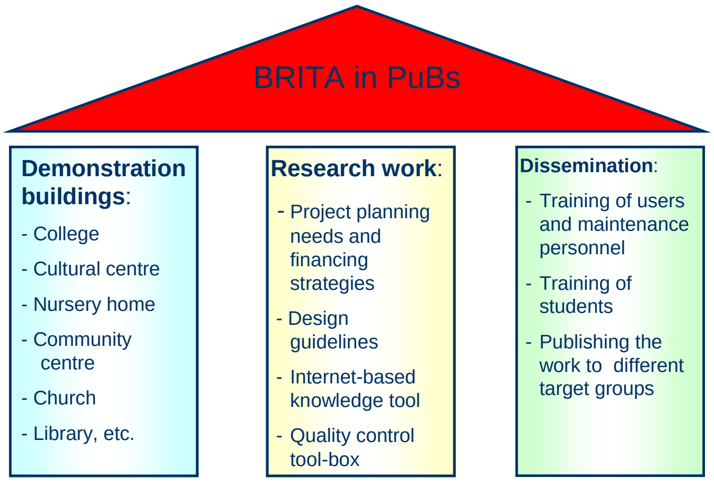



***Figure 1. Illustration of the three main pillars in BRITA in PuBs.***

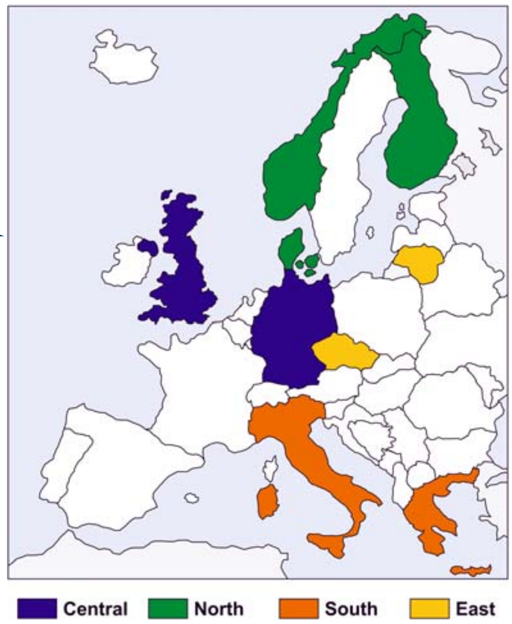



***Figure 2. Illustration of the four regional areas.***

**North:** Norway: SINTEF, NBI, Sunlab, Asker Municipality and Hol Church. Finland: VTT. Denmark: CENERGIA, UUF Copenhagen and SBi. **Central:** Germany: Fraunhofer Institute, City of Stuttgart. UK: IT-Power, Educational College of Plymouth. **South:** Italy: ENEA, Politecnico di Milano, University of Palermo, Garboli Conicos. Greece: N.T.U.A., EuDiti, Evonymos Library. **East:** Czech Republic: University of Technology, Brno. Lithuania: Vilnius Gediminas University. In this paper focus is on the Danish and the Norwegian examples. More information from the other examples can be found in [Cittero, 2005] and [Cittero, 2008] and on the Website www.brita-in-pubs.eu.

## Energy retrofit requirements in Denmark and Norway

For many years *Denmark* has had fairly strict energy requirements in the building regulations, an obligatory labelling scheme for buildings and an obligatory inspection scheme for boilers. Denmark has now tightened the energy requirements in the building regulations further and developed new labelling and inspection schemes. In multi-family houses and non-domestic buildings, the 25 % rule (recital 13) in the EPBD applies to all buildings, independent of floor area. Cost-effective energy-saving measures are required if renovation of the building envelope, or the energy installations, is higher than 25 % of the value of the building, excluding the value of the land, or if more than 25 % of the building envelope undergoes renovation. Furthermore cost-effective energy-saving measures not included in the original renovation plan have to be installed. Only churches, museums or protected buildings or buildings worthy of preservation are exempt from this requirement.

"Cost-effective energy-saving measures" are defined as measures that by simple payback calculation bring at least 33 % profit over a standard life time (dependent on the type of the measure). The cost-effective energy-saving measures are identified by the energy consultant as part of the certification of a building. There is a requirement for all buildings (also for small dwellings) to implement cost-effective energy-saving measures on the specific component in the case of renovation of roof, renovation of thermal envelope on external walls, renovation or change of windows, installation of a new boiler or change of heat supply.

In *Norway* the requirements for new buildings also apply to major renovations, major renovations being defined locally by municipalities, although defined by the Norwegian guideline as more than 50 % of the building area. New requirements will apply to new or repaired areas when there is a change of use, repair or extension, only to the affected parts. All buildings must meet the requirements of energy performance further described in the guidelines, either according to a) efficient energy performance or b) total net energy consumption.

## Energy-saving initiatives for motivating energy savings in existing buildings

The potential for energy savings in Denmark can be illustrated by the fact that the average energy consumption in existing buildings is nearly 3 times as high as the requirements in the building regulations from 2006. Approximately 75 % of all buildings were built before 1979 when the requirements were tightened for the first time. There are different types of initiatives which motivate and in some cases commit building owners to carry through the energy savings of existing buildings.

- *Economic incentives:* A duty is imposed on all energy consumption for heating on energy and $CO_2$ and that is also the case for the electricity consumption of households and the public sector. At the same time the duty on $CO_2$ quota means increasing prices on particularly electricity. These politically laid down conditions give considerable incentives to reduce the energy consumptions. Proposals for economic incentives should therefore urge people and the public sector to act environmentally sound and energy-efficient.
- *Regulation:* There are requirements in the building regulations concerning major renovation and also requirement for all buildings to implement cost-effective energy-saving measures on specific components. If regulation are to act as intended, it is very important that the rules are kept.
- *Information and campaigns etc*. There are a number of initiatives intended to motivate the building owner to carry through the energy savings e.g. energy certification of buildings, an agreement between government and energy supply companies, a new knowledge centre for energy savings and a specific amount of funds for campaigns etc.
- *Education, innovation etc.:* Education and in-service training courses for workmen, electricians and consultants influence the fact that the relevant and necessary renovation services can be offered. Innovation and new working methods are others ways of offering new solutions for the building owners.

Everything seems to show that it is not enough to use soft means such as information, knowledge communication, education, use of innovative method, renewables etc. It is also necessary to use more heavy methods like more regulation, or better economic incentives or the best option, a combination of both. The incentives should be chosen based on their costs-effectiveness. Furthermore it is necessary to consider how strict a regulation can be, and still be acceptable.

A retrofit has to be easy and quick to carry through and with a reasonable payback time. Other conditions than energy savings such as comfort and a good indoor climate play an important role and also the architectural retrofit has to be of high quality. There is a need to develop and demonstrate solutions for the building owners and for those responsible for the maintenance of public buildings. It is important that the manufacturers of building products, consultants and contractors work together and maybe in innovative ways. Analyses show that a way to reach consumers can be through banks and mortgage credit institutes. However, the situation today is not very favourable to loans for energy savings in many countries due to the financial crisis. Governments could have a mission here by setting up a guarantee for loans for energy conservation measures/retrofit. Package solution should be drawn up, so they can be sold on equal terms with insurance and pension products.

The aim is to achieve further savings in existing buildings. The annual savings should be increased to 1.25 % per year corresponding to a reduction of the total final energy consumption with 15 % by 2025.

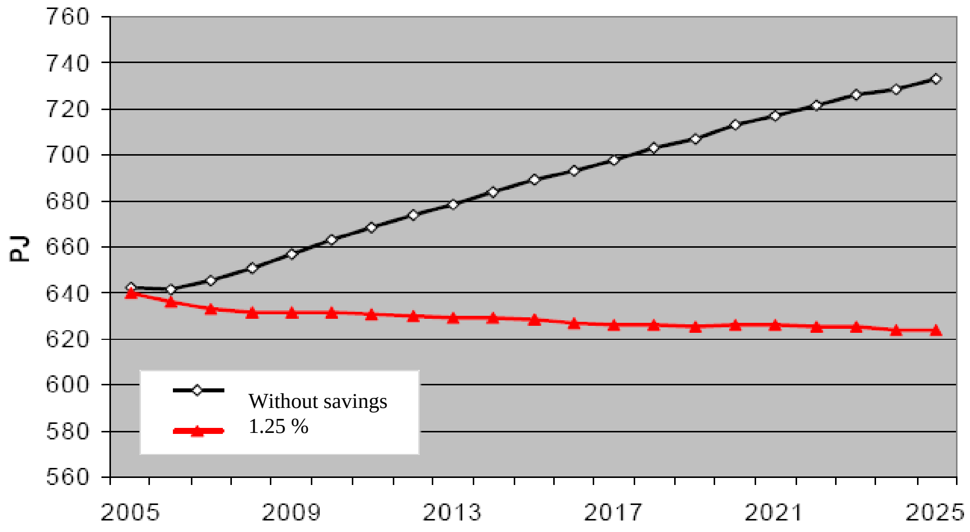



***Figure 3. Total final consumption with and without energy savings in Denmark*** [Danish Ministry of Transport and Energy (2007)].

To reach this ambitious goal there is a great need to develop new innovative technologies and to bring already known, but not finalised, technologies the last step to the market. Demonstration is urgently needed as investors and consumers should see the long-term economic advantage of investing in these technologies. In the following, two projects are described that use innovation methods and a high degree of energy-efficient measures.

## Demonstration project – Danish example

The site is located in an urban district called Valby in Copenhagen. The site is an old industrial area that is being completely reshaped, modernised and made into a new neighbourhood with its own identity including the building Ovnhallen (see below) renovated into a modern school and Proevehallen which will be a public cultural centre.

***Figure 4. The building site. Ovnhallen (to the left) and Proevehallen.***

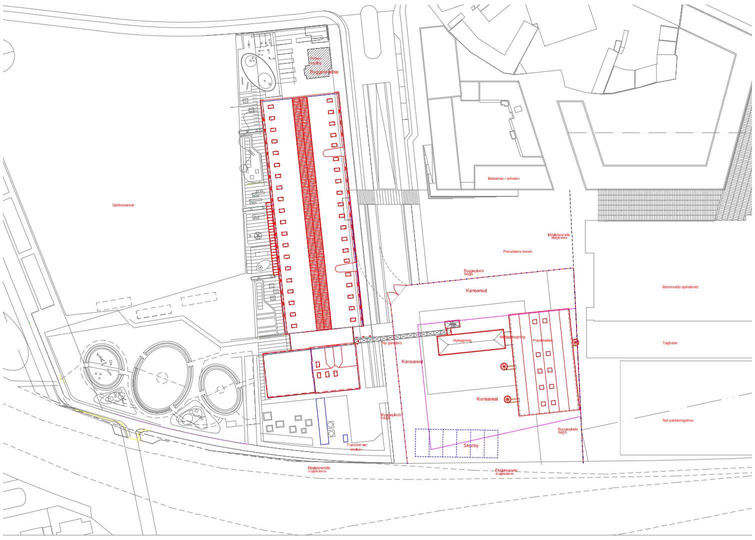


***Figure 5. The building site. Ovnhallen (to the left) and Proevehallen.***

Copenhagen is the capital of Denmark, latitude: 55.4°N, longitude: 12.4°E, altitude: 50 m. Temperate coastal climate. Mean annual temperature: 8°C, mean winter temperature: 4°C.

The buildings, Proevehallen ("The test hall") and right next to it Ovnhallen, were part of an industrial complex - a porcelain fabric. In Ovnhallen the porcelain was manufactured and in Proevehallen porcelain-insulators for the high-voltage electricity distribution cables were tested. Proevehallen is an old open-hall building constructed in 1930ies in 1 floor. However the height of the building was the same as that of a 5 floor building. See photos below.

***Figure 6. Proevehallen, seen from railway.***

***Figure 7. Ovnhallen – being retrofitted.***

## *Energy-saving concepts*

The target for energy saving was reached by implementing an integrated concept for energy savings and renewable energy utilisation. The energy savings were achieved by additional insulation of the thermal envelope of the buildings, low-energy windows and demand-controlled mechanical and natural ventilation. Renewable energy was utilised in two systems: An array of photovoltaic cells on the south gable wall and an innovative photovoltaic/thermal (PV/T) solar collector that was cooled by a heat pump and the heat delivered to the heating plant of Proevehallen.

### Building construction

Originally it was the intention to insulate the external walls on the inside to keep the architectural expression of the buildings' old brick walls. However, it turned out that for reasons of fire protection (law and regulations), this would require quite substantial and extremely costly treatment of the metal beam load supporting parts of the wall. Therefore it was decided to insulate the wall externally. This had no economic consequences for the project and from a technical point of view it was a clear advantage, as it is well known that external insulation is better at preventing thermal bridges than internal insulation.

**Table 1. Building construction data.**

| | Pre retrofit U-value [W/m$^2$] | Post retrofit U-value [W/m$^2$] |
|---|---|---|
| Walls | 1.6 | 0.18 |
| Roof | 3.1 | 0.13 |
| Windows | 6.0 | 1.56 |
| Doors | 6.0 | 1.56 |

**Heating**

The basic heating system selected for Proevehallen was a standard hydronic radiator system. This was not a special energy-saving measure of the project, so standard procedures for dimensioning the radiators, piping, pumps, etc. were used. The piping was insulated according to Danish standard specifications. The air supply in the mechanical ventilation system was preheated - if needed - by a heating coil. This was also supplied from the hydronic system. The monitoring of the heating energy consumption included this consumption.

**Ventilation**

The building was ventilated by a combination of natural ventilation – of the upper floor – and mechanical ventilation of the lower floors which included bathroom and toilets. The upper parts of the high windows were used for natural ventilation of the upper floor. As the openings were placed high above the ceiling, the incoming air were mixed with the indoor air – thus reducing the risks of cold draughts. The natural ventilation would required only when the gym on the upper floor was used by people generating heat that had to be vented out, so that preheating and heat recovery was not needed for this air exchange. The windows were demand-controlled according to $CO_2$ and temperature.

An efficient air-to-air heat exchanger was used for the mechanically ventilated part of the building. This balanced ventilation system kept the ventilation at a minimum for the toilets and supplied additional ventilation when $CO_2$, humidity (in the bathrooms) and temperature sensors demanded additional air exchange.

Based on the use of the naturally ventilated upper floor and the efficient heat exchanger in the mechanical ventilation system, the solar preheating of air could not be economically justified. The benefit and costs of solar preheating of ventilation air had not been explicitly calculated and shown in the original proposal, so this modification did not mean any changes for these calculations.

**Solar PV & solar PV/thermal (PV/T)**

In the original proposal a 25 kWp PV array was to be mounted on the roof of Proevehallen. In the design phase it turned out that the roof was constructed as a so-called “minimal-construction” and could not take the additional weight of the PV array. Therefore it was decided to place the array on the south gable wall – however maintaining the artistic expression, there was only space enough for 19 kWp PV arrays. As a consequence a combined solar collector/ solar cell panel was planned instead of the originally intended solar heating system and the remaining part of the PV array (6 out of 25 kWp) placed here.

**BEMS**

A Building Energy Management System (BEMS) was designed and installed to control the heating and ventilation systems. This will ensure optimal control of the building and thus save energy compared with simpler or manually controlled systems. The BEMS system is also used to record energy consumptions and data for temperature, $CO_2$, humidity plus external weather conditions that can be used for analysis with respect to indoor comfort, air quality and energy consumption.

## *Energy and water consumption*

**Energy demand: electricity**

The resulting electricity consumption is shown in the table below. The national benchmark for electricity is 62.7 kWh/m$^2$, and the predicted electricity demand is 47.8 kWh/m$^2$. It was furthermore estimated at the outset that the high-efficiency fans in the ventilation system and the use of the BEMS system would reduce the electricity consumption by 16.4 kWh/m$^2$. This meant that the measured electricity demand was 31.4 kWh/m$^2$ higher than expected. However, the explanation for this is straightforward: Proevehallen had become a real success as a local cultural centre and it was used far more than anticipated for theater plays and concert performances, which consumed high amounts of electricity for spotlights, amplifiers, etc. The very low figure for electricity consumption of the ventilation system showed that energy-efficient fans worked as expected. It was more difficult to evaluate the effect of the BEMS system.

**Table 2. Measured energy consumption.**

| | [kWh/m²a] | Total annual (kWh) |
|---|---|---|
| Total electricity | 70.3 | 127,000 |
| Electricity consumed ventilation system | 3.14 | 5,680 |
| Electricity consumed for lighting | 67.16 | 121,320 |
| Primary Energy (Total electricity x 2.5) | 175 | 317,500 |

**Energy demand: thermal**

The monitored yearly energy consumption (adjusted for the average number of degree days) for space heating is shown month by month for a 12–month period from October 2006 to October 2007, see Figure 8. It shows that the energy consumption was constantly decreasing during that period by approximately 4000 kWh. The reason for the lower energy consumption was the constant fine tuning of the operation of the energy system by the energy manager.

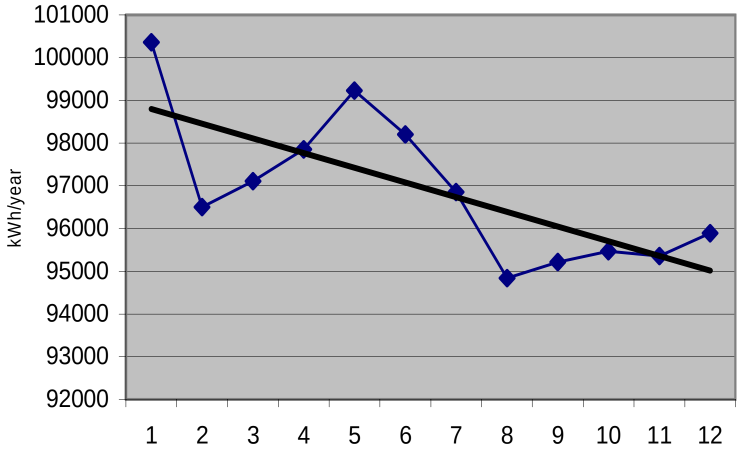



***Figure 8. Monitored yearly energy consumption for space heating shown for a 12-month period from October 2006 to October 2007.***

The graph below shows the monitored space heating depending on the heating degree days (HDD) supplied by the Danish Meteorological Institute. It shows a good correlation between energy consumption and heating degree days at the operation of the efficient energy system without unnecessary waste of energy. This perfect operation of the energy system was obtained by means of BEMS.

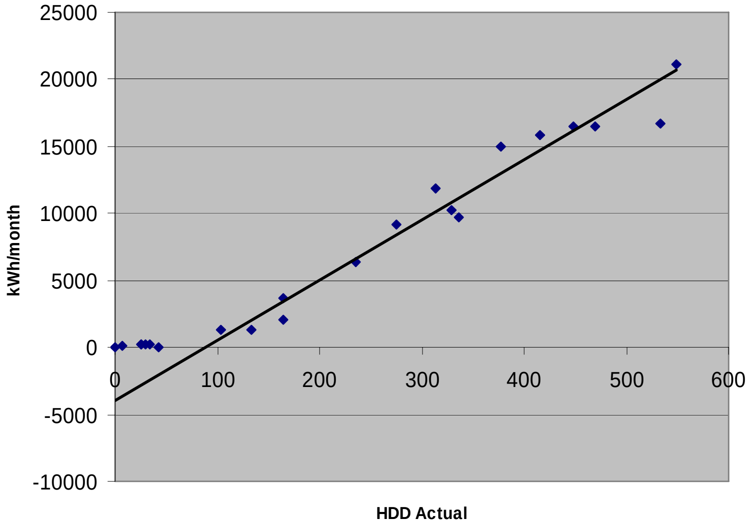



***Figure 9. Monitored space heating depending on the heating degree days.***

The building energy index is shown in the figure below. The reference building energy index for space was 132.0 kWh/m² per year. The target energy index for space heating (excluding domestic hot water) was 64.8 kWh/m² and the monitored as well as the adjusted building energy index was even lower. The actual energy consumption for space heating was 18 % lower than the target.

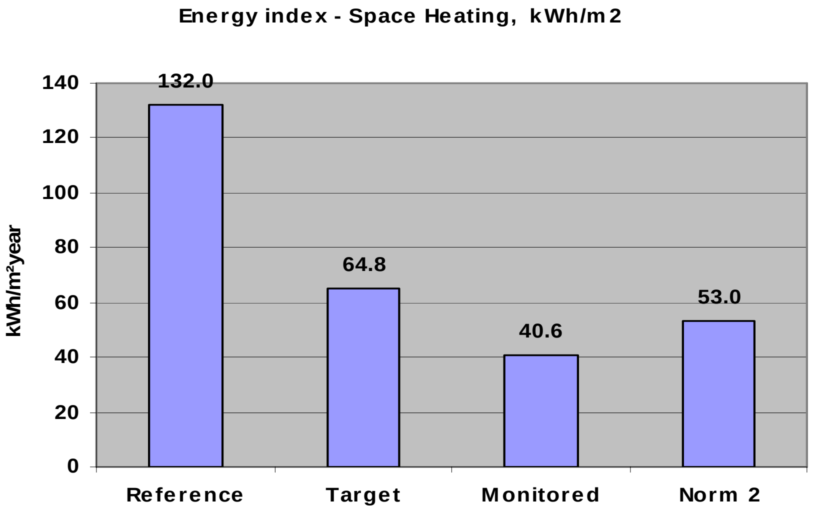



*Figure 10. Building energy index.*

**Water consumption**

The average hot water consumption was 1.00 $m^3$/day from August 2007 until May 2008 with a slight increase during the period.

**Table 3. Measured water consumption.**

| | [$m^3/m^2a$] | Total for the whole building [$m^3/a$] |
|---|---|---|
| Water | 0.20 | 365 |

The estimated reference hot water consumption (national benchmark) was 1.13 $m^3/m^2a$ and the estimated target was 0.88 $m^3/m^2a$ based on estimated savings of 0.25 $m^3/m^2a$. This meant that the monitored hot water consumption was far below the target. According to the caretaker, the main reason was that the school children did not always shower after their gym-classes. Actually, mostly they did not.

## *Conclusions and lessons learned*

The overall conclusion was that the energy-saving concept works according to the expectations maintaining a satisfactory thermal indoor climate.

The main impression was that by pushing and trying hard enough you can move “what is possible” quite a bit further than what was first indicated by building designers and contractors.

The examples of this experience are:

- The discovery of the architect that the minimal construction of the roof was already strengthened because of the crane, so it could actually carry the weight of the additional insulation
- The competition between window manufactures made it possible to come up with quite low U-values for the whole window even considering the rather small individual glazing areas.
- As always, the first reaction of the contractors was that “this is too expensive”. In the actual situation it was the BEMS system, but by negotiating, it was finally installed.

***Figure 11. Pictures showing the main building before and after retrofit.** The most visible features are the new daylight openings on the roof and new façades. The air inlet tower and a heat recovery unit (roof top) can be seen in the picture to the right. Architects for retrofitting: Hus Arkitekter AS. Photo left: B. Matusiak. Photo right: J. Rolland.*

## *Building type and size*

The Borgen Community Centre is located in a suburban area in Asker close to Oslo, the capital of Norway. The Borgen School was built in 1970 and retrofitted and converted in 2005 to Borgen Community Centre, a place for the whole neighbourhood. The Centre contains public enterprises and private organisations. The main building, which is part of the BRITA project, contains a secondary school and facilities for health-care services and leisure-time arrangements. One goal was to increase the possibilities for the local community to use the facilities, and thereby obtain social and economic benefits. The main building consists of 4,000 m$^2$ of renovated areas and 2,000 m$^2$ of new constructions.

## *Brief description of the renovation and its purpose*

The renewal of the main building was comprehensive, making the building suited for new working methods in school and for a diversity of activities as a result of new tenants from the neighbourhood.

The existing building was poorly ventilated, had minimal daylighting, and was not suited for modern working methods and cultural and social activities. The plan layout was totally changed.

The most visible feature of the renewed building is the daylighting openings on the roof and the new facades. Due to new regulations on snow loads, the roof construction had to be strengthened. The roof surface had to be replaced, and this allowed the installation of daylighting openings. The windows in the facades were enlarged and upgraded with respect to thermal insulation and solar shading.

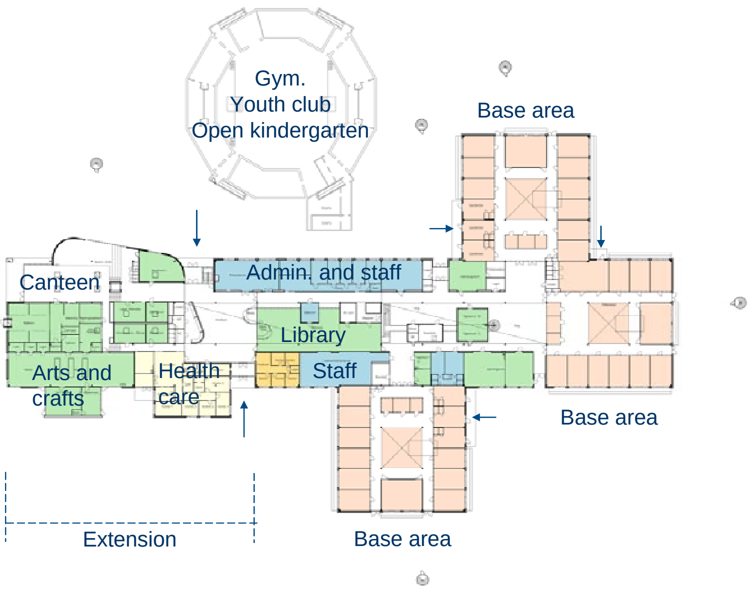



***Figure 12. Plan showing the main building.***

## *Research and development*

For the pre-project phase of Borgen Community Centre, an accompanying research and development project was initiated to assist the goal setting and planning. Within this R&D project SINTEF, a Norwegian research institute, had the role of facilitator, and researchers from SINTEF and the Norwegian University of Science and Technology (NTNU) were involved as expert consultants on environmental issues [Buvik 2003, 2008]. The task of sustainable retrofit did not have a purely technical focus, but a more integrated approach was used, combining building design and energy technologies, also including more 'soft issues' such as user involvement in the planning process and social issues. In order to create a vital local community and meet the need for more efficient use of resources, a shared location and coordinated use of facilities were emphasised.

The researchers' role at the early stage was to give input to discussions about plan layout and functionality as well as input to discussions about environmental issues. Analyses of various solutions followed next and ended with a building programme including statements of ambitions and intentions. In the design phase the researchers contributed to co-optimising a wide number of parameters and assessed how different building layouts, building structures and building envelope designs would influence the indoor climate and energy use for heating, cooling, ventilation and lighting.

## *Objectives*

Objectives regarding building suitability, energy demand and building materials were emphasised and put into specific terms:

- In accordance with standard practice, the school section should be space efficient and adaptable to various working methods and social events. A large part of the building should be accessible and suitable for various groups in the local community.
- In accordance with the Norwegian assessment method 'EcoProfile' the building and yard should obtain the best quality class for each of the three main areas: Environment, Resources, and Indoor climate.
- Purchased energy consumption for space heating, ventilation and artificial lighting should be halved by applying energy-efficient solutions and utilising renewable energy.

## *Strategy for energy efficiency*

In aiming to reduce the consumption of energy, the strategy 'trias energetica' was used, i.e. initially apply energy-efficient measures, then utilise renewable energy resources, and lastly supply remaining demand with an effective fuel burner.

- Area use
  Space efficiency and building flexibility were probably the factors that contribute the most to reducing the consumption of resources in a life-cycle perspective. In the community centre, public entities and private organisations shares rooms and equipment.
- Insulation
  Roof and facades were upgraded with respect to thermal insulation.
- Daylighting
  Daylight was used to reduce the expenditure of electrical power for artificial lighting. Daylight sensors controlled the use of artificial lighting. Due to new regulations on snow loads, the roof construction had to be strengthened. The roof had to be replaced, and that allowed daylighting openings to be installed. The windows in the facades were enlarged and upgraded with respect to thermal insulation and solar shading.
- Ventilation
  The building was provided with decentralised hybrid ventilation systems utilizing natural driving forces, buoyancy and wind, in order to reduce the demand for fan power. Demand control of airflow, heat recovery and low-emitting building materials further contributed to the energy savings.
- Energy supply
  Geothermal heat (heat pump) was utilised for space heating, preheating of ventilation air and domestic hot water. Under normal conditions the geothermal heat was enough, and the backup system of oil burners were used only a few days during winter.

## *Daylighting design*

Daylight was used to reduce the consumption of the electric energy for artificial lighting and, at the same time, to enhance architectural values. Separately operating zones for artificial lighting, and control by daylight sensors contributed to the energy savings.

A large glass surface facing north and placed high above the floor provided a high and even daylight level in the middle zone of the building. The daylight also penetrated to the side zones through the glazing in the partition walls and increased the daylight level considerably in these areas.

The glazing area was calculated to meet daylight factors required for this building. The optimal sloping was calculated to avoid shading devices and at the same time to ensure en extensive penetration of diffuse skylight [Matusiak].

The north-oriented glazing was supplemented with a narrow highly placed daylight opening to enable sunlight penetration to the building from the opposite direction. The roof of the ventilation duct functioned as a light-shelf.

*Indoor communication area before retrofit. Photo: B. Matusiak.*

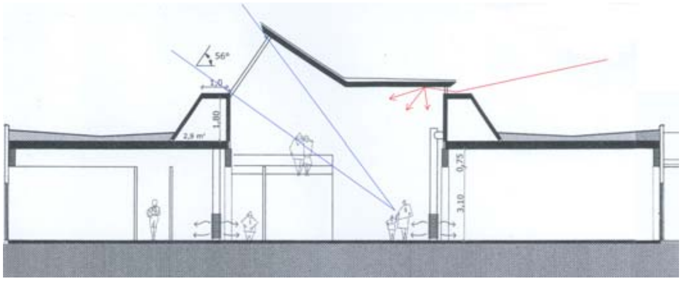
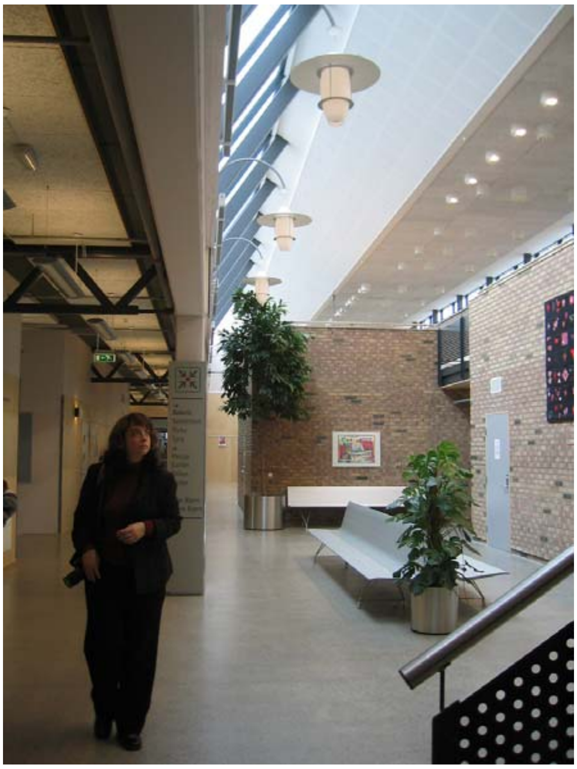


*Illustration: B. Matusiak [Matusiak]*



*Indoor communication area after retrofit. Photo: K. Buvik.*

***Figure 13. Pictures from Borgen Community Centre before and after retrofit.***

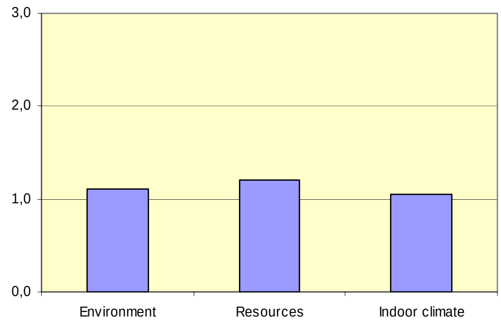
## *Environmental assessments*

A simplified environmental assessment was performed during the design of Borgen Community Centre [Andresen]. The assessment was based on the Norwegian EcoProfile methodology [Stiftelsen Byggsertifisering]. Due to the fact that the EcoProfile is primarily used for existing dwellings and office buildings, some adjustments to the method had to be made in order to make it suitable for school buildings still in the design phase. The assessment was carried out by the researchers, who also gave guidance on daylighting design and solar shading and were consulted on the design of the ventilation systems. Further the researchers made studies on exploitation of solar energy and application of double-skin façades.

EcoProfile classifies a building based on three main criteria: Exterior Environment, Resources, and Indoor climate. These main criteria have many sub-criteria. The criteria are assessed on three levels: Level 1 is 'low environmental loading', Level 2 is ''medium environmental loading' and Level 3 is 'high environmental loading'.

The assessment showed that the building design performed relatively well on all environmental criteria. The bar graph shows the result of the EcoProfile analysis. The project was classified in the best category: 'low environmental loading' for all the main criteria. The star diagram allows more detailed information on the resources sub-criteria.

Based on the assessment a focus list for further work was elaborated.



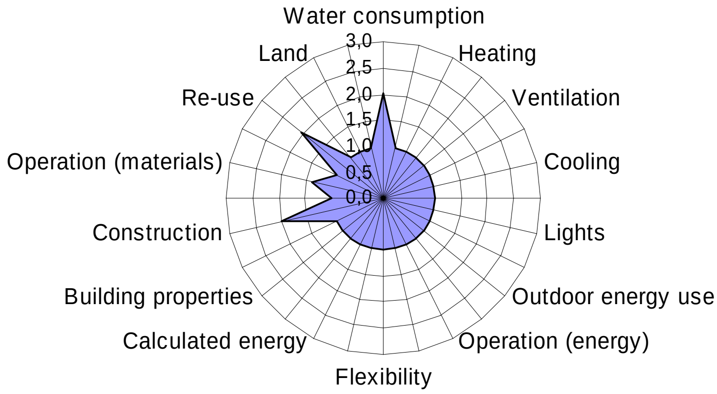



***Figure 14. Results of the EcoProfile assessment. The bar chart shows the levels of the areas Environment, Resources and Indoor climate. The star diagram shows the area 'Resources' with sub-criteria.*** *The parameters on the right side of the star, from Heating to Calculated energy, belong to the category 'energy use'. The parameters on the left side, ranging from Building properties to Re-use, deal with the characteristic of materials. Illustration: I. Andresen [Andresen].*

## Calculated energy consumption

The next table shows the estimated energy savings. The purchased energy consumption is calculated to be 50 % of new, existing Norwegian school buildings.

***Table 4. The budget for energy consumption for Borgen Community Centre.***

| | | |
|---|---|---|
| | **National Benchmark** | |
| | **220** kWh/m$^2$a | |
| | | |
| | **Budget for Borgen** | |
| | Energy kWh/m$^2$a | Power W/m$^2$ |
| Space heating | 29 | 30 |
| Heating ventilation air | 20 | 41 |
| Water heating | 13 | 10 |
| Fans and pumps | 15 | 6 |
| Lighting | 23 | 14 |
| Equipment | 11 | 8 |
| Cooling | 0 | 0 |
| **Total** | **111** | |

## Monitoring and evaluation

The energy consumption was estimated at 111 kWh/m$^2$a. The estimates are based on simulations with the Norwegian computer program 'Energy in buildings' [ProgramByggerne]. Measurements after retrofitting showed somewhat lower consumption than estimated in the design phase. Measurements before retrofitting showed 280 kWh/m$^2$a.

Energy consumption has been monitored daily since the renovated school was opened. In the beginning there were some problems regulating and adjusting the heat supply to some parts of the building. As a consequence, operation of technical installations was not optimal. Borgen Community Center has an advanced BEMS system with a large number of sensors and automatic valves, pumps, fans etc. It is therefore normal to spend some time on refining BEMS software and educating facility managers to optimise operation.

Overall, the implementation of energy-saving measures at Borgen Community Center has resulted in a total energy consumption that was even lower than the calculated expectations of 111 kWh/m$^2$a. In 2006 consumption was 107 kWh/m$^2$a and for 2007 the figures were as listed in Table 5.

***Table 5. The measured energy consumption in 2007 for Borgen Community Centre.***

| | [kWh/m²a] | Total annual (kWh) |
|---|---|---|
| Electricity | | 1,001,826 |
| Oil | | 6,174 |
| Total consumption | | 1,008,000 |
| Delivered to the church | | -116,500 |
| Total consumption Borgen | **98.5** | **891,500** |
| Degree days correction | | +31,203 |
| Corrected total energy consumption | **102** | **922,703** |

Consumption through the year is shown on the graph below.

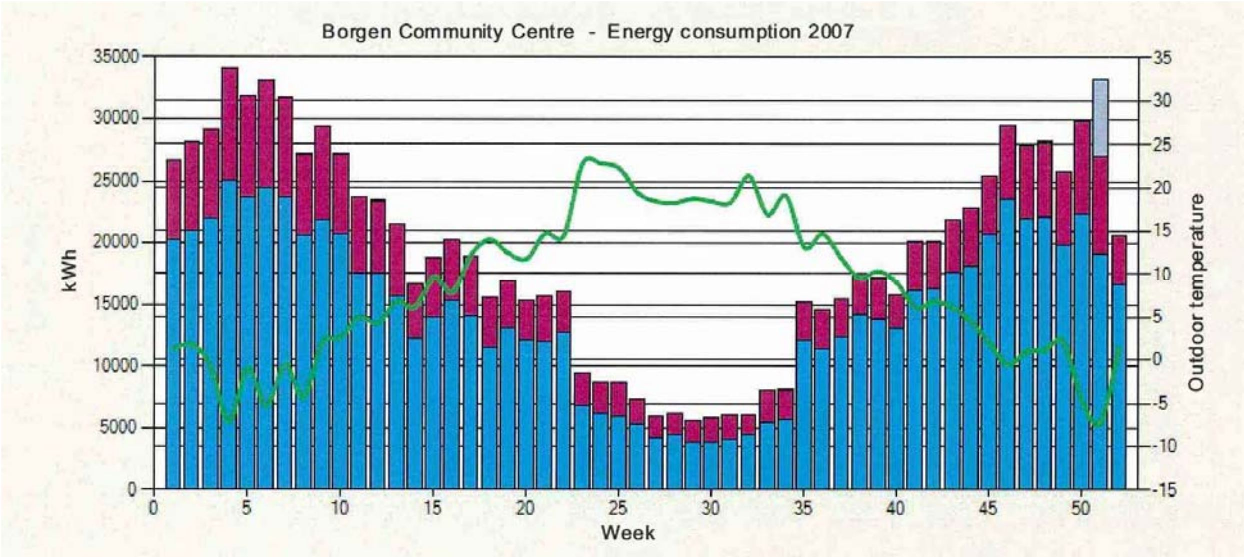



***Figure 15. Total energy consumption and mean outdoor temperature in 2007.***

*Blue:* *Electric power for heating and ventilation*
*Red:* *Lighting and appliances*
*Grey:* *Oil*
*Green:* *Mean outdoor temperature*

The preliminary results for 2008 indicated a total energy consumption of 100 kWh/m$^2$a adjusted for degree days. Based on today's energy prices (electricity 1 NOK/kWh (0.11 EURO/kWh), district heating 0.63 NOK/kWh (0.07 EURO/kWh) and oil 0.675 NOK/litre (0.08 EURO/litre)), the payback time will be approximately 9.5 years, which is very satisfactory. Asker Municipality has currently negotiated a very favourable energy price. However, when it expires in a few years, it is expected that the price will increase considerably and this will in turn reduce payback time accordingly.

A two-day training course was conducted for the building operating staff of Asker Municipality at the Borgen Community Centre. The training course was financed by the EU, as part of the BRITA project. Many of the other demonstration projects have similar courses. The intension is that the local authorities will give similar courses in other building activities.

## Conclusions

There is a great need to develop innovative technologies and to bring already known, but not finalised technologies the last step to the market. Demonstration projects are urgently needed, so that investors and consumers can see the long-term economic advantage of investing in these technologies. The Danish and the Norwegian projects are good examples of how to use innovation methods and a high degree of energy-efficient measures for retrofit. These two buildings together with the other six demonstration projects in BRITA in PuBs can serve as models for further development of the Energy Performance of Building Directive (EPBD). This is the way to solve the major challenge to the energy efficiency of buildings, namely the existing building stock.

**Denmark:** The Proevehallen demonstration project proves that by introducing the right concepts of energy-saving measures and by integrating renewable energy concepts into a renovation project, it can bring the resulting building up to an energy standard that is considerably higher than required by the current building regulations at a reasonable cost and payback time. It is possible by pushing and trying hard enough to move "what is possible" quite a bit further than what was first indicated by building designers and contractors.

**Norway:** Borgen Community Centre stands as a very successful project, representing a major contribution to the improvement of the environment and indoor climate. The goal of reducing energy consumption by at least 50 % has been achieved by a good margin. Measurements before retrofitting showed 280 $kWh/m^2a$, the national benchmark is 220 $kWh/m^2a$, and the measured energy consumption after retrofit was 102 $kWh/m^2a$. This experience with the technical principles applied to the building represents a good foundation for future buildings. The building has also been awarded a prize for being an environmentally friendly building, and the response from their users is very positive.

**More information:** For more information can be referred to the homepage of BRITA in PuBs project www.brita-in-pubs.eu. This can be seen as the main communication core and publications, deliverables, newsletters etc. can be found on the homepage. Furthermore the result from the project has been distributed by presentations on conferences, articles in national and international journals and courses for students.

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## Acknowledgements


The BRITA in PuBs project was carried out within the framework of EU Eco-Buildings programme as a cooperative effort. The authors gratefully acknowledge the input from all participants to the preparation of documents and reports used as source basis for this paper. Hans Erhorn and Heike Erhorn-Kluttig from the Fraunhofer Institute of Building Physics were coordinating and they developed the main concept paper for the project together with Ove Mørck, Cenergia.