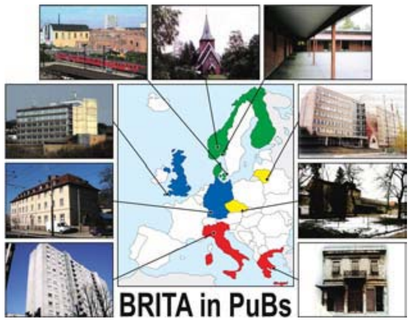
Project nº: TREN/04/FP6EN/S07.31038/ 503135

Acronym: BRITA in PuBs

Title: Bringing Retrofit Innovation to Application in Public Buildings– BRITA in PuBs



Instrument: Integrated project

Thematic Priority: 6.1.3.2.1 ECO-BUILDINGS

D8
Reports on the concept development of the demonstration buildings in BRITA in PuBs

Revision: **0**

Due date of deliverable: **31/10/2005**

Actual submission date: **15/11/2005**

Start date of project: **1/5/2004**

Duration: **48 months**

Lead contractor name for this deliverable and organisation:
Marco Citterio
ENEA

Project coordinator name and organisation:
Hans Erhorn
Fraunhofer Institute of Building Physics

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

D8
Reports on the concept development of the demonstration buildings in BRITA in PuBs

Authors:

Marco Citterio (ENEA, I)
Juergen Goerres (City of Stuttgart, DE)
Kevin Presland (Atkins, UK)
Gilbert Snook (PCFE,UK)
Jan Rolland (Asker Municipality, N)
Harald N. Røstvik (SunLab, N)
Ove Mørck (Cenergia, DK)
Mirslav Jicha (Brno University of Technology, CZ)
Pavel Charvat (Brno University of Technology, CZ)
Arturas Kaklauskas (Vilnius Gediminas Technical University, LT)
Saulius Raslanas (Vilnius Gediminas Technical University, LT)
Euphrosyne Triantis (NTUA, GR)
Eva Athanassakos (EuDiti, GR)

Disclaimer:

Bringing Retrofit Innovation to Application in Public Buildings – BRITA in PuBs has received funding from the EU 6th Framework Programme under the contract: TREN/04/FP6EN/S07.31038/503135

Content

Preface

The BRITA in PuBs project is an EU-supported integrated demonstration and research project that aims to increase the market penetration of innovative and cost-effective retrofit solutions to improve energy efficiency and implement renewable energy in public buildings all over Europe. Firstly, this will be realised by the exemplary retrofit of 8 demonstration public buildings in four European regions (North, Central, South, East). By choosing public buildings of different types such as colleges, cultural centres, nursery homes, student houses, churches etc. for implementing the measures it will easier reach groups of differing age and social origin. Secondly, the research issues include a socio-economic research study identifying real project-planning needs, financing strategies, the development of design guidelines, the development of an internet-based knowledge tool on retrofit measures and case studies and a quality control-tool box to secure a good long-term performance of buildings and systems.

Bringing Retrofit Innovation to Application in Public Buildings – BRITA in PuBs is therefore a leading project within the EU ECO-BUILDINGS programme. The ECO-BUILDING concept is expected to be the meeting point of short-term development and demonstration in order to support legislative and regulatory measures for energy efficiency and enhanced use of renewable energy solution within the building sector, which go beyond the Directive of the Energy Performance of Buildings (EPBD).

Introduction

Author: Marco Citterio

It is well known that the design of an ecobuilding can not be considered as a routine task: for its own nature, ecobuilding is a building that works in a closer contact with the environment. Exploitation of natural phenomena as natural ventilation, daylighting, passive cooling and heating, integration of Renewable Energy Sources in a framework of an energy efficient building envelope and of energy efficient building energy systems, are the main characteristics of a building that aims at to be defined "ecobuilding". In doing this task, designers have then to take into account that interactions between building and climate, building and plants, plants and users and users and building, often present problems that can not be solved with common procedures. Integrated approach is then a prerequisite of ecobuildings design and cooperation between architects and engineers has to be closer. A recursive design procedure is often a necessity: what was considered solved in a previous round can change during the following round, or, even more frequently, the solution of a problem opens another problem.

This aspect is evident in new buildings design process but becomes even more important in developing energy saving concepts and during the detailed design phase of a retrofit intervention on an existing building: real situation of some aspects is rarely well known at the beginning of planning phase. In some cases real situation becomes evident when the design phase is at an advanced stage, and part of the work already done has to be cancelled. This situation was well documented by design teams of BRITA in PuBs demonstration buildings, moreover these difficulties led to changes of some of foreseen retrofit measures in 4 of 7 buildings that completed their design work in due time. The changes procedure took several weeks for the necessary approval of all the involved parties, leading to, in some cases, a substantial delay of design time schedule.

Nevertheless, looking at outcomes of BRITA in PuBs project design phase, some interesting considerations can be done. Walking through the experiences reported by design teams of these demo buildings it is possible to notice that arising problems in design phase of ecobuildings were, in some cases, the opportunity to explore alternative solutions, and in some cases the first and most obvious solution would not have been the best one. At the same time, "*pushing and trying hard enough you can move "what is possible" quite a bit further than what is first indicated by building designers and contractors" (from "Proevehallen Lessons learned".)*

Of course this approach should require flexibility, open mind and decisional rapidity in all the partners involved: designers themselves first of all, building owners, authorities and, last but not least, bodies co-financing the intervention. In some cases "the barrier" was not to find the technical solution but achieve, in reasonable time, the approval of all these partners. Finding adequate technical solutions is, definitely, less time expensive and tiresome than convincing all the partners involved of the opportunity of choosing the new solution.

This report summarizes the concept development of retrofit interventions on 8 of 9 demonstration buildings originally foreseen in BRITA in PuBs project. The default of Italian building (Daniel's Student Hostel in Milan) in presenting its report was due to financial problems: public funding necessary for the realization of major refurbishments were not granted in due time.

Because it was clear that the uncertainty of achieving public funding would not have been solved in short time, the Italian demo partner Garboli decided to resign the project in April 2005. A substitution of the partner with a new company proposing another Italian demonstration building, that would have guaranteed the realization of intervention in due time, was not accepted by the Commission.

At the time of writing these notes also the situation of Greek demoproject presents the same kind of problem and has not yet been definitely solved: the Greek building report is then added at this document but has to be considered as an annex, being the design phase still incomplete in many parts.
In some cases the information provided by the design teams are not yet complete, due to the fact that in these cases the design phase is still ongoing and the final decision on some items has not yet been taken. They will provide necessary information in the final report.

1. Filderhof, Stuttgart

Author: Dr. Jürgen Görres

1.1. General data

1.1.1. General information

Year of construction: 1890
Year of renovation (start): 2005

Total floor area (m^2): 2875
after the retrofit the floor area is reduced to 2102 m^2
Surface to volume ratio (S/V): 0.3
Number of storeys: 4
Window/glass areas (m^2): 260

1.1.2. Site

Address of the building:

Pflegeheim Filderhof, Filderhofstreet 1, 70563 Stuttgart

The building was built in the south of Stuttgart. It is located in an urban surrounding.

Figure 1

On the south of the building is a local railway station "(Stuttgart-) Vaihingen". On the west, north and east side a small park/garden surrounds the building.

The geographic position is: Longitude 9,2 E, Latitude 48,7 N. The altitude of the district of Vaihingen is 420 m above sea level. The minimal winter temperature in 2004 was -10 °C, the maximal summer temperature 36.8 °C. The mean annual temperature is 8,6 °C, the mean winter temperature: 5,8 °C. Generally the minimum temperature in winter can drop to –24 °C. The norm degree days in Stuttgart are 3555. In 2004 there were 3386 degree days. For the Test Reference Year (TRY) Würzburg is the baseline.

1.1.3. Building type

The building is used as a nursery home and could be therefore put in the typology as both habitation and social facility.

1.2. Before retrofit

1.2.1. Building construction

The nursery will be renovated and enlarged by an extension. Since the energy consumption of the building is very high in comparison to the public building stock of Stuttgart, the building will energetic retrofit. Thereby the windows will be changed, the walls insulated, a new heating system with solar plant installed, the lighting system completely rebuilt and a PV-plant installed. After the retrofit the floor area of the existing building will be reduced to 2102 m² since part of the building will be torn down and replaced. An atria will be designed between the existing building and the new building wing. The new and the existing building are shown in the above figure.

Figure 2 existing building and planned extension

The building was built in 1890 (shown in figure 3 on the left hand side). The extension in 1952 on the right hand side of the entrance enlarges the building.

Figure 3 existing building

Figure 4 main entrance

Under architectural aspects the façade allows no external insulation. Thus an internal insulation is the only possible way to reduce energy transport through the walls.

The building is used as a nursery home for people with dementia. A typical patient room is shown in figure 5.

Figure 5 patient room

Figure 6 upper ceiling

All building components (roof, upper ceiling, cellar ceiling(figure 6) and walls) have no adequate insulation before the retrofit. The U-values are assumed in table 1.

Table 1 U-values [W/m² K] of the different components

	U-value [W/m²K]
windows	3,0
walls	1,4
Roof	1,0
upper ceiling	2,0
cellar ceiling	1,9

Besides the energetic improvement of the building envelope a new heating plant shall be part of the retrofit.

1.2.2. Existing heating, ventilation, cooling, lighting systems

The heating system was built in 1952. The boiler with a thermal heat power of 276 kW was replaced in 1988. The effectiveness of the furnace lays only by 88 %. The heating system has an old measurement control system. The preheated water goes with 80 °C to the radiators.

Figure 7 existing boiler

Figure 8 lighting system

The boiler system did not work very efficiently because of the dropping insulation and the missing control system.

The ventilation was realised by opening the windows. No mechanical ventilation system was installed. A cooling system is in this habitation-like use for Germany not necessary.

The lighting system consists of energy saving flourescent tubes and bulbs in the rooms and the traffic areas. It was controlled by manual switch on/off. It is shown in figure 8 exemplary.

The lighting system work not very efficient. The power of the installed lighting system runs up to 12.5 W/m² for 300 lx.

1.2.3. Energy and water use

	Measured year (2004)	**Total for the whole building**
Space heating	249,9 kWh/m^2 a	679468 kWh/a
DHW	above included	
Electricity	45,5kWh/m^2a	131134 kWh/a
Water	1.794 m^3/m^2a	5213 m^3/a

1.3. Energy saving concepts

1.3.1. Building construction

All the windows and entrance doors will be retrofit. The new windows will have high-efficient glasses with an U-value of 1 W/m² K and thermal spacers to minimize the thermal bridges at the edges. The retrofitting of the windows are completely designed, there is still work on the insulation of the walls, the cellar floors and the roofs.

Originally it was the intention to insulate the external walls on the outside with a composite insulation system (polystyrene insulation with plaster as cover). To keep the architectural expression of the building (frame of the entrance door, balcony, foundation of the building, see figure 1) the external insulation is turned into an internal insulation on most parts of the external walls. In the rear side of the building an atrium is placed. With this building, the whole complex is very compact after the rebuilding. Because of the internal insulation at the front walls a lot of technical details have to be solved in order to prevent thermal bridges. About 20 % of the front wall will get an external insulation. During the planning process ways to apply vacuum insulation were investigated. Unfortunately the vacuum insulation can not be applied in the project, because no system is suitable for our building. The long term behaviour of these systems is still unclear.
The installation of light wedges in order to secure more daylight through the windows in the area of external insulation is still under investigation.

The roof cannot be insulated like initially planned due to constructional reasons. The insulation will now be on top of the rafters instead of under and between the rafters. Additionally the use of some basement rooms changed. They will now be heated. Thus the thermal insulation had to be modified as well. Only a part of the upper ceiling is insulated at the top of the cellar. The other areas, which are used as kitchen and as dressing room, gets an insulation at the base floor and insides of the external wall.

1.3.2. Heating

The old heating system will be replaced completely. A combined heat and power unit (figure 9) with an electrical power of 18 kW and a thermal power of 34 kW will be installed.

Figure 9 Combined heat and power unit

Two condensing boilers with 150 kW and a thermal solar plant (60 m²) complete the heat supply. The system temperature of the radiators are reduced to 60 °C / 40 °C.

1.3.3. Ventilation

To transport the humidity away from the new bath rooms, a ventilation system will be installed. The air which comes into the building will put into the plain. Under the entrance doors is a small split. Thus the air can flows into the rooms and the humid air in the bathrooms will leave the building. In order to reduce the ventilation losses the mechanical system will include a heat exchanger. At the proposal time the ventilation system was planned with a heat recovery rate of 60 %. During the design phase the team decided for a system with a (much) better heat recovery rate of 85 %.. The room will be ventilated by opening the window.

1.3.4. Cooling

A cooling system is not necessary for this type of building in the German climate.

1.3.5. Lighting systems

A new energy-efficient lighting system will be installed. All lamps will get instead of a mechanical an electrical ballast. In the near of the windows the lamps will be controlled in function of the daylight. The installed electrical power of the lighting system will be reduced to 2.5 W/m² and 100 lx. The work on the improved daylighting concept is still ongoing.

1.3.6. BEMS

The building energy management system has two components. First a conventional control system in the building will be installed. It controls the water temperature of the heating system in dependence of the surrounding temperature and the room temperature. In dependence of the heat consumption, the control system has to decide, from which energy source the heat is produced: from the combined heat and power unit, from the condensing boilers, from the solar plant or from the storage tank. Finally the BEMS has to decide, when the storage tanks has to reloaded and when the combined heat and power unit has to reduce its power.

Additionally the Stuttgart's energy control model (SECM) is used, to control the daily energy consumption of building. With this system, the energy mangers in the office of environmental protection are informed automatically if the consumption is to high. Thus a long-term-controlling instrument is installed.

1.4. Overview of design process

1.4.1. Building construction

The building construction was guided by the architect and the building physician. By a finite element calculation the temperatures in the wall are quantified to assume the possibility strength of the insulation in the inside of the wall.

connection internal wall to external wall

without insulation **with** 5 cm insulation

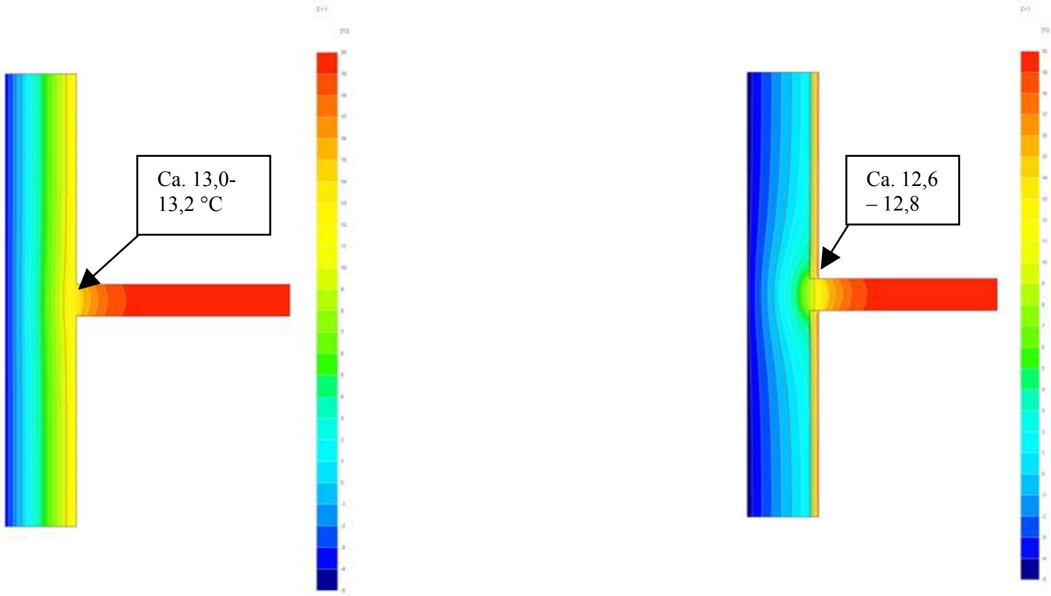


Figure 10 Finite element calculation for the wall temperatures

Furthermore details to involve the new windows into the external insulation are shown in Figure 11.

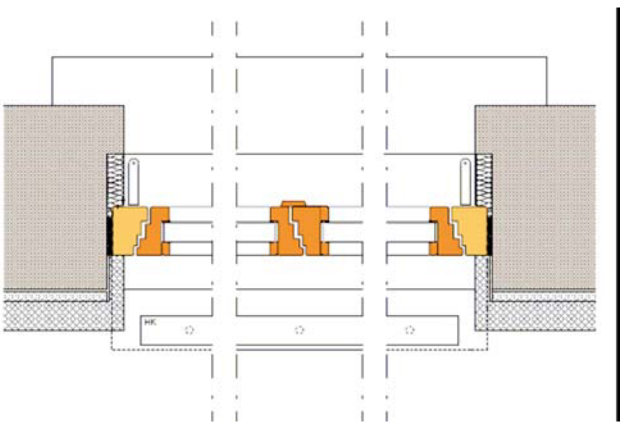


Figure 11 Embedded windows

Table 2 U-values [W/m² K] of the different components after the retrofitting

	U-value [W/m²K]
windows	1.0
walls with external /internal insulation	0.2 / 0.56
Roof	0.2
upper ceiling	0.2
cellar ceiling / cellar wall	0.4 / 0.5

1.4.2. Heating / ventilation / cooling and lighting systems

1.4.2.1. Heating/cooling

The heating is calculated by DIN EN 12831. The solar thermal is considered for heating the domestic water. The locations of the radiators are fixed. A thermals simulation was not be done.

1.4.2.2. Ventilation

The heating is calculated by DIN 18017 for the bath rooms.

1.4.2.3. Lighting

The lighting is calculated by DIN VDE 0100.

1.4.2.4. Solar thermal

The growth of the thermal plant depends on the growth of the roof. 60 m² can be integrated into the roof on the south site. The effectiveness of the solar plant rises to 85 %.

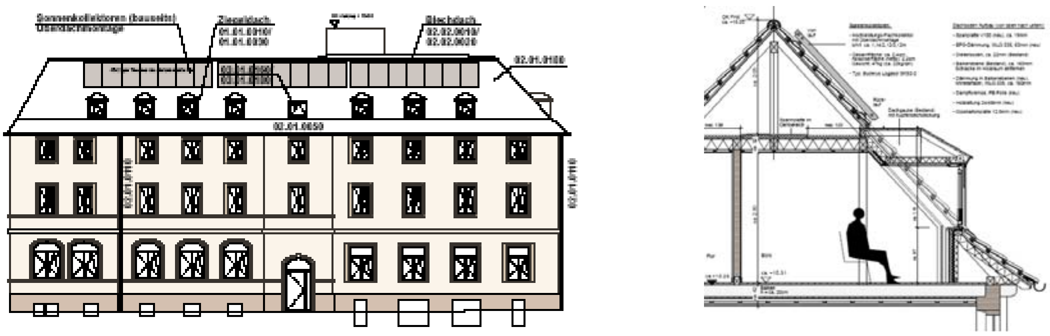


Figure 12 Thermal solar plant

1.4.2.5. Solar PV

The roof of the atria was modified to reduce the costs. Therefore the fraction of glass is reduced to a minimum. Thus the PV-integration of 100 m² in the glazed parts is impossible and the PV will now be integrated in the opaque roof. During the planning process, various applications of PV systems were investigated according to their efficiency, costs, architectural appearance. The area of 100 m² will not be reduced and consequently the energy gains by the PV-system will be higher than originally expected, because the glass integrated systems are not as efficient as the now chosen one.

The produced electricity is used in the building. If the production is higher than the use in the building, the electricity is put into the grid. For the account with electricity company, always the tariff for renewable energy by PV is used.
The mono crystalline PV-plant has an efficiency of 12 %. The electrical power lays in the order of 119 Wpeak / m².

1.4.2.6. CHP

For the combined heat and power plant the domestic hot water consumption was measured. In combination with solar heating plant and the electrical power consumption of the building the plant is laid out. The goal of economical plant is a high number of working hours. Thus the electrical power was reduced to 18 kW.

1.4.3. BEMS

The design process of the building energy management system is started in august. At the moment, only the controlling strategy is development.

1.5. Predicted energy savings

Energy saving measures, heating, cooling, ventilation	[kWh/m²a]	Total [kWh/a]
High efficient windows	20	42.600
Insulation of the opaque elements	80	167.400
Ventilation	39	82.500
Heating system	46	95.900
Solar heating system	11	23.400
Total heating energy savings	**196**	**411.800**
Heating system (CHP)	37	78.800
Efficient lighting	10	21.300
Daylighting transfer	3	6.400
PV-system	7	13.700
Total electrical energy savings	**57**	**120.200**

1.6. Predicted costs and payback

Energy saving measure/ investment/ savings/ payback	**Total costs [EUR]**	**Eligible costs [EUR]**	**Saving [EUR/a]**	**Pay-back periods [a]**
high efficient windows	82800	82800	1900	43.6
insulation (wall, roof, basement)	246700	228400	7400	30.9
Ventilation	99800	67800	3600	18.8
heating system	279100	176900	15000	11.8
solar thermal DHW	30000	30000	1000	30.0
efficient lighting	213000	85200	2900	29.4
daylighting transfer	20000	20000	900	22.2
PV-integration	98000	98000	7000	14.0
Total	**1069400**	**789100**	**39700**	**19.9**

energy prices for calculating payback periods:

heating energy 44 €/MWh
electrical energy 137 €/MWh
fictitious feed into the grid 514 €/MWh

1.7. Lessons learned

- architectural influences may have a strong influence into the retrofit concept even though a building is not listed. In the case of Filderhof it caused the change from external insulation to internal insulation on the outside walls. This may lead to less energy savings and result in more planning work on details in order to prevent thermal bridges.
- economic influences may change the material used for building parts. At Filderhof, the glazed atria roof will now have only small glazed parts. Designer had to react on the situations and transfer the planned PV system to the opaque roof parts.
- the use of rooms in the cellar has to be carefully planned in order to keep the heated zone as compact as possible. However the given situation and necessary functions of rooms may be more important for the building owner than the compactness and energy efficiency.

- the planning process over five years requires changes in the retrofit measures of a building. Therefore a detailed information on the planned measures and the resulting energy savings at the proposal time of the EU project is not always possible. Necessary modifications at the retrofit measures have to be presented and elaborated at the Commission. The time spend on that and on the waiting for the decision delays the planning process of the project.
- There are a lot of coordination work to done with several partners of the project inside the city and especially with financial government. Thus the project times enlarges to five year from the earliest planning phase to now. To take into account of all partners is a very busy work.

2. Plymouth college of Further Education

Author: Kevin Presland, Atkins / Gilbert Snook, PCFE

2.1. General data

2.1.1. General information

Year of construction: 1972
Year of renovation (start): 2006
Total floor area (m^2): 5784m²
S/V ratio: 0.21
Number of storeys: 8
Window/glass areas (m^2): 1528m²

2.1.2. Site

Plymouth College of Further Education is situated between Devonport Docks and Plymouth City Centre. It is within walking distance of the University Campus.
It is located at the heart of a city rich in maritime history and surrounded by glorious countryside. Situated at 50º 22’ 26’’ North, 4º 10’ 03’’ West and at an altitude of 19.9 m above mean sea level. The climate is ‘temperate’ with generally mild winter temperatures varying between 4ºC (Min) and 8ºC(Max).
In summer the bright sunshine is interspersed with occasional showers to create a lush green environment. Summer temperatures vary between 13ºC (Min) and 19ºC (Max).
Mean annual temperature is 10.6º C with mean winter temperatures at 6.3ºC.

2.1.3. Building type

Education and Research Facility – Post 1970.

2.2. Before retrofit

2.2.1. Building construction

The building was erected using a simple cavity wall construction and single glazed windows, all of which results in very low insulation values. The existing walling is typical of its time with an outer face of imperial sized bricks and a 50mm dry cavity with no insulation. 150mm concrete blocks form the inner skin off the concrete floor plates. Existing window units are single panes in metal frames. The external facades, in common with many buildings of its type and age, are now in a poor state of repair, and suffer particularly because of their close proximity and exposure to the South West coast line, with its prevailing weather conditions. The existing U Values are:

Element	U Value (W/m²k)
Window (centre of pane)	5.64
Walls	0.54
Roof	1.95
Ground Floor	0.73

The following particular problems were identified with the existing construction:

1. **Overheating/Rapid Cooling**: With un-insulated building facades and high window/glass areas the inevitable consequence is summer time over heating through high solar gain and rapid cooling in winter.
   The building is noticeably hot in summer creating an unpleasant atmosphere particular when the temperature regularly exceeds the accepted comfort level of 26ºC.
   In winter a high heating load is necessary to maintain ambient room temperature because of thermal loss through walling and glazing.
   Draughts are also noticeable at external walls from ill fitting windows. These are also a consequence of air movement due to the convection cycle under radiators, or as warm air moves towards ‘cold bridges’ in the building fabric.

No insulation to existing structure

2. **Ageing Fabric Profil**e -

- Building Facades: The external façade of the building has been exposed to coastal wind and rain since construction with little or no soffit protection at roof level. It is evident that areas of mortar have deteriorated under these conditions particularly where repeated patterns of wind driven rain has occurred.

Mortar and brick deterioration at base

Little or no soffit at roof level to shield building facades

- Windows: The existing single glazed metal frame windows are now at the end of their life expectancy and showing signs of deterioration around their seals. Some no longer open. Some of the windows have received a painted finish which is now flaking. Windows of this age and type exhibit a U Value performance in the range of 5.6 W/m²K- over twice current UK standards.

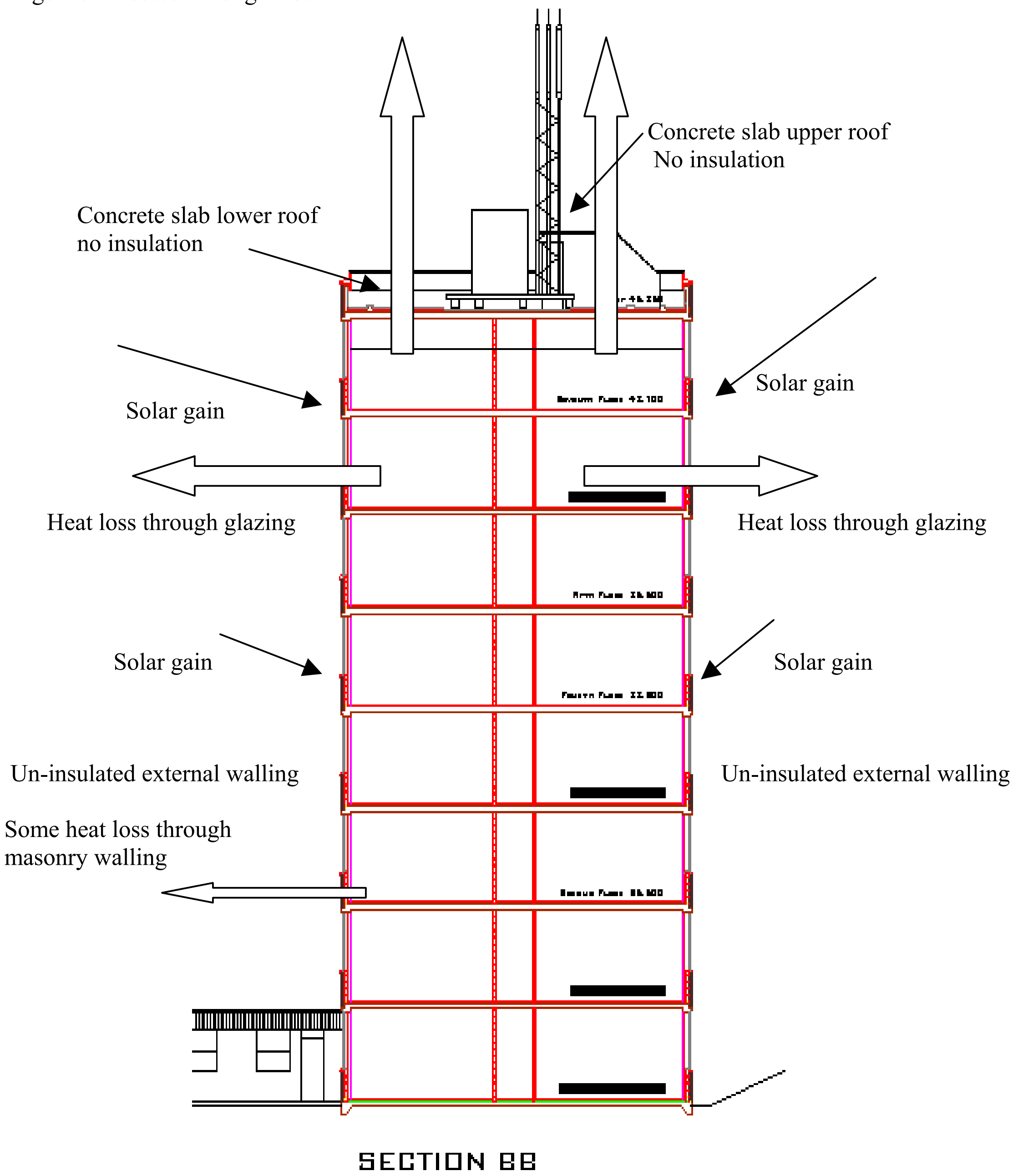
paint flaking on panels and window

- Roof Construction: The principal concern is the lack of insulation. The roof is effectively divided into a lower and upper roof section. Both these areas are waterproofed with asphalt directly over the concrete roof slab. Taking into account that the roof area mirrors the building footprint of 725m², this effectively forms a major area of heat loss potentially greater than losses through glazing and significantly increasing the building energy requirement. It also promotes overheating.

No insulation between slab and waterproofing

Lack of insulation causes significant heat loss in winter and solar gain in summer

Large Heat Losses Through Roof



3. **Water In-efficiencies:** As part of the college's commitment to sustainable development, waterless urinals were fitted in the past 2-3 years, saving approximately 460m³ of water each year. However, percussion taps and old we cisterns continue to use unnecessarily high volumes of water.

2.2.2. Existing heating, ventilation, cooling, lighting systems

2.2.2.1. Heating

The existing heating within the Tower Block is a wet system served from the large central boilers that serve the whole site, and a piped distribution system serving natural convector units within the tower block itself.

Existing Plant Room

The main boilers are oversized for the site as capacity had been built in during the original construction for expansion of the site to include a second tower block which was never constructed.
Due to the age of these boilers and their general inefficiency, it is proposed to replace these with new high efficiency modulating boilers and a completely upgraded pipework and distribution system within the boilerhouse including new variable head pumps to maximise plant efficiency.
The existing natural convector units within the tower block will also be replaced as part of the upgrading works at each floor level.
Wherever possible, existing pipework external to the boiler house including underground and rising mains will be re-used if it is in good order and will provide a minimum of 15 years life without the need for major maintenance or upgrading.

2.2.2.2. Ventilation

The existing ventilation system comprises openable windows. There is some extract ventilation to specialist areas such as the hair salons and some of this may require retention in the new scheme in order to ensure that the airflow rates in these areas are maintained.

There is currently no automated control of the ventilation to the building and no use is made of night time cooling. These items are to be addressed as part of the new ventilation design concept.

2.2.2.3. Cooling

There is currently no mechanical cooling to the building other than the server/equipment rooms which are fitted with small comfort cooling units. It is likely that these will be retained in the revised scheme in order to ensure that the operation of equipment is not affected by high temperatures.

2.2.2.4. Lighting Systems

The existing lighting comprises surface and suspended fluorescent batten fittings, compact fluorescents and some tungsten display lighting. The lighting is for the most part manually controlled via local switches apart from the areas where previous upgrading works have incorporated presence detection.

There are large windows which provide a good degree of natural light, however the manual lighting controls do not take advantage of this and switch off lights as and when the light levels are sufficient to be met by daylight alone. This will be addressed in the revised scheme design.

2.2.3. BEMS

There is an existing Satchwell BAS series BEMS serving the tower block building and the rest of the college campus. This will require updating and upgrading to serve the needs of the refurbished tower and central boilerhouse. Wherever possible, existing controls will be retained and integrated into the new system.

2.2.4. Energy and water use

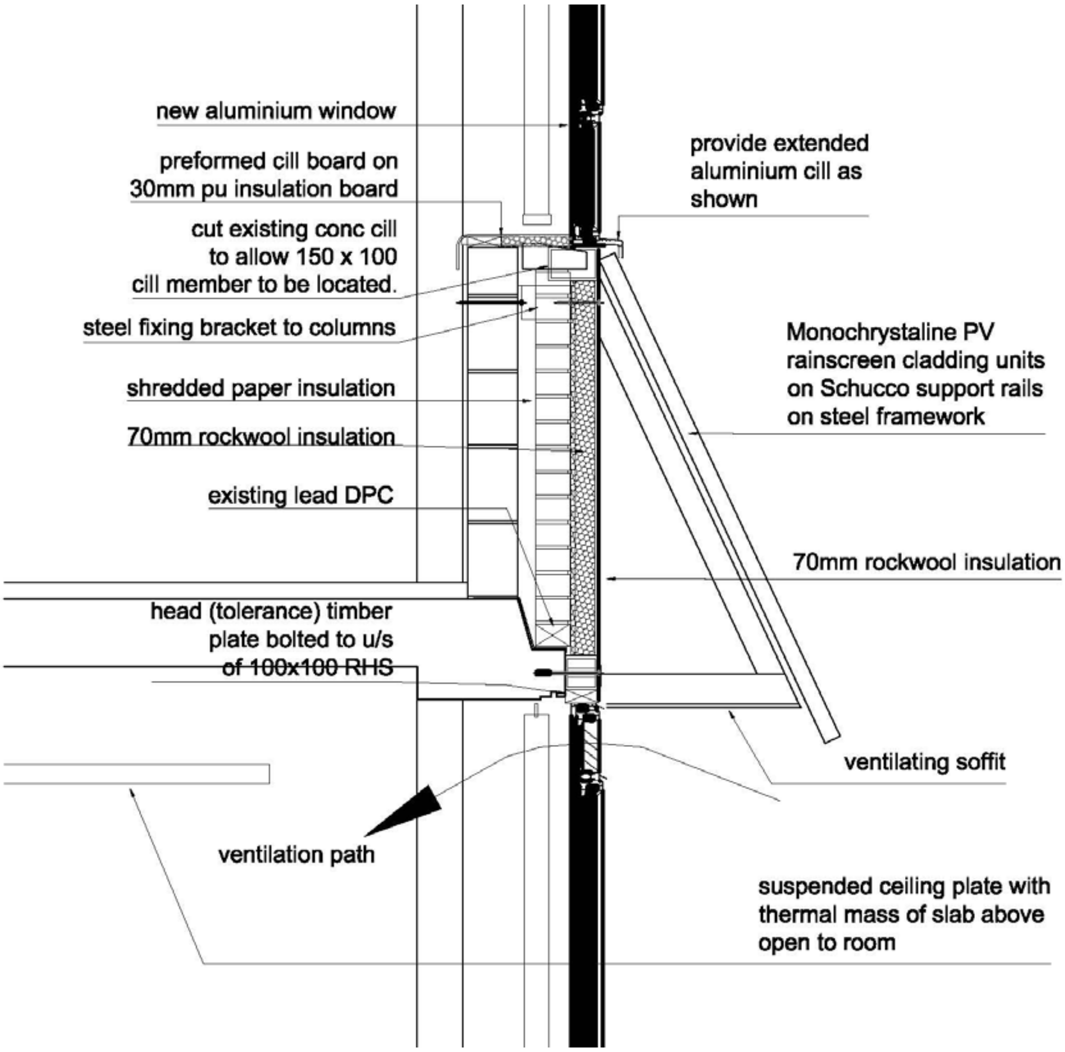
	Measured year (..)	**Total for the whole building**
Space heating	207kWh/m^2 a	1.2MWh/a
DHW	kWh/m^2 a	kWh/a
Electricity	112kWh/m^{2}a	650000kWh/a
Water	0.373m^3/m^{2}a	2165m^3/a

2.3. Energy saving concepts

2.3.1. Building construction

- The replacement of the existing single glazed window units with new thermally broken double glazed reversible units. New units to include solar glare control to reduce thermal gains, sealed elevations to reduce infiltration gains, improved U-Value of 1.2 W/m²K at centre of pane and reversible window action for reduced cleaning and maintenance costs.

- The installation of a photo-voltaic system architecturally integrated into the building envelope. This installation is designed to be capable of delivering circa 57,000 kWh per year at the same time providing weather protection , ventilated rain screen cladding and solar shading to the south and west facades. On the West elevation the curtain wall to the stair well will be replaced with photo-voltaic panels laminated within the glazing. This will permit approximately 30% light transmittance allowing sufficient day light whilst reducing thermal gain.



Typical PV installation detail

- Full insulation of facades and roof. The design is to incorporate an insulated envelope approach generally utilising an inert mineral wool slab. The insulation will specifically be chosen to provide a dual density for use behind rainscreen cladding, providing high resistance to wind and rain at height, low fixing requirement and robust face detail to avoid installation damage. Because of their composition the insulation will also contribute to the acoustic performance of the building, aid condensation control and be A1 fire rated when tested to EN 13501-1. The aim will be to solve the cold bridging inherent in the existing construction by addressing this issue as part of the façade treatment. It will also be possible as part of the glazing re-fit installation to introduce cavity wall insulation where this had not previously existed. Finally a best technical solution will be adopted to the proposed 'inverted roof' to insulate the existing concrete decks above their waterproof layer.

- Rainscreen cladding – Will be introduced to the North and East non- pv elevations. The cladding will enhance the building elevations and will be chosen based upon the following criteria:

a) Cost
b) Technical Approach
c) Appearance
d) Sustainability
e) Long Term Maintenance
f) Product availability / delivery periods

- Glazed Screens – Will provide borrowed light into corridors. In addition the new vertical window position to the south elevations will increase natural light levels to the south of the main corridor. Reorganisation of the door layout to the north of the corridor will allow more light fall into this area, thus increasing daylight levels.

Consideration of quality, health and environment is integral to the concept development and product selection within the QSE packages contained in Atkins BS 9001, 14001, and 18001 processes. The ICE Demolition Protocol is being used to evaluate the value of the demolition material (compared with primary materials).

2.3.2. Heating

The heating is proposed to be a fully zoned wet system served by an upgraded, centrally located boiler system. The existing boilers are to be replaced with three in number high efficiency modulating boilers sized to suit the existing site load and that of the upgraded tower block.

These boilers will be sized such that two boilers can serve 66% of the total maximum heat demand of the building to allow for maintenance and servicing of the third boiler without a substantial loss of heating performance.

Currently, further work is ongoing to assess the heat loads of the areas of the site not under the scope of the Tower Block refurbishment project, and this, once completed will permit accurate sizing of the central plant.

It is likely that due to the increased insulation levels and better draughtproofing of the tower block, that the heat demand of this building will decrease substantially and therefore the central plant will be downsized accordingly. However, much of the plant size will be dictated by the remainder of the campus and its associated heat loads.

Within the Tower Block, the existing heat emitters will be replaced with high efficiency convectors and radiators served from a zoned distribution system.

The zoning of the building will be divided such that the east and west elevations are run independently to maximise the efficient use of the plant. Zoning will also be carried out on a floor by floor basis such that the upper floors where heat rising through the building is likely to increase the ambient temperatures, can be shut down in advance of lower floors where heat input is still required.

The system will be fully automated and BMS controlled.

Zone sensors will be fitted in each area and linked back to the BMS for both control and monitoring purposes.

Averaging sensors will be provided in larger spaces to ensure accuracy.

Heat metering will be incorporated into the main flow and returns from the central plant room to the various areas of the campus. The outputs from the heat meters will be logged and monitored by the BMS such that the energy consumption of the areas can be identified and any deviation from the normal energy use profile noted. Such deviations could indicate plant faults or inefficient use of energy by poor control or user discipline with respect to closing of doors and windows to minimise heat loss.

2.3.3. Ventilation

General room ventilation

The ventilation strategy for the building is based on a natural system whereby mechanical plant is eliminated as far as is reasonably practicable.

Thermal Modelling has been carried out by constructing the existing building within computer software, and then using this model to formulate the general strategies and concepts for heating ventilation and cooling.

The strategy is based upon night time cooling of the thermal mass of the structure to maintain a reduced internal temperature during occupation.

External ambient air will be used during occupation to provide both the required air change rates to meet the Building Regulations and relevant Chartered Institute of Building Services Engineers guidance and also cooling of the space where external ambient conditions will permit this. The free area of the louvres has been selected such that the required air flows can be achieved based on normal external conditions.

It is clear that a fully natural scheme has an inherent risk that the airflows could be reduced in the event of very still external conditions or that the cooling effects may not be achieved if the external ambient temperature conditions are above average. This risk is not believed to be significant and a natural scheme should be followed in preference to introducing plant which will consume energy.

High level louvres in each room will provide the inlet and outlet air paths for the natural vent strategy. These louvres will be BMS controlled such that they are fully opened at night to permit the night time cooling to take place. Once the space temperature has dropped to the required set point to maximise the stored “coolth”, the louvres will close in preparation for occupation.

By day, the louvres will be controlled to maintain the required air change rate and to maintain comfort temperature as far as is reasonably practicable.

Opening windows are also to be included into the scheme to permit boosting of the natural ventilation as required to deal with higher than average heat loads during the day or special conditions that cannot be met by the louvre system alone.

The ventilation system will be zoned by the BMS but also some degree of local control will be integrated such that the rooms are controlled dependant upon occupancy and heat gain. All of the control strategy will be designed to maximise the efficiency of the system and its use.

Stairwell Ventilation

The ventilation to the two main stairwells will be achieved by a natural stack effect utilising high and low level controllable louvres within the stairwells.

This stack effect will also assist in the ventilation of the corridors as there will be a tendency for the air to be drawn from the corridors into the stair towers when the connecting doors are opened.

Specialist and WC Core Areas Ventilation

As far as is reasonably practicable, the ventilation to the specialist areas shall be by natural means. Where this is not possible due to the required airflows not being achieved by natural means alone, localised mechanical extract will be considered.

This will only be installed to ensure compliance with legislation/regulation as in the case of the toilet areas where the air change rate has to be at a guaranteed and maintained level. Low energy consumption fans will be utilised and the minimum amount of energy consumed to service these requirements.

2.3.4. Cooling

No mechanical cooling will be used in this project unless this is absolutely unavoidable due to the specialist nature of the space such as server/equipment rooms where temperatures are critical to equipment function as detailed above.

The cooling of the building will be achieved by permitting the internal temperature to fall overnight, and for the exposed thermal mass to drop in temperature. The cooled mass will then assist in maintaining a lower internal temperature during the occupied periods.

Thermal modelling carried out during the development of this area of the design indicates that night time cooling in conjunction with solar shading and the natural ventilation strategy, will maintain temperatures within acceptable limits with no requirement to add mechanical cooling into the general areas of the building.

The addition of solar shading to the building which forms part of the Photo Voltaic system has been proven to reduce the solar gains in the building by more than 50%.

2.3.5. Lighting systems

Lighting to the refurbished building will as far as is reasonably practicable be provided by natural daylighting. Calculations are being undertaken to assess the glazed areas of the building with respect to the penetration of natural daylight into the spaces. It is expected that due to the size of the windows that there will be a large amount of daylight available during normal hours even with the inclusion of the solar shading and solar control glass. Further work will be undertaken to fully assess the daylight factors and compliance with the CIBSE guidance for daylit spaces.

Where lighting cannot be provided by natural means, high efficiency light sources and control gear will be utilised. The actual fittings have yet to be selected in accordance with the building aesthetics, but in general, high frequency electronic control gear and T5 lamps will be favoured. Compact fluorescent will also be used and this again will be fitted with high frequency control gear.

Lighting control will be provided by occupancy and light level control. Where there is sufficient daylighting in a space to meet the needs of the occupants and tasks, the lighting will be locked off by the control system to save energy.

All spaces will feature occupancy detection to call lights on only when required. The control system will feature an override to switch lights "off" only. This is due to a Client requirement to use projection equipment in the spaces.

All lighting controls will feature timed off functions so that lights are automatically extinguished after a pre-determined time if no occupancy has been detected.

Corridor lighting will be controlled by long range detectors and timer.

The architects are integrating glazing into the corridor walls to permit a higher level of natural lighting to penetrate into this space than is currently available. All of this will assist in making the corridor spaces more aesthetically pleasing and will minimise the requirement for artificial lighting to these areas and thereby save energy.

All lighting will be served from dedicated lighting distribution boards and will be locally metered with an output from each meter to be taken to the BMS. The electrical consumption of the lighting services will therefore be able to be monitored and logged on a floor by floor basis, to provide an ongoing record of the usage pattern of the lighting. Any deviation from normal patterns could indicate a failure of the control system or inefficient usage of the lighting system.

2.3.6. BEMS

A fully computerised and integrated Building Management System based around a Satchwell Sigma system shall be provided to control all heating and ventilation services in the Tower Block.

The system shall also be integrated with the existing services around the campus which will be upgraded such that a complete system is available to make the most efficient use of the plant on site and to minimise its energy consumption.

The BEMS will control the heating and ventilation zones as detailed in previous sections of this report and shall be capable of monitoring.

In addition, the BEMS shall be interfaced with heat meters, electricity and gas meters and other energy monitoring devices as appropriate to provide a fully integrated system.

The system shall be provided with a graphical user interface such that it can be interrogated by the trained Responsible Person and graphical energy use profiles produced.

The system shall be capable of being interrogated remotely by maintenance contractors if so required by the Client

The system will incorporate fail safes such that in the event of a control system failure, no damage will occur to plant and no danger will be presented to users.

The system shall incorporate a central head end and remote outstations to serve local plant and equipment.

Wherever possible, the BEMS equipment will be located such that cable runs at mains voltage are minimised.

2.3.7. Wind Turbines

Available data on wind exposure and prevailing wind direction together with the outlook of the site suggested the installation of wind turbines would be appropriate. But they had to be raised to gain clearer air currents which would otherwise be disturbed by the adjacent buildings and trees. It was agreed with Proven, the turbine manufacturers, that the Innovation Centre roof would be a reasonable location and probable generation capacity was agreed using their experience. The scheme originated with the design team for the Innovation Centre and the M & E design engineers Hoare Lea & Partners. The scheme did not proceed at that time due to a lack of funding but the structure was assessed and stub columns for the turbine mountings included.

The college then worked with a small firm based in the South West who were interested in developing a horizontal axis turbine specifically for building mounting. Planning consent was obtained for their prototype but works did not proceed due to a lack of funding.

The college finally obtained three grants, BRITA in Pubs, Clearskies and EDF Energy, which represented nearly full funding for the wind turbine installation. The senior management team of the college were unwilling to commit college funds to any significant amount since the original predicted returns seemed not to be commercial, given a 25 year payback period.

The final installation using vertical axis turbines has been designed and will be installed by Sustainable Energy Installations. Planning Consent and Building Regulation consent has been obtained.

Proven was chosen as the turbine supplier due to their capacity and cost both being most suited to the proposed location. Also their units had a better known track record than the very few other alternatives.

2.4. Overview of design process

A design team have been commissioned in July to develop the design of the tower refurbishment through the statutory planning & Building Regulation processes and preparation of the tender documentation:

- Lead consultant, architect, planning supervisor, structural engineer: **Atkins**
- Services engineers: **Faber Maunsell**
- Quantity Surveyors: **Hill's**

Following submission of tenders for the PV cladding installation in May, Solar Technologies have joined the design team to develop the design of the south and west elevations in conjunction with the design team.

Feasibility work has been completed and the design is in the latter stages of sketch design.

Favourable responses have been received from the planning authorities.

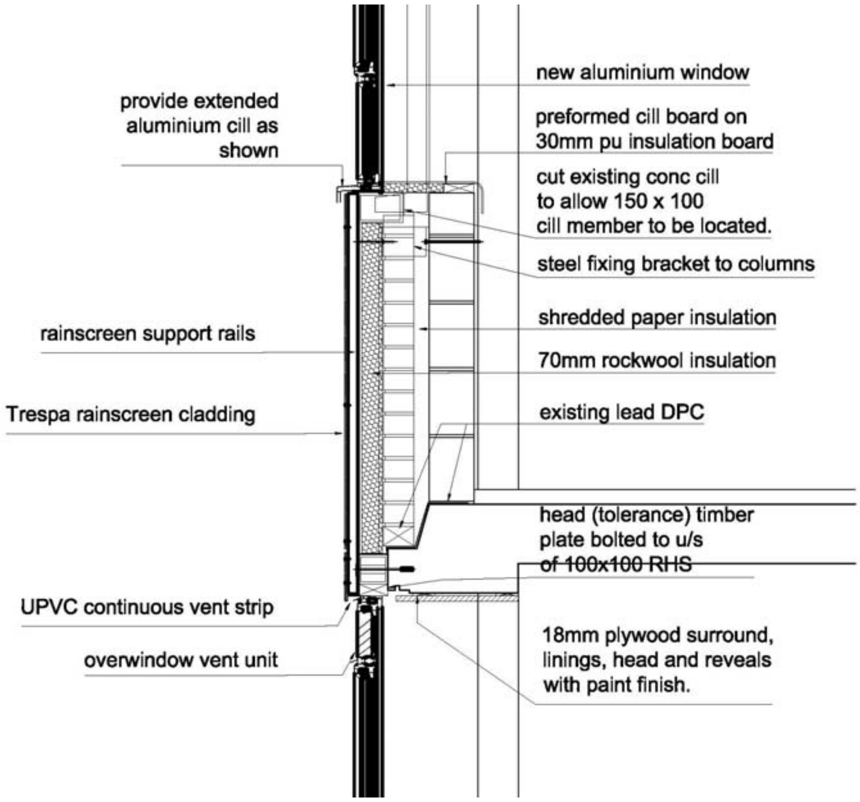
2.4.1. Building construction

In the upgrading of the existing building fabric the current Building Regulations have been treated as a minimum standard to be exceeded, with the clear aspiration that the new Building Regulations will be achieved, however at this time there is uncertainty regarding the standards that will be expected. The second benchmark is achieving an excellent BREEAM (Building

Research Establishment Environment Assessment Method) rating; however this has less focus on the individual building.

U-value and dew point calculations are currently being developed by the cladding manufacturers under consideration. These two factors are taken in to consideration within the standards used for the building fabric model, the IES Environment – APACHE Module.

Element	**U Value (W/m²k)**
Window (centre of pane)	1.2
Walls	0.35
Roof	0.25
Ground Floor (as existing)	0.73



Proposed window section

Part of this consideration is the filling of the cavities while the windows are being replaced. This should be an economic operation that reduces the cold bridging present in the existing building. Economic and technically suitable sustainable options are being reviewed for this situation.
The windows have been located outside of their existing location, to offer a number of benefits:

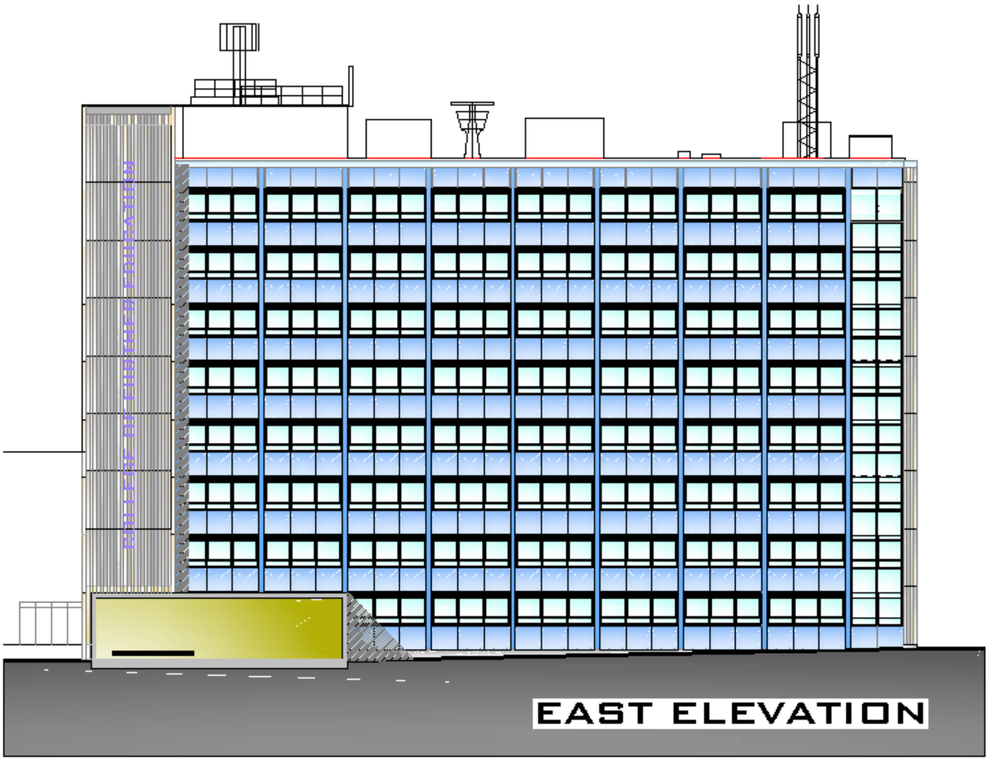
- The windows will be replaced in the optimal sequence to suit the cladding contractor rather than a slower operation to suit the internal refurbishment works.
- The deeper reveal will reduce the period of time that the sun will directly penetrate the room, the deeper cill will provide a deeper surface to reflect light in to the depth of the classroom.
- The insulation will align with the windows, thus reducing cold bridging.

- The depth of support steelwork provides a zone for the mineral wool insulation, otherwise additional structure would have been required to enable use of this product.

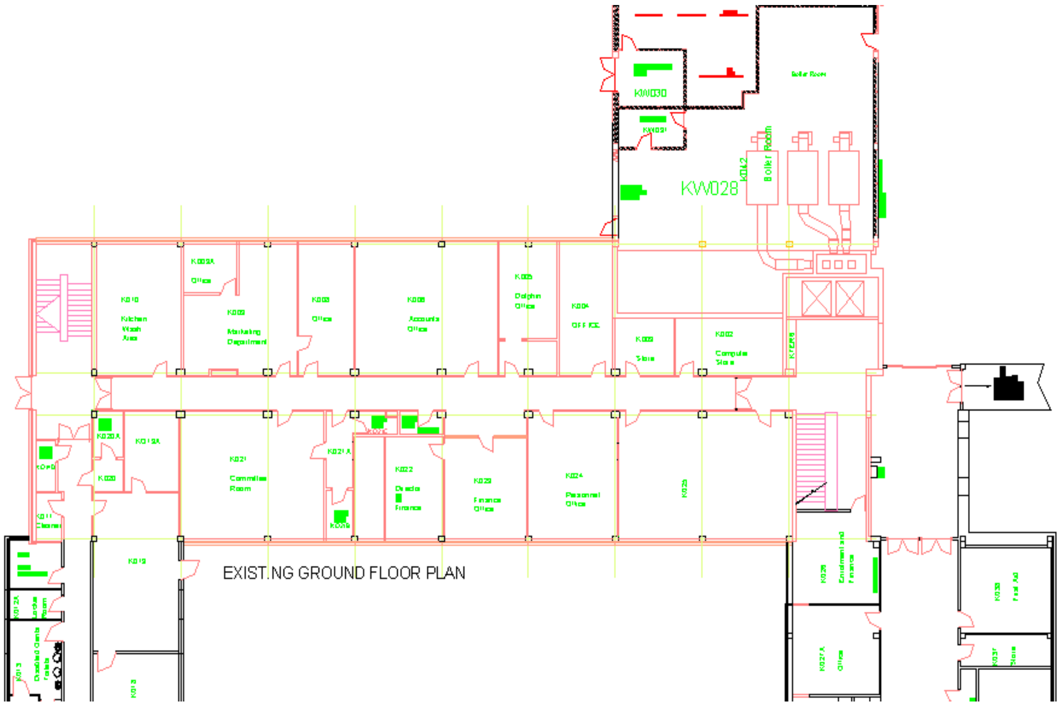
Typically in the selection of products consideration is offered to:

- Technical suitability,
- Cost, sustainability and
- Appearance.

Location and risk will affect the prioritisation of the selection process.



Proposed East Elevation



Proposed Ground Floor Plan

2.4.2. Heating / ventilation / cooling and lighting systems

2.4.2.1. Heating

The heating is proposed to be a fully zoned wet system served by an upgraded, centrally located boiler system. The existing boilers are to be replaced with three in number high efficiency modulating boilers sized using Manual Calculation and manufacturers boiler/plant sizing software products (preliminary sizing) to suit the existing site load and that of the upgraded tower block.

These boilers will be sized such that two boilers can serve 66% of the total maximum heat demand of the building to allow for maintenance and servicing of the third boiler without a substantial loss of heating performance.

The current proposal is to install three boilers which shall be step controlled such that the boiler output is more closely matched to the actual system demands at any given time in order to minimise energy usage.

The boilers shall be fully condensing and sized at approximately 400kW to serve the tower block heating load alone. It must however be recognised that the the boiler plant serves more than just the Tower Block.

Currently, further work is ongoing to fully and accurately assess the heat loads of the areas of the site not under the scope of the Tower Block refurbishment project, and this, once completed will permit accurate sizing of the central plant. Initial appraisals of the site would indicate that the total site load including the Tower Block will be approximately 950kW. On this basis, three boilers rated at approximately 330kW per unit will be required.

It is likely that due to the increased insulation levels and better draughtproofing of the tower block, that the heat demand of this building will decrease substantially from current levels and therefore the central plant has been downsized accordingly from the currently installed 1200kW . However, much of the plant size is dictated by the remainder of the campus and its associated heat loads.

Within the Tower Block, the existing heat emitters will be replaced with high efficiency convectors and radiators served from a zoned distribution system.

The zoning of the building will be divided such that the east and west elevations are run independently to maximise the efficient use of the plant. Zoning will also be carried out on a floor by floor basis such that the upper floors where heat rising through the building is likely to increase the ambient temperatures, can be shut down in advance of lower floors where heat input is still required.
The system will be fully automated and BMS controlled.
Zone sensors will be fitted in each area and linked back to the BMS for both control and monitoring purposes.
Averaging sensors will be provided in larger spaces to ensure accuracy.
Heat metering will be incorporated into the main flow and returns from the central plant room to the various areas of the campus. The outputs from the heat meters will be logged and monitored by the BMS such that the energy consumption of the areas can be identified and any deviation from the normal energy use profile noted. Such deviations could indicate plant faults or inefficient use of energy by poor control or user discipline with respect to closing of doors and windows to minimise heat loss.

2.4.2.2. Ventilation

Thermal modelling of the building has been undertaken to assess the solar gains and the internal temperatures that would be encountered in both the existing and the upgraded building using the IES Environment programme – APACHE Module.
The results of the Macroflow computer modelling and manual calculations have been used to progress the natural ventilation design concept and to assist the architects in the selection of appropriate glazing to minimise solar gain.
The concept as detailed in section 3.3 has been agreed, and subject to final calculation, and where applicable, further computer analysis, it is known that the general ventilation to this building can be provided by natural means.
The detailed design of the natural ventilation is ongoing in consultation between the Architects and Engineers with respect to louvre size and final locations.
The use of a natural ventilation solution is clearly beneficial as the energy consumption due to mechanical ventilation is negated.
Further works are ongoing to finalise louvre and damper sizes to enable the elevations of the building and the cladding system details to be agreed.

The louvres to be used are 200mm high by 1400mm long and are fitted to each window bay. Each louvre will be controlled by an electrically operated actuator linked to the BEMS such that each room is individually controlled.

The actual manufacturer of the louvre is still under consideration due to the implications of integration with the facade cladding and window systems

2.4.2.3. Lighting

The lighting design has been progressed by initial appraisal of the available daylight, the solar shading to be provided in order to minimise internal heat gains and its effect on the daylight penetration. The design has been based on the Dialux and Relux programmes for internal lighting design and calculation and the FACET programme together with manual calculation for Daylighting calculation as required
In addition, agreement has been reached on the general lighting concepts for the spaces including controls and integration of daylight monitoring and occupancy detection.
The lighting layout has been considered and how this can maximise the use of the available daylight by careful use of switching and control.
Further works and more detailed design are required to enable the final selection of fittings and layout to be made. This ongoing work will include the actual numbers of fittings and locations to be agreed.
Calculations will be carried out using a proprietary software product such as Dialux or Relux to ensure that the required light levels and the most efficient use of lighting is being achieved.
Luminaires will be selected for their high efficiency and high Downward Light Output Ratio (DLOR) to ensure that the energy consumed is used to best effect.

Only after finalising all of the above can an accurate assessment of the actual connected load and energy consumption for the lighting scheme be made.

2.4.3. Solar thermal

A detailed analysis of hot water demand is to be undertaken as part of the next design phase as well as the generation of a simple load profile in order to ascertain whether the building could benefit from the inclusion of solar thermal water heating.
Should the analysis reveal a positive case for solar thermal water heating, the exact technology that might be used will be determined according to its appropriateness. It is likely that an evacuated tube type product would be used. The system would be connected into a

dual coil calorifier thus ensuring that any demand not met by the system will be delivered by the gas boiler driven LTHW system.
Sizing of the system will be such that the maximum output of the solar collectors is slightly below the minimum demand (summer) to ensure the highest possible Utilisation Factor whilst not exceeding a Solar Fraction which might require dumping of excess heat at periods of low demand.

2.4.3.1. Solar PV

Building Integrated Photovoltaics (BIPV) has developed over recent years striving for better usage of PV as a building material in envelope designs.

The solar PV's have been integrated into the new building envelope fabric by framing the open edges such that a thickness of structure is presented to the outside. This framing integrates the PV's as a component of the building rather than an accidental appendage.

The dimension of the PV panels has been reviewed together with the need to increase shading to the windows on the west elevation. The length of the panel has been increased, but through changing to the more aesthetically pleasing polycrystaline panel, and reducing the number of panels, the same power output has been achieved. Further consideration is being offered to a 300mm vertical brise soleil under the PV array to provide further shading. Cost, scale of cooling benefit and aesthetics benefit are being used as the criteria for assessment.

The South West and South East elevations will be overclad with a rainscreen constructed using standard PV modules and the South West stairwell glazing will be replaced with bespoke double glazed glass/glass PV laminates. To maximise the performance of the rainscreen PV the arrays have been angled at 30 deg and 10 deg from the vertical which also enhances the shading effect to the continuous windows below.

The PV modules will be electrically connected into a number of inverters with all inverters coupled together and connected to the grid. The system will comply with the Engineering Recommendation G59/1

The energy output from the PV system has been simulated using PVSyst, the results are attached. The PV system is rated at 83.75kWp and the total energy output from the PV installation is expected to be 64,732 kWh per annum.

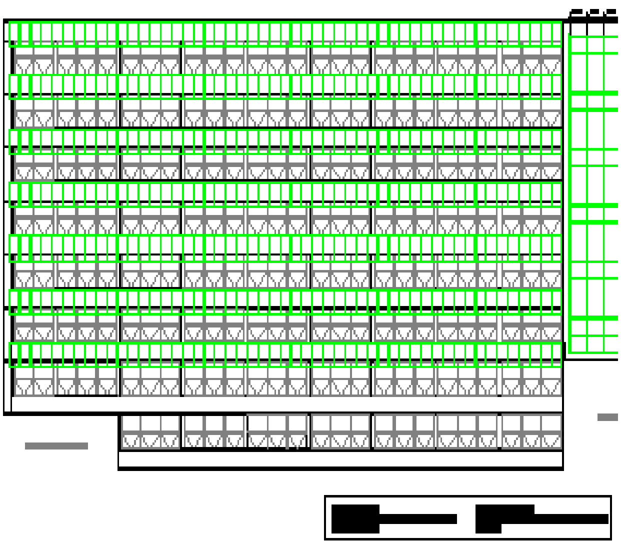
A monitoring system will be installed collating data from the inverters as well as from external temperature and irradiance sensors. Basic information will be displayed in the entrance foyer including instantaneous kW production, cumulative kWhours produced and CO2 saved. Full monitoring will be take place for 1 year with published results.

A summary of the PV simulation results for all of the different areas of the building are contained in the table below.

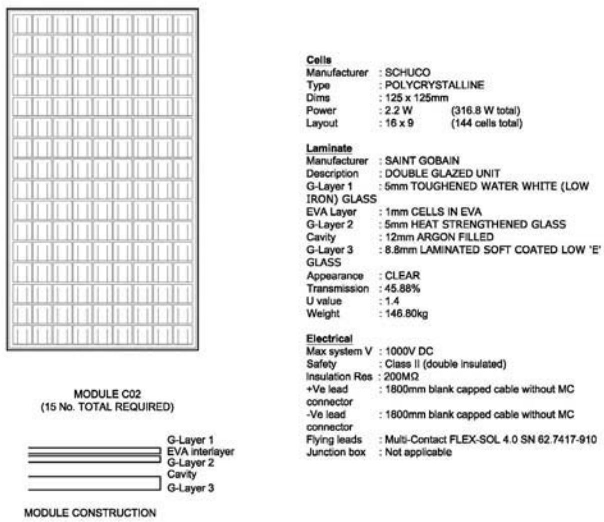
Based on NASA data for Plymouth grid reference 50N23, 4E10

Balances and main results;;

	GlobHor	T Amb	GlobInc	GlobEff	EArray	EOutInv	EffArrR	EffSysR
	W/m²	°C	W/m²	W/m²	kWh	kWh	%	%
January	31	7.5	44.6	38.1	45.5	40.6	8.97	8.01
February	47	6.7	59.6	51.4	61.9	55.9	9.14	8.25
March	84	7.9	89.1	77.6	93.9	85.4	9.27	8.43
April	131	9.0	131.8	115.9	138.4	127.0	9.24	8.47
May	171	11.3	140.1	121.8	145.7	133.3	9.14	8.36
June	171	13.5	139.4	122.1	144.0	131.7	9.08	8.30
July	175	15.8	146.5	128.7	149.2	136.6	8.95	8.20
August	145	16.0	127.6	111.2	129.7	118.5	8.94	8.17
September	101	14.8	105.0	91.5	106.5	97.2	8.91	8.14
October	57	12.6	63.8	55.2	65.0	58.3	8.95	8.02
November	33	10.1	49.5	42.1	50.1	45.2	8.89	8.02
December	30	8.7	62.1	52.3	63.5	58.0	8.99	8.20
Yearly sum	1176.1	11.2	1159.0	1008.0	1193.4	1087.6	9.05	8.25



Solar Panelling to S W Elevation



PV Glass Glass to SW elevation

2.4.3.2. CHP

A feasibility study looking into the viability of a Combined Heat and Power scheme is being undertaken during the next design phase. Currently a load profile of the site is being generated in order to understand fully the nature, location and magnitude of both heat and electricity loads. Should the load profile recommend itself to the use of CHP a number of options will be investigated including the possibility of alternative fuel types such as bio-mass. In addition, any scheme put forward would endeavour to comply with the UK Government Good CHP Scheme in order that Climate Change Levy payments on fuel (assuming fossil fuel use) can be avoided. This has the added inherent benefit that such systems are more efficient in operation.

Initial appraisals indicate that a CHP scheme will be beneficial and economically viable if it can be run in excess of 4000hours /annum. On this basis, it has been elected to consider a scheme that runs for a minimum of six months of the year to provide electricity and heat.

It is known that the site has a base electrical load of 100kW which is present at all times. This includes the Tower Block which would account for a minimum of 50% of this load based on floor area. The CHP scheme has initially been sized to provide approximately 65% of the base electrical load so that it will not be under run when energy saving measures are brought in to reduce the base load.

The unit will also produce a quantity of heat and it is proposed to use this to provide background heating to the tower block 24hours/day. The CHP will be linked into the main heating system and will be used as the lead machine in sequence with the Boiler Plant. This method will again ensure that the CHP is fully utilised with respect to its heat output.

The savings that will be seen by the use of the CHP are mainly quantified by a reduction in warm up times of the building and in increased system efficiencies by generating power locally.

A statement has been submitted to BRITA in support of the inclusion of CHP into the scheme and this illustrates the potential savings.

The current scheme under consideration is a gas fired microturbine but this is not necessarily the final solution as Bio Diesel and alternative fuels are also under further consideration.

It is likely that any CHP scheme proposed will not be limited to the project building but would serve further buildings on the same campus via what would effectively be a district heating scheme. The implication of having excess capacity in the early stages (i.e. before other buildings are brought online) will also be investigated and a strategy put in place to mitigate any waste heat scenarios.

2.4.4. BEMS

The design development of the BEMS is in early stages at present and will be more fully developed within the forthcoming period. However, the current proposals are to use a Satchwell Sigma system with local sensors to monitor each space and all plant items. This is a computer based system which shall be provided with a graphical front end to enable easy monitoring and control of the systems. The Sigma system will also be fully integrated with the existing Satchwell BAS system currently installed across the rest of the campus.

A typical naturally ventilated room will be provided with both temperature and CO2 detection such that the ventilation rates and air quality can be controlled by the BEMS.

The local heating will be zoned by the BEMS to ensure that the heat input into the building is optimised. This will be achieved by the use of zone valves at each level and additional internal and external temperature monitoring to ensure the most economic levels of energy input.

The Satchwell Sigma system is compatible with existing services and systems within other areas of the campus which fall outside of the area of the Tower Block works subject to some alteration and modification which will be built into the design and specification of the overall system.
The BEMS will be designed to provide full optimisation and compensation control of all systems as required by the Building Regulations and shall minimise the energy consumption of the plant as far as is reasonably practicable.
Lighting controls are not to be integrated with the BEMS as it is believed that the local automation of these services will provide sufficient control and associated energy saving.
Metering of items as previously referred to in this document will be integrated into the design of the BEMS system to permit logging and monitoring of energy consumption as required. This required further design development and is currently in the early stages. There will be further works undertaken in the next period to agree the metering strategies and scope of services to be monitored and logged.
The BEMS will be fully commissioned upon completion and all set points arranged to optimise the use of plant and to minimise energy consumption.

2.4.5. Rainwater Harvesting

Currently, there is no available data regarding energy specifically concerned with the heating of Domestic Hot Water. An estimation will be undertaken in order to provide comparative data during the next phase of design.

Energy saving concepts are dealt with in the following section, however measures undertaken in order to reduce water use in the finished building are described here.

Water use within the building will be reduced by the combined effect of a number of measures, these include:

- Reduced capacity cisterns
- Continued use of waterless urinals
- Aerating taps
- Rainwater Harvesting

Currently, two schemes are being examined for the Rainwater Harvesting Scheme. The first would be to install a full system whose collection area would be the entire roof surface of the building. In this case a below ground tank would be installed into which all rainwater downpipes would be collected via a passive filtration system. The water would then be pumped to a tank at high level and wc's gravity fed. The tank would have a mains water back-up for use in the event of maintenance of the system of should there not be sufficient rainwater stored to meet demand.
The second scheme would be to re-use one of the existing water tanks situated just below roof. Whilst this scheme would involve less work, it would reduce considerably the rainwater collection area and therefore the effectiveness of the measure for offsetting mains water use.
Currently, specialist manufacturers are being consulted regarding the appropriateness of each optiona and an options appraisal will be produced shortly to assist in the decision making process.
It is anticipated that collectively the above measures will reduce water consumed from treated, mains sources by approximately 5 - 10% / year depending on the scheme adopted.

2.4.6. Wind Turbines

The UK Wind Speed Database – NOABL2000 was used to estimate the wind speed at the site based on the Ordinance Survey grid reference of the college. This gave an annual average wind speed at 10m above ground level of 5.2m/s and an annual average wind speed at 25m above ground level of 6.0m/s. The actual unit height will be about 21m above ground level. Manufacturing information for the 6kw turbines, on this basis, indicated an annual output of 16900kwh/year per turbine or 33800kwh/year. This represents about 1.8% of the whole site consumption or 5.2% of the tower block consumption in isolation. Units manufactured by a Scottish company called Proven.

An estimate on the cost of energy saved together with the potential income from Renewable Obligation Certifications suggested a payback period of between 20 to 25 years.

A noise impact assessment was prepared by Hoare Lea & Partners and was one of the supporting documents for the Planning Application. Assessments were constructed in line with BS4142 1997 and the Assessment and Rating of Noise from Wind Farms (ETSU 1996). On site background noise readings were also taken. Given the Proven turbine has no gear box and the other manufacturer's data regarding noise it was predicted the two turbines were unlikely to disturb the nearest residential properties.

Structural engineering assessment indicated the structure of the Innovation Centre is suitable to take the forces from the turbines and some minor alterations have been made to produce fixing points and hoisting points for lowering the turbines during maintenance.

The electrical system of the Innovation Centre has been altered to take the power feed from the turbines. This has included the installation of inverters to ensure the power output is modulated to the existing building supply. Western Power Distribution accepts the scheme satisfies "Recommendations for the connection of small-scale embedded generators in parallel with public low-voltage distribution networks (G83/1)".

Recent Turbine installation to Innovation Centre

2.5. Predicted energy savings

In order to establish the likely energy savings and thereby analyse the validity of the projected savings put forward before design work was commenced the following methodology has been used;

In order to establish the likely energy savings and thereby analyse the validity of the projected savings put forward before design work was commenced the following methodology has been used;

The position of the current building in terms of its relative performance compared to national benchmark data is difficult to determine with certainty as these data exist for schools but are not readily available for further education establishments which tend to have a higher degree of technical or specialist space and longer operating hours.

Building Bulletin 87 provides benchmark data (measured in kgCO2/m2) for secondary schools and divides this into six bands (A to F). The data excludes specialist area consumption such as food technology rooms and are also based on a 7.5 hour occupancy period.

To create valid comparison data, we have proportionally increased the benchmark in line with the extended operating hours (i.e. 12 hours being 9am to 9pm). It is accepted that there may be some minor operational activity outside these hours which is likely to consist of cleaners moving through the college for a short (perhaps 2 or 3 hours) period, occassional maintenace which cannot be carried out during normal working hours and members of the academic staff working in their offices. As this activity is anticipated as being infrequent and for relatively short periods, it has been disregarded for the purposes of this initial assessment.

Measured data for space heating and electrical energy has been used and is converted below to comparable kgCO2/m2 values.

CO2 Calculation (based on measured data 2002)

Existing Building

	kWh/m^2	Fuel Type	Conversion Factor	Estimated $kgCO_2/kWh$
Space Heating	207	Natural Gas	0.194	40.158
Hot Water		Natural Gas	0.194	0
Electricity	112	Grid Electricity	0.422	47.264
		Increased Occupancy Ratio	1.73	**87.42**

BB87 Values ($kgCO_2/m^2$)

Band	Emissions rate	Proportionally Increased Rate	PCFE Building
>F	>60	>104	
F	60	104	
E	51	88	=
D	43	74	
C	35	61	
B	27	47	
A	19	33	

NOTES

Benchmark data has been multiplied by the Occupancy Ratio in order to provide valid comparative data

Hot water use assumed included in Space Heating figure above

BB87 Benchmark data is for a building of ~$5800m^2$

When we compare this to the BB87 benchmark data for a building of comparable size, we see that the existing building, at 87$kgCO_2/kWh$, is well outside acceptable limits (maximum acceptable for existing buildings is 64kgCO2/m2). The savings put forward previously are shown below:

Previous Energy Savings

Energy saving measures, heating, cooling, ventilation	[kWh/m²a]	Total [kWh/a]
Low-e windows	30	174000
Improved façade design	20	116000
Improved insulation of facades	15	87000
Improved insulation of roof	8	46000
Improved heating and control systems	35	202000
Total heating energy savings		625000

Energy saving measures, electricity	[kWh/m²a]	Total [kWh/a]
Low energy light fittings	7	40000
Lighting controls	7	40000
Window design to reduce lighting need	10	58000
Wind Turbines (20kWp approx)	-	33800
PV (80kWp)	-	56000
Passive cross ventilation	35	202000
Total heating energy savings		429800

Water saving measures	[m³/m²a]	Total [kWh/a]
Rainwater harvesting & tap replacement	0.04	230
Total heating energy savings		230

The savings to be made in the refurbished building have been estimated previously and results of translation into consumption figures give the following;

Refurbished Building

	kWh/m²	Fuel Type	Conversion Factor	Estimated $kgCO_2/kWh$
Space Heating	99	Natural Gas	0.194	19.206
Hot Water	52	Natural Gas	0.194	10.088
Electricity	48	Grid Electricity	0.422	20.256
		Increased Occupancy Ratio	1.73	**49.55**

BB87 Values ($kgCO_2/m^2$)

Band	Emissions rate	Proportionally Increased Rate	PCFE Building
>F	>60	>104	
F	60	104	
E	51	88	
D	43	74	
C	35	61	<
B	27	47	>
A	19	33	

NOTES

Benchmark data has been multiplied by the Occupancy Ratio in order to provide valid comparative data
Predictions of energy in the refurbished building will be refined during the ongoing design process
BB87 Benchmark data is for a building of ~5800m²

The various bandings shown above are defined as follows; A is a good low energy design for new schools, B & C indicate an improvement on the maximum permissible for new schools, D is the maximum permissible for new schools and anything beyond that is a limit for existing buildings.

These calculations result in the following energy savings when all proposed measures are achieved and deliver the predicted savings;

Saving Analysis (kWh/m^2)

	Existing Building	Refurbished Building	Saving	
Space Heating	207	151	56	kWh/m^2
Electricity	112	48	64	kWh/m^2
Totals	319	199	120	kWh/m^2
		Saving Percentage	38	%

NOTES

Space Heating & Water Heating figurs have been summated for the refurbished building in this table

In addition to these savings, the installation of the 80kWp photovoltaic array will directly offset energy consumption 49114kWh/year and corresponding carbon emissions of 3.5kgCO2/m2/year.

Further analysis work will be carried out to ascertain more precisely the areas in which the various savings are being made and to see where further improvements can be achieved if possible.

2.6. Predicted costs and payback

Energy saving measure/investment	Area [m²]	Eligible costs [EUR]	Saving [EUR/a]	Pay-back periods [a]
PV, window,facades	210	886,148	49,100	18.0
Roof insulation	760	23,000	5,100	4.5
Heating system +control	5800	35,000	20,000	1.8
Natural Ventilation	5800	40,000	20,000	2.0
Light Control	5800	10,000	4,000	2.5
Rainwater Harvesting		12,000	4,000	0.6
Wind Turbine		75000	3000	25
Low-Energy Lighting		2550	2,900	0.6
Total		**1,343,352**	**108,100**	**12.4**

2.7. Lessons learned

- Untested opinions and ideas are critical to the creative process, however the modelling of these ideas are essential. Time needs to be built in to the programme to facilitate sufficient analysis and testing of ideas, particularly when dealing with the constraints offered by an existing building. It is important to establish a model of the building to allow the rapid testing of ideas, as the most obvious concepts do not always offer the greatest benefit.

- An example of this has been the vertical brise soliel under the PV array to the west elevation. Modelling of this has demonstrated that there is clear benefit, but that this needs to be kept in perspective as it exceeds standards that are currently considered endurable by the client.

- The long payback period discourages the choice of such technologies unless grant funding is available to support investment. Consultants are very inexperienced in putting turbines on roofs. In this case the issue of the winching point for the lowering the turbine for maintenance was left to a very late stage, delaying the project.
- Alternative and more adventurous solutions should always be considered as they can have positive benefits if properly researched, proved and implemented.
- It is possible to integrate technologies to serve dual purposes. In the case of this building, the PV arrays are also serving as solar shading. Careful consideration or all aspects of a project at the outset will permit such integration.

- The goal for all designers is that the services concepts should always start from a desire to consume zero energy and only add what is required to make the building function. It is not acceptable to use established benchmarks for similar buildings as a starting point as this can stifle innovation and lead to tried and tested solutions coming to the fore. This should apply to all projects and not necessarily just to a specific project with a specific requirement.
- Better control of services can save considerable quantities of energy. This should be coupled with high quality commissioning procedures and concise training of the Client in the best use of the systems. Poorly trained people will not use systems effectively and energy consumption will suffer as a result.
- There is an education process required at the handover stage to ensure that building users understand the advantages and/or limitations of any installed systems. There may be an expectation that the systems will perform functions or provide results that are outside of design parameters. This needs to be clearly explained such that the end users are "bought in" to the processes at an early stage. Close liaison with the Client and end users through the design process is a great advantage.

3. Borgen Community Centre

Author: Jan Rolland

3.1. General data

3.1.1. General information

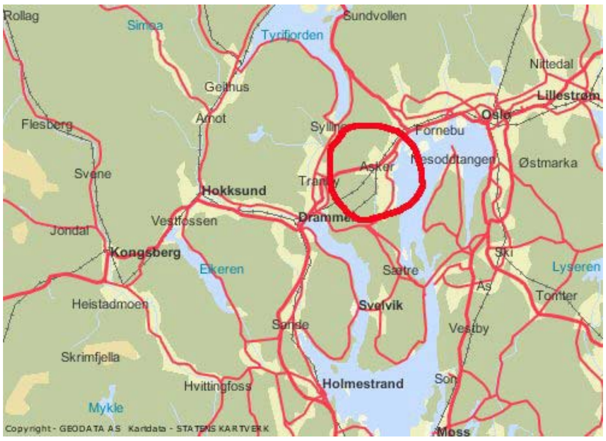
Year of construction: 1971
Year of renovation : 2002 - 2005

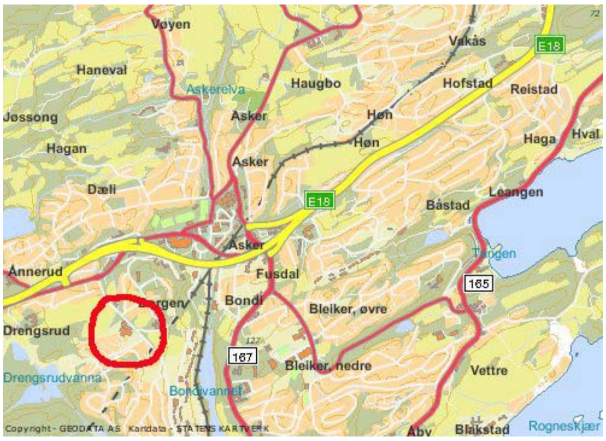
Total floor area (m^2): 6000
Surface/Volume ratio: 0,30
Number of storeys: 1
Window/glass areas (m^2): 750/398 (skylight)

3.1.2. Site

Borgen Community Centre is located in an open suburban area approximately 2 kms from the centre of Asker, which is situated 20 kms southwest of Oslo, the capitol of Norway. The location is 59˚50´ northern latitude and 10˚25´ eastern longitude. Altitude is 164 meters above sea level. The climate is typical for inland areas in southern Norway.

Normal summer temperatures range from 15 to 28˚C, while winter temperatures range between +5 and -20˚C. Average precipitation is 1100 to 1200 mm per year. Snow depth varies from 20 to 80 cm.





3.1.3. Building type

Local Community Centre containing 5 parallel secondary school, kindergarten, youth activity centre, health care, dental services and rooms dedicated to private organisations.

3.2. Before retrofit

3.2.1. Building construction

Prefab concrete pillars and beams carrying a roof structure of U-shaped insulated concrete elements. The building had concrete foundations secured to underlying rock and concrete slab floors with vinyl covering. Outer walls were made with 4" wood framework and brick cladding. Wooden windows had standard double glazing. Internal walls were also made with wood framework and plasterboards on both sides.

Old school with large shed roofs that reduced daylight through windows

3.2.2. Existing heating, ventilation, cooling, lighting systems

The building had electric heating with resistance heaters underneath the windows. Ventilation was based on a decentralized system with five ventilation units placed on the roof above each of the main building sections. Fresh air was filtered and preheated with electric heaters before it was distributed to the building. Used air went through a heat recovery system before it was exhausted. The units had low capacity and efficiency, and there was no cooling.

3.2.3. Energy and water use

	Measured year (average)	Total for the whole building
Electricity	280 kWh/m^2 a	1.120.000 kWh/a
DHW (included)	-	-
Space heating (included)	-	-
Water	na	na

Water saving measures was not and issue in the project. The school and health centre have normal water consumption and there would not be need for special initiatives. The gymnasium located in the adjacent dodecahedron building had already installed water saving showers, and the retrofit only applied to upgrading the facades, changing windows and doors and improving insulation.

3.3. Energy saving concepts

3.3.1. Building construction

The overall goal for the retrofit was:

- reduce total energy consumption by 50% or better
- create a good indoor climate with low energy consumption with respect to heating, ventilation and lighting.
- optimise use of space with flexible plans that allow new pedagogical working methods as well as integrating local community activities

The building was generally in poor condition with insufficient insulation, air leakages in both windows and walls and extensive damages on brick cladding. The roof elements did not meet new requirements to snow loads and needed to be replaced. This would enable opening roof areas to let daylight into the dark central areas of the building and also increase roof insulation.

A worn down interior

…..and exterior

The main structure had to be strengthened with steel trusses. Rehabilitation of the walls would be more expensive than replacing them with completely new walls. Windows area could then easily be increased as well as insulation thickness.

3.3.2. Heating

To optimize the use of renewable energy, a geothermal heat pump was chosen. It would yield about 2,5 to 3 times more energy than the electricity used to run the heat pump. Heat could be pumped from the ground from energy wells. During the summer it could provide cooling by pumping excess heat back into the ground and thus "recharging" the wells. A 150 m deep test well was drilled to map potential capacity, and calculations were made to estimate expected payback time. Depending on the interest rate and electric energy prices, payback time was calculated to 10 to 13 years. Since then interest rate has gone down and energy prices up, and payback time is expected to be a lot shorter. The heat pump produces low temperature hot water, 45 to 50˚ C. Heat is distributed by water to radiators under the windows. It is also used to preheat DHW to about 40˚C and the temperature is then lifted to 75˚C by electric heating.

When using heat pumps, it is mandatory to have a backup system, and two oil boilers are installed. Together they have sufficient capacity to heat the building and supply hot water if the heat pump is out of function. The heat pump is dimensioned to 60% of total needs. Under normal conditions this is enough and the oil burners will kick in only a few days during the winter. The energy plant also supply hot water for heating to the nearby Vardåsen church, which is part of the local community centre but a not part of the BRITA project.

Heat pump

3.3.3. Ventilation

To reduce running costs for ventilation, a natural hybrid ventilation system was chosen. By, to a large extent, using natural driving forces, buoyancy and wind, the need for electric power to run ventilation fans is greatly reduced. Fresh air is brought into the building through air towers and underground concrete culverts. The culverts have a large volume that reduces air speed and allows distribution of fresh air with relatively low temperature and close to the user without feeling a draught. Air flow is regulated individually in each room by sensors for temperature, CO2 and motion and therefore adjusted to actual needs.

3.3.4. Cooling

Excess heat is a problem in schools for long periods during the year due to human generated heat and extensive use of computers, electric lighting and other heat generating equipment. With traditional ventilation systems this is often a problem. Fresh air is supplied at relatively high speeds which require higher temperatures to avoid sensation of draught. This in turn leads to high evacuation temperatures, and active cooling is often needed to keep temperature at an acceptable comfort level. Cooling is expensive and it was decided to aim at passive systems. The ventilation culverts are cooled by the ground and their massive concrete construction supplies enough thermal mass to even out temperature changes during the day. Ventilation is automatically run during night to cool the building when this is needed. The use of building materials with high thermal capacity then helps to keep the temperature throughout the day. The lower fresh air temperature also helps keeping room temperature at the recommended 20 - 21°C.

3.3.5. Lighting systems

The old school building was built as an open plan with few parting walls. The base areas were roughly 27 by 27 meters, resulting in large central spaces with relatively poor daylight conditions. Over the years new needs had also lead to building more internal walls, strongly worsening the daylight situation. One of the challenges was therefore to find ways to bring daylight into these deep areas far from the façade. New facades made larger windows possible and thus generally increasing the amount of daylight. Raising the roof in central areas and installing new skylights would improve daylight situation and a flexible use of these areas.

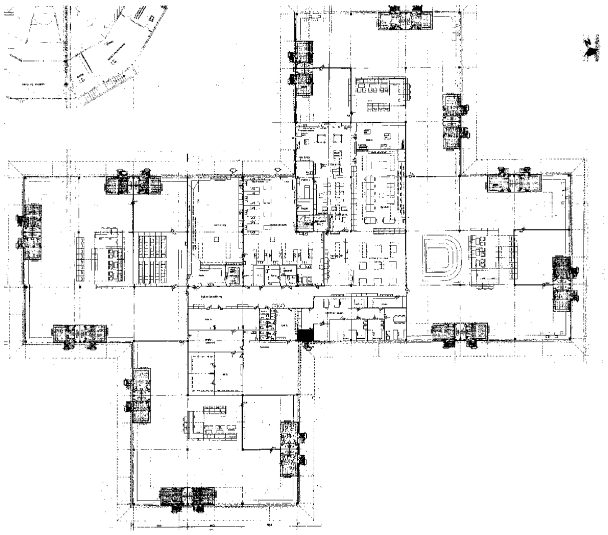
3.3.6. BEMS

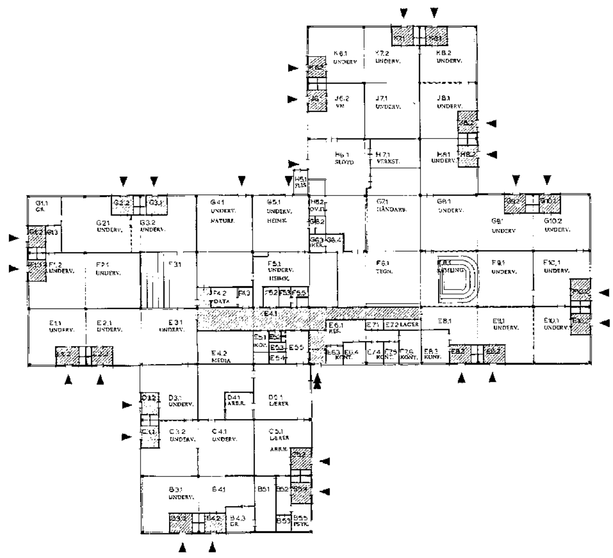
To manage such a complex building, an advanced BEMS system had to be installed. All functions should be controlled and monitored from operation terminals in the building and at the operation centre in the municipality of Asker. BEMS should provide fully automatic registration of energy consumption on hourly bases, and energy supplied to the church should be registered separately. It should show total energy consumption as well as electric power used for ventilation, heating (heat pump), electric lighting etc in relation to outdoor temperature

3.4. Overview of design process

3.4.1. Building construction

When the planning started, the main objective was to turn the building into a modern local community centre with emphasis on *environment, resources and indoor climate*. The building itself was a challenge with its deep areas with poor daylight condition and the general state of the building envelope. All internal walls had to be replaced to allow flexible solutions that would meet the requirements of the school as well as the local community.

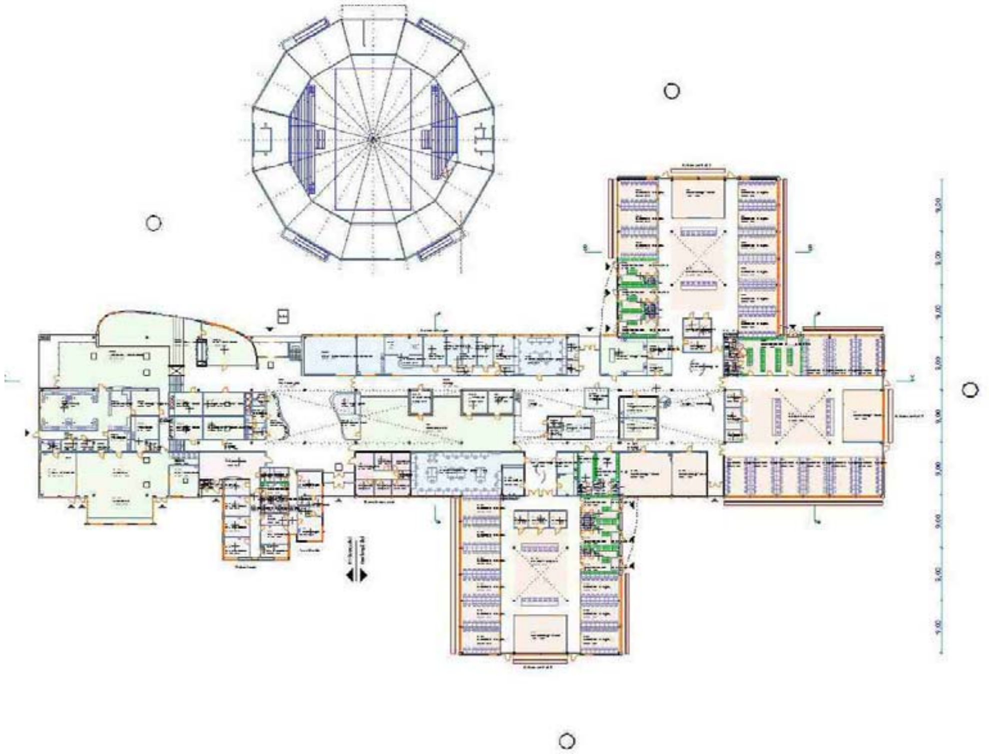




Original plan from with decentralized entrances

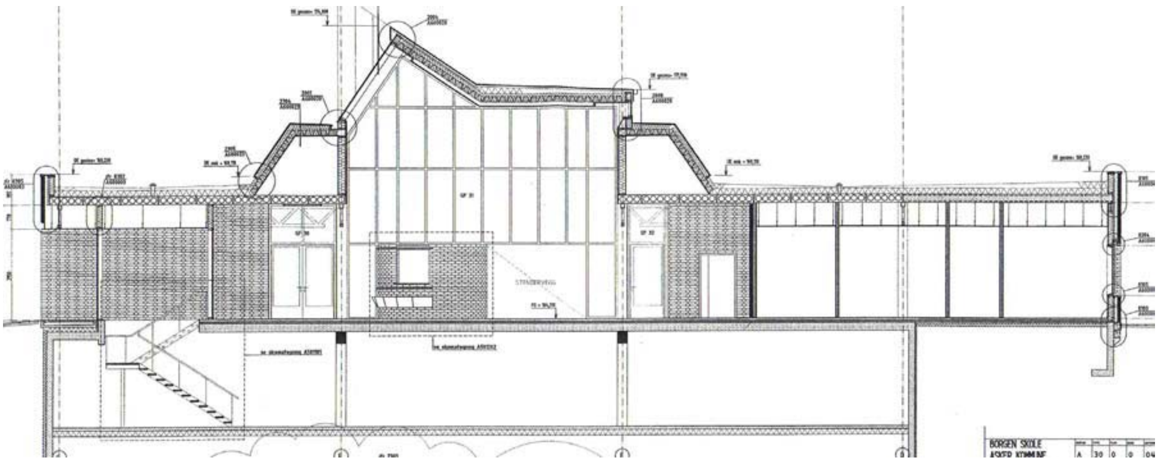
The modified plan before retrofit

The base areas for teaching and learning should allow implementation of new ideas where students have their permanent work space in “student’s offices” with room for up to 15 students. Close by there would be rooms for small groups and a large “auditorium” where two “classes” (60 students) could gather for shared studies, performances etc. We soon realized that the building was not big enough to hold the increased number of students and new activities, and it would have to be extended. It was natural to locate special activities, which should also be accessible to the local community, in the new extension.



The new plan

When we started to investigate the problems and possibilities of natural ventilation, active use of daylight and thermal heat, it became evident that we needed to consult specialists. The design group contacted SINTEF research centre in Trondheim to get an evaluation of the concept model. This resulted in an environmental assessment report based on the Norwegian Eco Profile method. The recommendations with respect to natural ventilation, thermal mass, daylight resources, heat pump, space efficiency, artificial light control etc, were then implemented in the project. SINTEF also prepared an energy budget based on recommended constructions and U-values for the building.



Studies were also made for solar PV´s, solar energy collectors and double facades. The conclusion was that no reliable and cost effective system was yet on the market and these solutions were abandoned. On the other hand we came in contact with a group of companies that were working with new concepts for solar collectors and a turnable window that would let heat from the sun in during winter and reflect heat in summer. This was interesting and we accepted to participate in the project and install prototypes in/on our building and monitor the effects during a test period of one year. The aim is to get necessary feedback to refine the products and prepare them for marketing. The test period will be integrated in the learning process of the school with participation of the students.
Total cost for the SINTEF research and participation in the project amounts to about € 100.000. We believe this was necessary because of the nature and complexity of the project, and it is fair to assume that it reduced design costs for the architect and the consultants, even if it is difficult define the amount.
A complete rehabilitation of the walls was calculated and turned out to be more expensive than replacing them with completely new walls. We planned to reuse old bricks for internal walls, but in order to do so, they had to be cleaned from old cement and this turned out to more expensive than using new ones. Instead they were reused as foundations for the outdoor areas.

In order to meet the new requirements for snow loads, roof elements were replaced. Central areas were lifted to allow daylight into the building. Underlying structure was strengthened with steel trusses between the pillars, which had sufficient capacity. Roof insulation was increased to an average thickness of 300 mm which resulted in a U-value of 0,13 W/m2K.

Walls were rebuilt with 8″ wood framework and brick cladding. Inside was covered with two layers of plasterboards. 200 mm insulation gives a U-value of 0.2 W/m2K which is within Norwegian requirements. An increase in insulation thickness would be expensive and would yield poor energy benefit.

New windows have wooden frames with outside aluminium cladding. Glass is high quality double glazing with low emissive coating. Theoretical U-value is 1,1 W/m2K which is well below the national requirements of 1,6.
Existing floor slabs were given a new 100 mm insulation layer underneath a new 100 mm concrete floor slab. Some areas were covered with oak floorboards, but the greater part was grated and waxed to give a robust surface with high thermal capacity. The insulation layer was also used to lay new water pipes and electric cables.

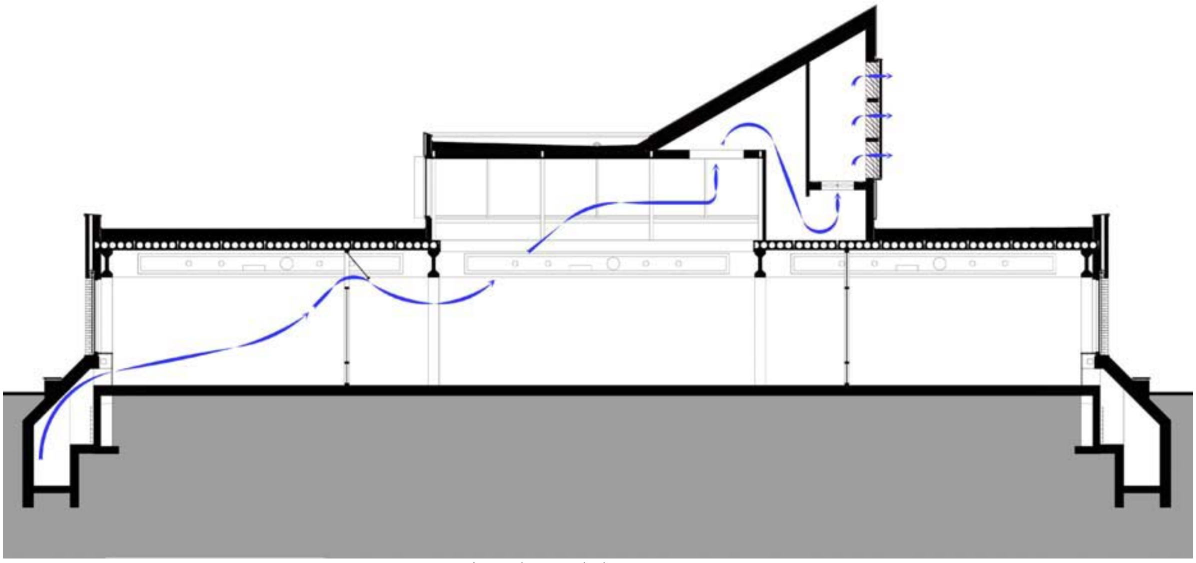
3.4.2. Heating / ventilation / cooling and lighting systems

3.4.2.1. Ventilation

There are three different ventilation systems in the building:

1. Natural hybrid system
2. Natural hybrid system – Swedish model
3. Normal balanced ventilation

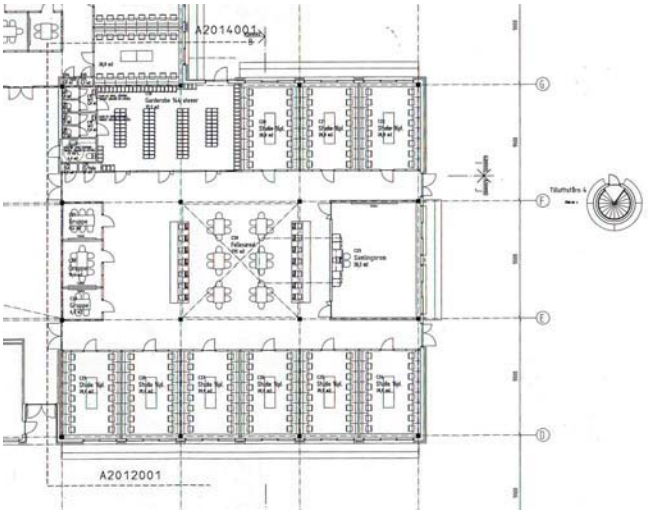
The main ventilation is based on a natural hybrid system which is designed and built according to the recommendations from SINTEF. Since this was an existing building, air culverts had to be built outside along the foundations. Normally culverts would have been built under the building, but this was not possible in our case. Inlet towers were placed about 14 – 15 meters from the building and the connecting culvert was designed to give room for backup fans, filters and preheating battery. This solution does not give optimal length for the culverts and it was necessary to install fan to ensure air transport during period with low thermal force i.e. during warm periods in the summer.



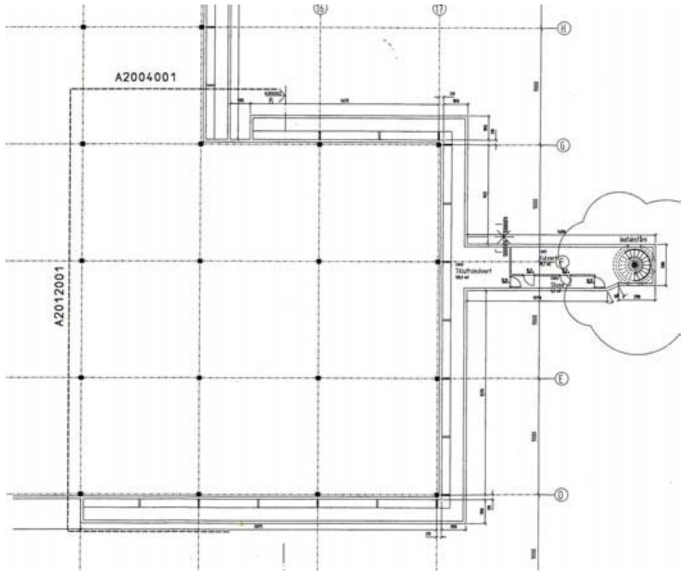
Section through base area

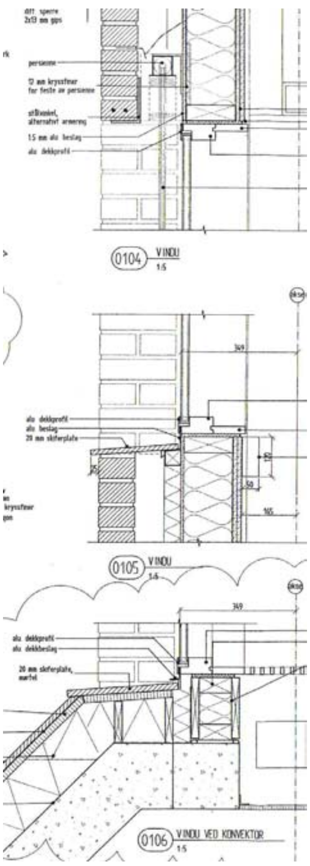
Culverts serve as filters since low air speed allows particles to settle on the floor. However, because of the reduced length, we had to install additional filters. All culverts have central vacuum cleaning systems to remove sediments from the airflow. The massive construction of the culverts helps to cool the air in the summer and preheat during winter. The temperature is fairly stable at about 6 to 10°C which is enough to cool summer air to a comfortable level. In very hot periods it necessary to run the ventilation during the night to cool the building elements, which to a great extent consist of heavy materials with good thermal capacity. This in turn helps keep the temperature during the day.

Typical base area with student "offices"



Base area culvert system

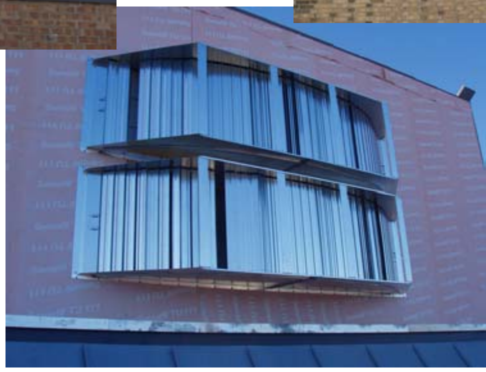




Typical wall section

Details from culverts

From the culvert air is let into the room through specially designed grids that allow people to stay very close without feeling a draught. From each room the air is lead to the central area where exhaust towers evacuate the used air. Air flow through each room is regulated by electrically operated windows in the wall towards the central area. The opening (and the air flow) is regulated by temperature and CO2 sensors in each room and thereby adjusting to the actual need. Exhaust towers are equipped with fans that are activated when natural driving forces are insufficient and heat recovery systems that supply heat to the preheating unit in the culverts. To benefit from wind forces a special shutter system was developed in close cooperation with the technical university in Trondheim. It ensures that the wind always helps evacuate the air and never build up a pressure that could reduce or stop the natural air flow.

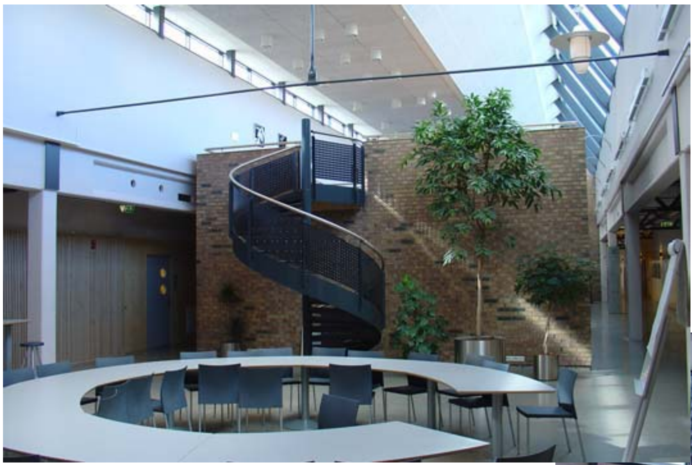


The new section of the building has a Swedish model with culvert under the building. From the culvert air is distributed to the rooms above through double walls of massive brick. Exhaust towers on the roof have electrically operated shutters on both sides that are regulated by temperature and CO2 sensors, and they automatically open on lee side. The towers have glass roofs which provide extra daylight to the rooms, but also helps warm up the air and increase air speed. The school kitchen and all wardrobes and toilets have mechanical exhaust systems.

The health centre and administration offices have traditional balanced ventilation systems. The different areas have separate electric meters and heat meters, which makes it possible to monitor the running costs of the different systems. This will be followed up in a case study the next couple of years. It is difficult to estimate potential savings, but the results of the study will clearly show the reduced energy consumption for the building.

3.4.2.2. Lighting

The shape of the building made it necessary to improve daylight conditions, and SINTEF was engaged to make a study of the possibilities and effects from the suggested solutions. A model was built of the central area and a typical base area. These were then tested in the sun laboratory at the university in Trondheim. Tiny light sensors were placed in the models to measure the amount of light entering the building through the suggested windows and skylights. Results were positive. The large skylight facing north at an angle that would not let direct sunlight and heat into the building, would very much increase the level of daylight in the central area. The narrow window facing south would also contribute without letting in much heat. The result was the same in the base area, but shutters had to be used to prevent unwanted heat.

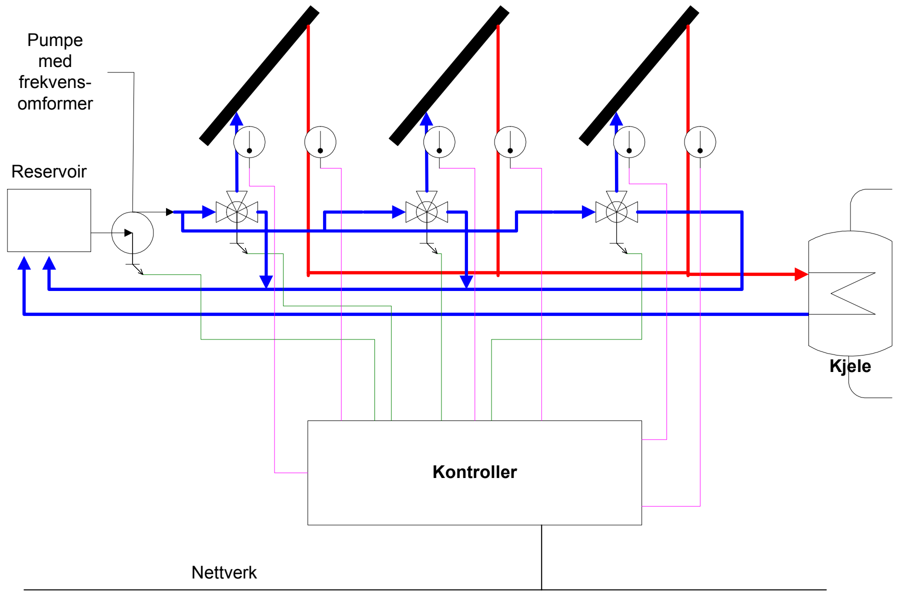


Studies have shown that daylight is good for the human health and should be used more actively than the case is today for many buildings. In addition, it reduces costs for electric lighting and makes buildings more agreeable places to be. To optimize the effect of daylight, all artificial lights are adjustable and regulated by light sensors. In addition, light is also regulated by motion sensors that will turn the light on when someone enters the room, if conditions require so. When a room is left empty, the light will automatically be turned off after a preset time elapse. The IR-sensors also serve as detectors for the burglar alarm.

3.4.3. Solar thermal collectors

Planning and design of the solar collector is still in its early stages. SINTEF has been involved in simulation studies of potential energy gain under different solar conditions and different locations. Naturally, the results improve as one moves south, but the low sun in the winter gives good results for vertical collectors. The study indicates that collectors should have mountings that allow seasonal adjustments. SINTEF has also made studies of surface temperatures for solar collectors. Preliminary results indicate temperatures from approximately 22 to 43°C for the southern Norway region. “Our” collector with highly efficient glass and liquid heat media has not been tested and the project group expects to obtain higher temperatures. At any rate, for production of domestic hot water it will probably be necessary to connect a heat pump to raise the temperature to a level where problems with legionella is avoided. This may not be a problem with closed circuits for heating only.
Plans are to have design ready for a prototype in February 2006 and the first prototype ready for installation at Borgen by mid April. The exact location of the collector will be decided at our next meting in February.

Concept for solar collector system



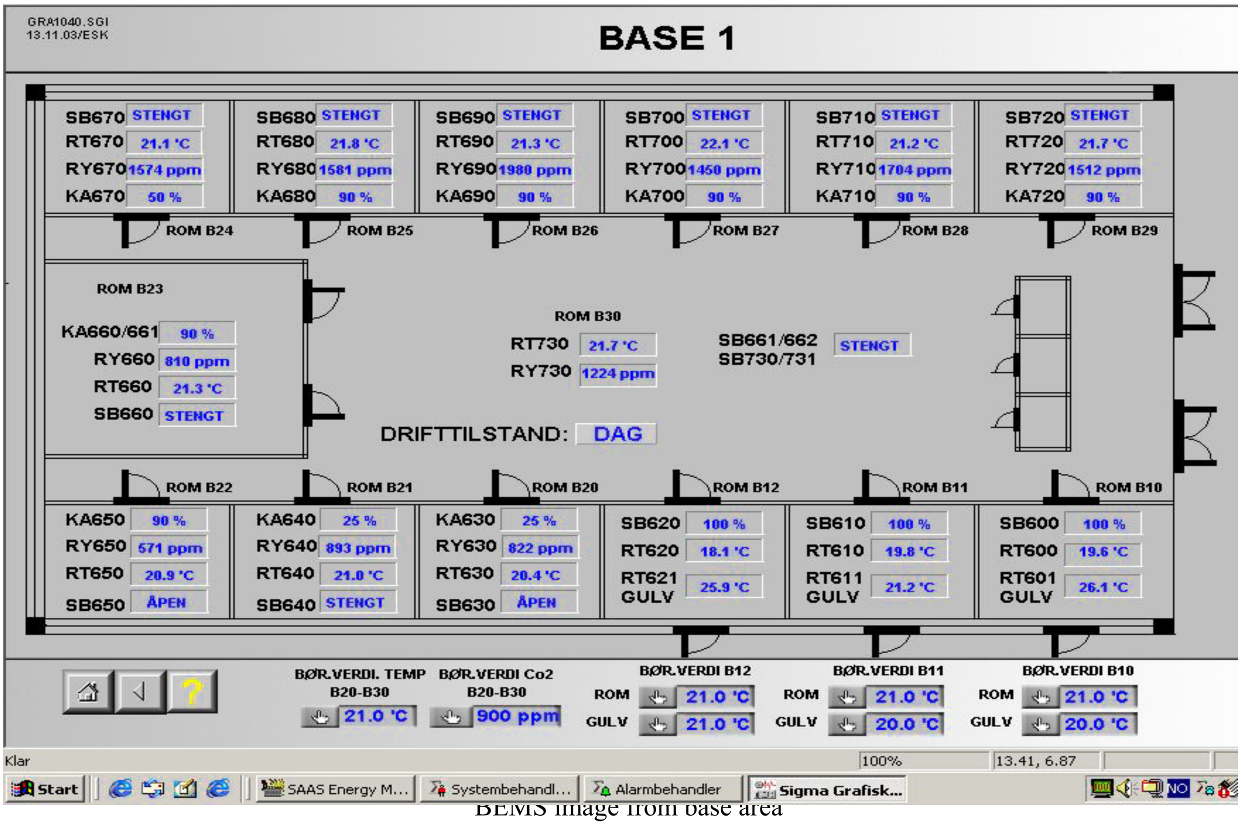
3.4.3.1. ACC windows

Preliminary design for window frames and sashes have been completed. A prototype for the special hinges is produced and details concerning the wind tight sealing have been designed. A prototype of the ACC window will hopefully be ready for installation along with the solar collector next spring.

3.4.4. BEMS

Ensi AS (later changed name to EvoTek) was engaged as a special consultant to help us make specifications for the BEMS system and to follow up installation, programming and test runs. With such a large number of sensors, meters, electric valves, shutters, pumps etc, it was extremely important that all units could communicate properly. All installations had to operate with open protocols and Evo Tek ensured full compatibility. After tenders had been evaluated, Satchwell was chosen for BEMS contract. The system was prepared for OPC protocol, but the server was not installed as of today.

The operation of the BEMS has been described in previous sections.



BEMS image from base area

3.5. Predicted energy savings

One should bear in mind that energy consumption for heating and hot water to a great extent is based on electricity in Norway and oil burners are used as backup systems. This allows lower rate electric prices. Note that the estimated total consumption is for the whole building, including the new extension, while the figures in 2.3 only covers the old building.

Energy saving measures, heating, cooling, ventilation	[kWh/m^{2}a]	Total [kWh/a]
Space heating	29	174000
Water heating	20	120000
Fans and pumps	15	90000
Lighting	23	138000
Equipment	11	66000
Cooling	0	0
Total heating energy savings	**111**	**588000**

Preliminary results indicate that we shall reach our goal. Last winter, during periods with optimal use of the heat pump, total consumption was recorded to as low as 100 kWh/m2a.

3.6. Predicted costs and payback

Energy saving measure/investment	Area [m²]	Total costs [EURO]	Saving [EURO/a]	Pay-back periods [a]
Heat pump	6000	475000	50000	9,5
Natural hybrid ventilation	6000	540000	55000	10
Total		**1015000**	**105000**	

Energy costs used for the payback calculation:
Electric: €0,10 kWh

Total costs have been corrected for installation of electric boilers instead of heat pump and necessary traditional ventilation systems to replace natural ventilation.

3.7. Lessons learned

- Problems with sound carried from one room to another through ventilation culverts. Measures had to be taken to minimize the problem. There have also been complaints from neighbours because of noise spread through exhaust towers on the roof. This is particularly the case from the music rooms.
- Difficult to build and expensive culverts along the existing building.
- IR sensors for light regulation combined with burglar alarm has caused problems because the early morning sun hits the sensor and triggers the alarm. Sensors had to be moved to a corner and directed inwards.
- Extensive and complicated BEMS system requires a long testing and adjustment period.
- Technical personnel should be educated during the building period to get acquainted with the technical installations before the building is opened.

4. Hol Church, Gol, Norway

Author: Sivilarkitekt Harald N. Røstvik

4.1. General data

4.1.1. General information

Year of construction: 1924
Year of renovation (start): 2005-2006

Total floor area (m^2): 555
S/V ratio: 0.20 (External surface 1180 m2. Volume 6.100 m3).
Number of storeys: 1 – but storey height 20 metres
Window/glass areas (m^2): 70

4.1.2. Site

Mountain countryside.
Hard winter climate. Temperatures down to minus 30 C.
Latitude 64 degrees N.
Longitude 14 degrees East.
Approximately 300 m above sea level

Location : Hol, Hallingdal, Norway

4.1.3. Building type

Timber Church – stave church type construction.
Listed building chosen as a highlight of architectural heritage cultural building types where the challenge is the following: What can we do when the antiquarian authorities have the power to prevent us from doing practically anything with the building?

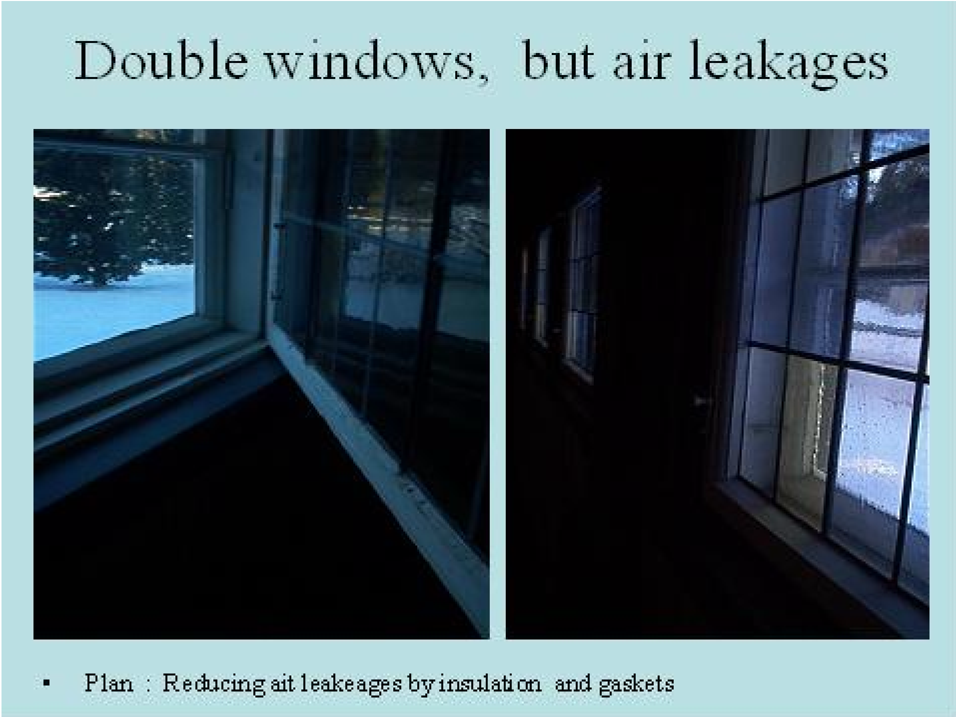
4.2. Before retrofit

4.2.1. Building construction

Uninsulated loft with sawdust covering – extremely fire hazardous. Underfloor crawl space – only one meter high. Extremely difficult to access due to low height
Listed timber building. National antiquarian authorities have to approve every minor move.
Achieving approval is time consuming. Difficult to get approval for every minor detail proposed.


Insulating the roof
▪ Plan : Insulating flat roof from loft side , sloping roof from outside


Basement - height : One meter
▪ Plan : Insulating under the floor planks from basement side .



4.2.2. Existing heating, ventilation, cooling, lighting systems

A major challenge in a church is the need for large heating capacity at short intervals during service and other functions. Between periods of activity in the church it is cooled down to fairly low temperatures between 5 and 10 degrees C above zero. Different activities demand different temperatures, depending on length of activity, seated or standing etc.:
During services 16-19 C is required. During weddings 19-22 C and during funerals 16 C and above.

The heating system in the church is based on electricity and with a normal running capacity of 40 kW. It can however be raised to 90 kW in extreme situations and at short spells.

Annual electricity use over the last few years have been :
2000 : 137.792 kWh/year (248 kWh/m²/year).
2001 : 112.120 kWh/year (202 kWh/m²/year).
2002 : 142.635 kWh/year (257 kWh/m²/year).
2003 : 126.651 kWh/year (228 kWh/m²/year).
2004 : 108.000 kWh/year (195 kWh/m²/year).

All heating is electric, which is not uncommon in Norway.
Round electric resistance heaters are located under some of the benches.
They keep a very high temperature but are old and inefficient.
Due to the rising energy costs however, the caretaker frequently shuts off the system and only puts it on a few hours before there is a service or other function in the church, This has led to a chilly and not so welcoming atmosphere for random visitors when there is no other activity in the church.
The tight church economy as a result of rising energy costs has led to this necessity for saving electricity.
In a study on energy in churches in Norway it was found a great variety in energy need.
Most of this is for heating. Two typical examples were :
Average: 366 kWh/m²/year (85 kWh/m³churchspace/year). Installed effect: 24 W/m³ church space.
Best example : 155 kWh/m²/year (24 kWh/m³ church space/year).

4.2.3. Energy and water use

	Measured year (2002)	**Total for the whole building**
Space heating Electric	220 kWh/m^2 a	122.100kWh/a
DHW	N.A.	N.A.
Electricity	37 kWh/m^2a	20.535 kWh/a
Water	N.A.	N.A.

4.3. Energy saving concepts

4.3.1. Building construction

This listed building requires a close collaboration in every detail with the antiquarian authorities.
This was foreseen and has been carried through.
It has been time consuming but not created a considerable progress delay - so far.
All planned insulation and air tightness work has been approved, although the antiquarian authorities turned down the original application due to worry about the need to drill in and disturb timber that had been stable since the church was constructed. The church council, however, did not give in and approached the authorities arguing that many churches in Norway had been closed as a result of rising energy costs. Closed and unheated churches are certainly not the best way of maintaining the valuable from an historic point of view timber construction. The authorities listened to reason and finally approved the planned work.
The final approval of the solar system still remain. Discussions are taking place. They go along similar lines as did the insulation issues.
The church council also argues that it is also the responsibility of the church to stimulate the development of new innovative solutions, in view of the global threat from climate change.
Several alternatives to full approval of the 15 meter high solar thermal system have been discussed. Among these, a solution with a more low lying solar absorber.
In 2004 a Thermophotographic inspection was carried out. It revealed the locations for the major heat leaks – due to a combination of overall lack of insulation and lack of air tightness.
The major problem-locations were :

- Floor insulation in timber floor construction is non-existent. A one meter crawl space under the whole floor makes access extremely difficult and complicated, yet that is the only way to approach the challenge of insulation. While average temperatures in the church was measured to be 18 C, large floor areas held only 14 °C. The worst air leakage spots only held a temperature of 7 C.
- Horizontal parts of the ceiling have - as the photos show - just sawdust insulation. The inspection revealed some air leaking spots where timber columns passed the ceiling and a generally poor insulation value towards the cold loft.
- Cold bridges where timber columns meet the floor. Due to_tiny openings caused by shrinking dried wood.
- Air leakages where the brick chimney passes through the wood floor.
- Area surrounding windows due to cracks in wood construction.
- Spots where timber girders meet the wall construction.
- Cold bridge on the lower part of doors.

Work planned to be carried out :
Floor:
Removal of rotted timber from below – working from the low crawl space.

Rotted timber exchanged with new timber.
All of the 372 m² church main room floor insulated with 20 cm Rockwool A-quality.
No vapour barrier will be installed.
Old U-value 0.80W/m²K.
New U-value 0.19 W/m²K.
Calculated annual energy saving :
(0.80 - 0.19) x 372m² x 6028 degree days x 24 x 10^{-3} = **32.828 kWh/year**

Major Roof/Loft:
The 122 m² horizontal roof insulated with 35 cm Rockwool A-quality. No vapour barrier.
In addition and on top of this insulation a 5 cm insulation with wind barrier included on top.
Old U-value 0.80 W/m²K.
New U-value 0.11 W/m²K.
Calculated annual energy saving :
(0.80 – 0.11) x 122m² x 6028 degree days x 24 x 10^{-3} = **12.178 kWh/year**

Loft over Organ position:
The 40 m² area covered with 25 cm Rockwool A-quality.
Old U-value 0.80 W/m²K.
New U-value 0.19 W/m²K.
Calculated annual energy saving :
(0.80 – 0.15) x 40m² x 6028 degree days x 24 x 10^{-3} = **3.761 kWh/year**

SUM - Calculated annual energy saving : **48.767 kWh/year**.

In addition, eliminating air leaks will further reduce the energy need.

4.3.2. Heating

The present heating in the church is all electric, which is common in Norway. We plan the introduction of a solar thermal system to reduce the use of electric power. After considerable evaluation and design a solar air based system has been selected. It uses air as heat transfer medium, which is an advantage in a mountain climate where winter temperatures can drop to minus 30 C and make water freeze. The solar heated air will be transported by a fan run by solar PV. No further regulation is hence necessary. The solar absorber is vertical and will deliver heat only autumn, winter and spring when the sunrays enter the absorber with a low angle of almost 90 degrees to the vertical plane. In summer when the sun is high the absorber glass will reflect the sunrays as they. The Solar PV run fan will start its operation when the sun provides enough energy to the vertical plane to produce current. When that happens there is also sufficient solar heat in the absorber to be usable heat. When the sun moves away from the absorber, the current stops and the fan is stopped from moving cold air from the absorber and into the church. The solar PV can also be connected to a switch so that it does not deliver current at all in the summer of that is found to be a more reliable way of regulation the heat in the summer.

4.3.3. Ventilation

No work planned.
No need.

4.3.4. Cooling

The building – like most churches - has little window area to wall area ratio.
Hence, no cooling needed.

4.3.5. Lighting systems

Solar PV being considered. The payback time for PV though is extremely long and we will reconsider if we are able to defend the relatively huge investment to achieve the relatively few kWh from solar PV.

4.3.6. BEMS

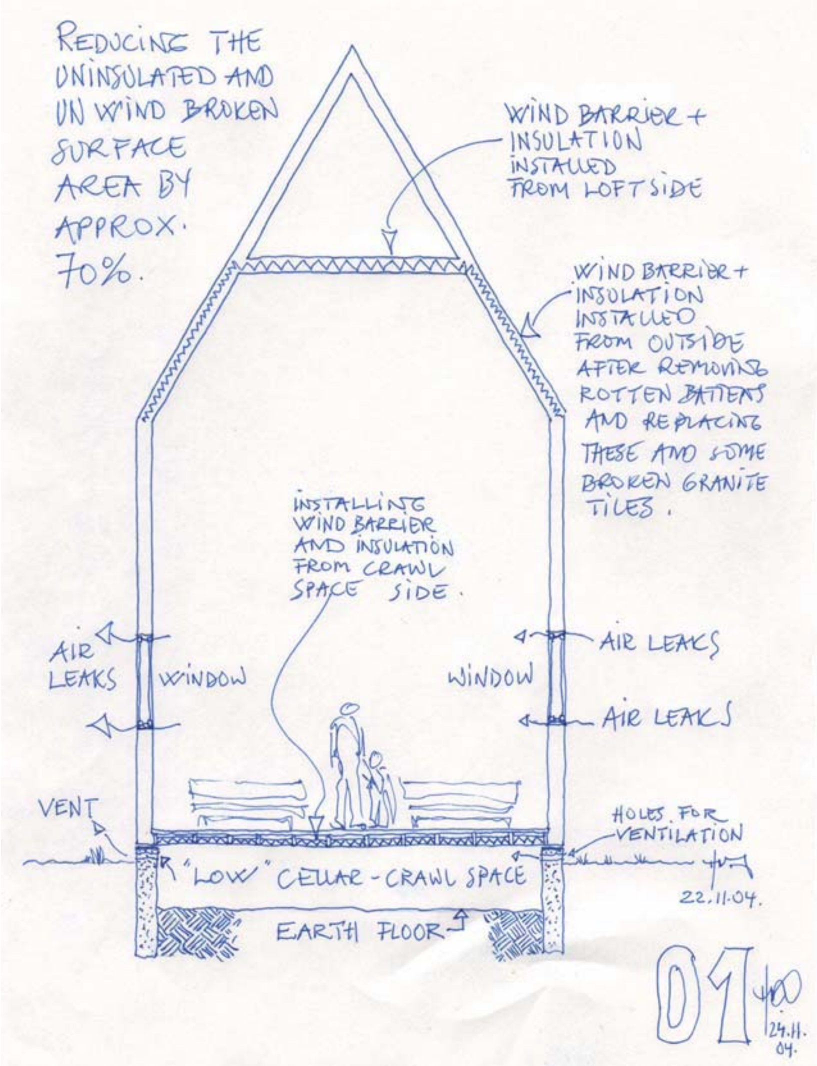
4.4. Overview of design process

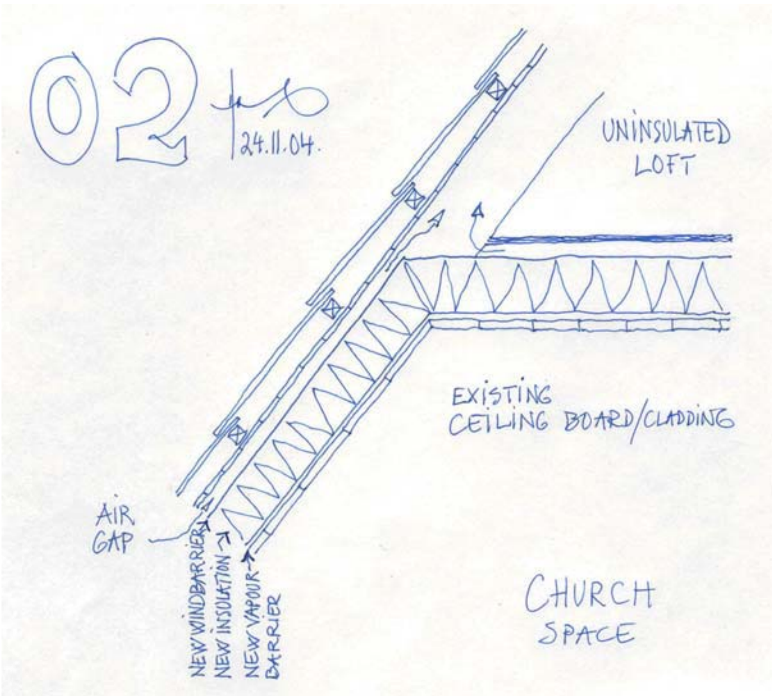
4.4.1. Building construction

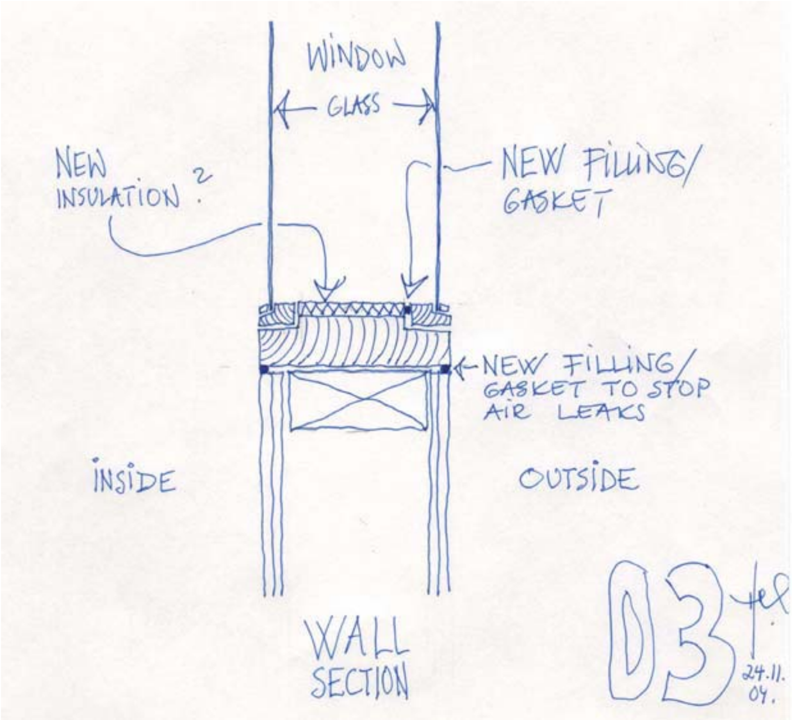
After several inspections and after receipt of the Thermophotographic inspection report, the design process was initiated.
Sketch drawings for improving the conditions were developed so that a dialogue with the antiquarian authorities could be started.
The evaluation and discussion process revealed that we would have to concentrate our work on three issues related to energy conservation : Insulating the flat roof, insulating the floor from the crawl space and work on air tightening the areas around penetration of floor, roofs and walls.
The major job was to actually get tenders for the job of insulating from the crawl space. Tender documents were developed. To our great surprise two tenders were handed in. The lowest bidder offered a price of only one third of the other. The lowest bid was selected and work has been completed within budget.
The antiquarian authorities demanded the following alterations to our design drawings :

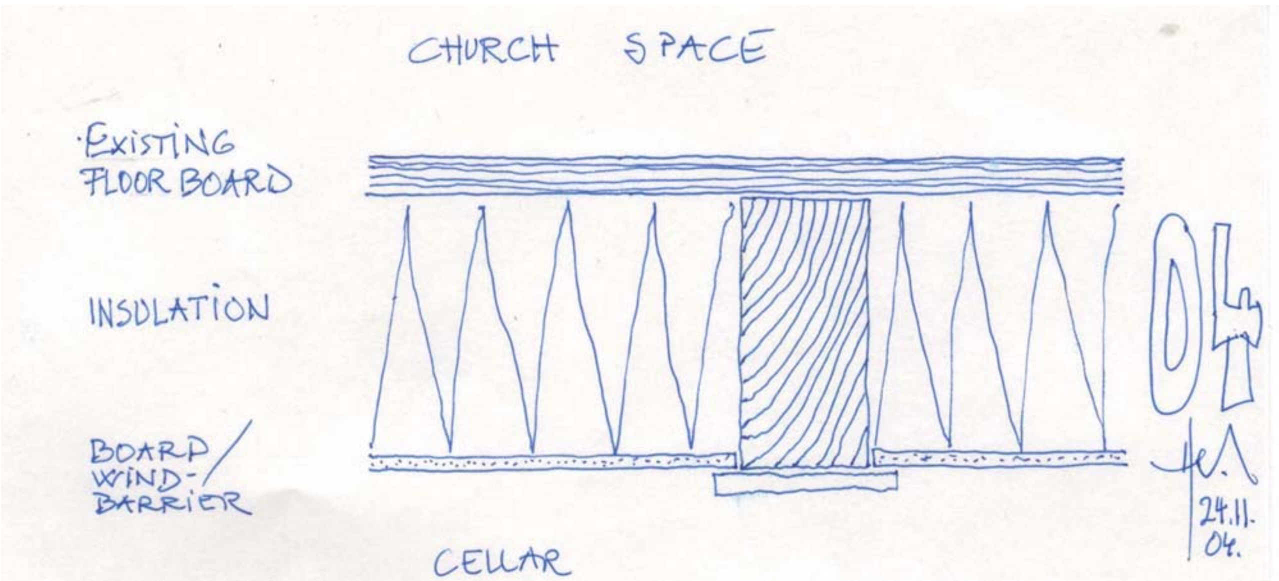
- Floors: No vapour barrier against the ground, only wind barrier. The reason : Fear that if vapour barrier be installed, risk of timber damaging moisture getting stuck within insulation could rise.
- Roof: No removing of the existing sawdust. We protested against this for fire reasons, but were overruled. Insulation were to be laid out above the sawdust and also here, no vapour barrier, just wind barrier.

The status is now as follows :
-All insulation work accepted by the antiquarian authorities..
-All work on gaskets around windows and doors accepted by the authorities..
Work has mainly been focusing on insulation and air leakages.


REDUCING THE UNINSULATED AND UN WIND BROKEN SURFACE AREA BY APPROX. 70%.
WIND BARRIER + INSULATION INSTALLED FROM LOFT SIDE
WIND BARRIER + INSULATION INSTALLED FROM OUTSIDE AFTER REMOVING ROTTEN BATTENS AND REPLACING THESE AND SOME BROKEN GRANITE TILES.
INSTALLING WIND BARRIER AND INSULATION FROM CRAWL SPACE SIDE.
AIR LEAKS
WINDOW
WINDOW
AIR LEAKS
AIR LEAKS
VENT
HOLES FOR VENTILATION
"LOW" CELLAR - CRAWL SPACE
22.11.04.
EARTH FLOOR
01
24.11.04.


02
24.11.04.
UNINSULATED LOFT
EXISTING CEILING BOARD/CLADDING
AIR GAP
NEW WINDBARRIER
NEW INSULATION
NEW VAPOUR BARRIER
CHURCH SPACE





4.4.2. Heating / ventilation / cooling and lighting systems

4.4.2.1. Heating and cooling

See also 4.2.4. The plan to install a solar thermal system is progressing. It is however not approved by the antiquarian authorities yet. Meetings have taken place. Documents have been handed over. Conclusions are expected to be reached late 2005. It is however not approved by the antiquarian authorities yet.

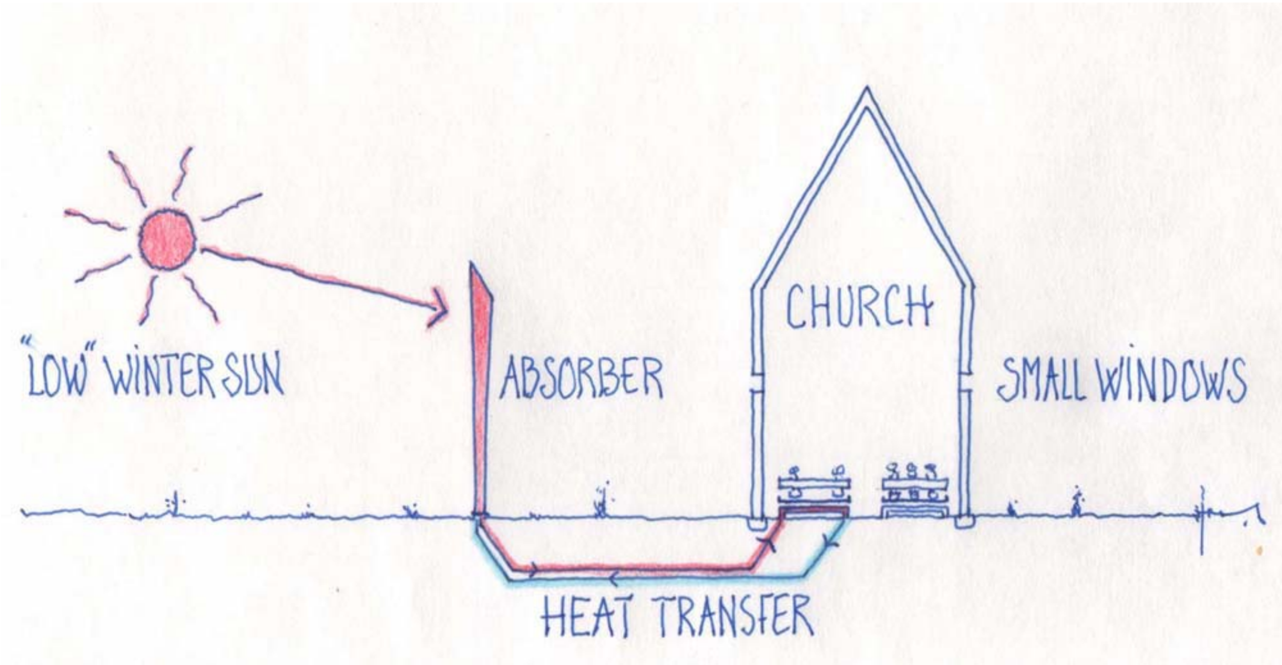
4.4.3. Ventilation

There are normally no ventilation system in old churches in Norway. All ventilation is natural.
Since the church room is very high in this church, as in most churches, the heat have a tendency to rise and gather at the top. The temperature stratification gets considerable. Studies have shown that a simple method to even out the differences is to use an air “canon”. It has the shape of an oil drum –although slimmer and has a height of two metres. Inside there is a fan, electric driven . It blows air and “shoots” it upwards towards the roof, without developing noise. This air pushes down the warm air at the top of the room, under the ceiling, and it almost immediately feels warmer. The effect is very good. The “canon” is used a short while before a service starts..

4.4.4. Lighting

Electric. Energy efficient lighting planned or being considered. The aim being to install more energy efficient light bulbs internally. Two strong external light canons to floodlight the church at night will be reduced to one. The efficiency of the remaining one is being considered.

4.4.5. Solar thermal



Since this is a listed building, it is almost impossible to interfere with construction. All possible changes have to be approved by the antiquarian authorities. The insulation work was improved. We are now in the process of having the solar thermal system approved. The condition is this: No solar panels on the church wall or roof.
As a result of this we have designed a vertical solar air based thermal system, at a distance of 12-15 meters from the church East wall. The solar absorber is South facing and vertical to catch the low sunrays on late autumn, winter and spring days It consist of a slim one meter wide, 25 cm thick pole that could be approximately 15 metres high. Pending approval by the authorities.
Solar thermal design has been based on experience figures and own data.

The vertical solar air based system will supply 300 – 500 kWh /m2 absorber usable energy, depending on whether the system delivers solar heated air directly into the church space from under the benches or via a heat exchanger in a closed loop.
15m2 solar absorber will hence be able to deliver up to 7.500 kWh/m2/year.
25m2 will deliver 12.500 kWh/m2/year.
The solar heated air will be transported in a 15 cm diameter heat insulated pipe underground at frost free depth, through the foundation wall of the church into the crawl space. From here it will enter upwards into the church room at several intervals to be decided by the antiquarian authorities. Under the church benches it will be going through a thin aluminium tube that transforms the heat to the church space. The air in the closed loop will thereafter return to the solar absorber in an insulated 15cm diameter return tube in the same ditch as it came in.
Around the church there is a 60 meter zone where all works have to be approved by the antiquarian authorities. They will also have to approve the vertical free standing solar absorber. Discussions related to approval and conditions are now ongoing and will hopefully be settled within November 2005.

4.4.6. Solar PV

PV planned and being considered. See also 3.5.
In Norway solar electric PV can provide approximately 100 kWh/m2 solar module per year. This is only 1/4 of what a solar thermal system can deliver. Solar PV is many times more expensive than solar thermal. A reconsideration of the investment in solar PV will hence have to be carried out.

4.4.7. CHP

None

4.4.8. BEMS

None

4.5. Predicted energy savings

Energy saving measures, heating, cooling, ventilation	[kWh/m^{2}a]	Total [kWh/a]
Insulation flat part of roof and under floor	48	27.115
Solar thermal system	15	8.000
Total heating energy savings	63	35.115

Energy saving measures, electricity	[kWh/m^{2}a]	Total [kWh/a]
Solar PV	5	2.700
Efficient lighting	5	2.700
Total electric energy savings	10	5.400

Water saving measures	[m^3/m^{2}a]	Total [kWh/a]
N.A.		

4.6. Predicted costs and payback

Energy saving measure/investment	Area [m²]	Total costs [EUR]	Saving [EUR/a]	Pay-back periods [a]
Insulation		37.000 *	5.056*	7 years
Air tightness				
Solar thermal				
Total				

* Saving calculation based on average Norwegian electric energy price of NOK 0.8/kWh and actual tender costs. Cost for Air tightness and solar thermal not yet settled: figures will be given with the final report.

As stated in the original project proposal application, a project of this kind has a considerable replication potential. There are 1900 old churches in Norway and 3000 in Scotland alone. Many of these are listed buildings. Overall payback time: 22 years.
Energy costs used for the payback calculation: 80 Norwegian Øre/kWh = 1/10 Euro.
Thermal : Oil when used for heating (not in this building) costs approximately 1 NOK/kWh
Electric: NOK 0.8/kWh (average price in Norway). Local price in Hol NOK 0.62/kWh.

4.7. Lessons learned

- Energy need varies strongly with climate from year to year.
- Rising energy costs lead to urge towards energy saving,
- Energy saving (switching off, lowering temperature setting) results in colder interiors and harsh conditions for old timber and art work etc.
- The atmosphere also becomes hostile.
- The more one saves, the less there is to save when installing for example energy control units and other energy sources.
- To get approval for building works is time consuming as central antiquarian authorities (Riksantikvaren) has to be involved whenever a listed building is to be touched.

5. Prøvehallen

Author: Ove Mørck

5.1. General data

5.1.1. General information

Year of construction: 1930
Year of renovation (start): 2004
Total floor area (m^2): Originally: 765, after renovation: 2300
S/V ratio: 0,19
Number of storeys: Originally: 1, after renovation: 3
Window/glass areas (m^2): 220 m^2

5.1.2. Site

The site is located in an urban area called Valby located 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.

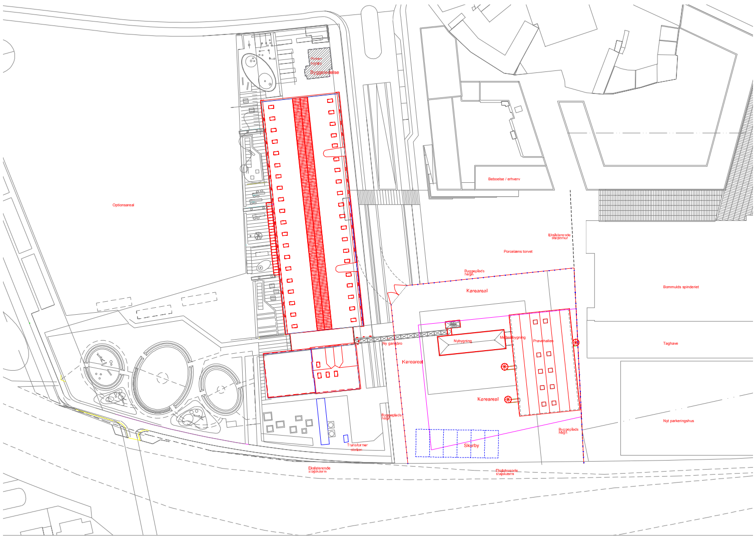


Fig. 1 The building site. Ovnhallen (to the left) and Proevehallen.

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.

5.1.3. Building type

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

Fig, 2 Proevehallen, seen from railway

Fig. 3. Ovnhallen – being retrofitted.

5.2. Before retrofit

5.2.1. Building construction

Proevehallen had not been used for a number of years. It was an empty hall with only a ground floor in spite of a height of 18 m. Because of its original purpose it had been built as a minimal construction with no insulation in walls and windows and simple single glass metal frame windows. In the renovation process 2 new floors had to be fitted in, and insulation and new windows had to be installed. The building had been unheated and ventilated solely by the port opening and the windows, so also complete heating and ventilation systems had to be designed and installed. As there was no energy consumption before retrofit to compare to the energy saving design had to compare to the existing requirements in the Danish building regulations and estimate the savings compared to a building renovated to these requirements. Complying with the requirements in the building regulations was not a requirement for the renovation as it was valid only for new buildings.

There was no existing drawings available for the project. Below the two ¨photos show the state of the building before retrofit.

Fig. 4 and 5. Proevehallen before the retrofit process started.

5.2.2. Existing heating, ventilation, cooling, lighting systems

There was no heating nor cooling system and the building was ventilated by the large port opening and the windows. Lighting was simple incandescent light fixtures in the ceiling.

5.3. Energy saving concepts

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

5.3.1. 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 fire protection reasons (law and regulations) this would require quite substantial and extremely costly treatments of the metal beam load supporting parts of the wall. Therefore it was decided to insulate the wall externally. This has not economical consequences to the project and from a technical point of view it is a clear advantage, as it is well known that external insulation is better at preventing thermal bridges than internal insulation.

5.3.2. Heating

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

5.3.3. Ventilation

The building is ventilated by a combination of natural ventilation – of the upper floor – and mechanical ventilation of the lower floors which includes bathroom and toilets. The upper parts of the high windows are used for natural ventilation of the upper floor. As the openings are placed high above the ceiling the incoming air will be mixed with the indoor air – thus reducing the risks for cold draughts. This ventilation will be required only when the gym on the upper floor is used by people generating heat which has to vented out, so preheating and heat recovery is not needed for this air exchange. The windows will be demand-controlled according to CO_2 and temperature.
An efficient air-to-air heat exchanger is used for the mechanically ventilated part of the building. This balanced ventilation system keeps a minimum low ventilation for the toilets and supply additional ventilation when the CO2, humidity (in the bathrooms) and temperature sensors calls show that there is a demand for 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 does not mean any changes for these calculations.

5.3.4. 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 here was (with the artist design – see below) only space enough for 19 kWp PV arrays. Therefore a combined solar collector/ solar cell panel was planned in stead of the originally intended solar heating system and the remaining part of the PV array (6 out of 25 kWp) placed here.

5.3.5. BEMS

A Building Energy Management System (BEMS) has been designed and installed to control the heating and ventilation systems. This will assure optimal control of the building and thus save energy compared to simpler or manual control systems.

The BEMS system will also be used to capture energy consumptions and data for temperature, CO2, humidity plus external weather conditions that can be used for analysis with respect to indoor comfort, air quality and energy consumptions.

5.4. Overview of design process

5.4.1. Building construction

Figure 6 shows a cross section of Proevahallen. The energy saving concept included additional insulation of the building envelope and new low-energy windows.

Roof:
As stated above the roof was a so-called minimal construction – meaning that its load bearing capacity was very limited. It turned out that it could hardly carry the weight of the insulation according to the requirements in the building regulations, so an additional 10 cm as required by the BRITa-in-PuBs project would require costly construction strengthening, which would be out of the question. So, this part was almost given up, when the project architect suddenly came to think of the fact that most part of the roof was already strengthened because of a large

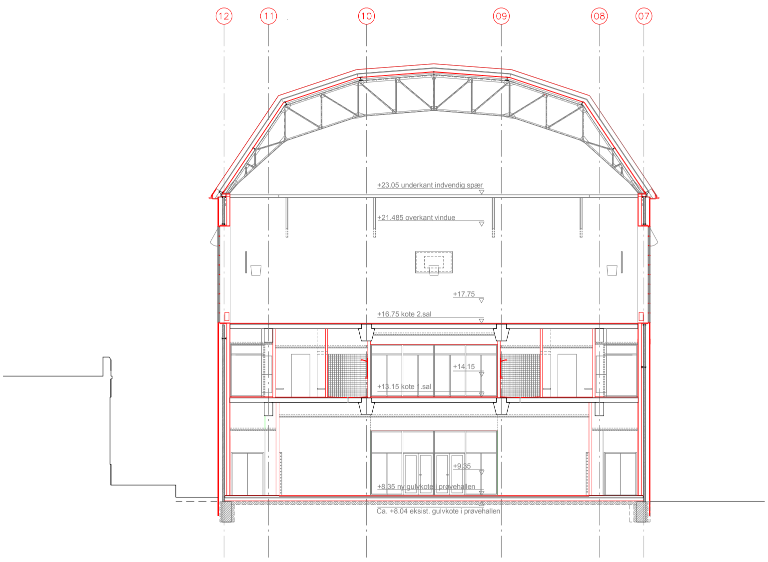


Fig. 6. Cross section of the renovated Proevehallen.

crane that was hanging from the roof to move the isolators to be tested. This meant that only a small part of the roof had to be strengthened and thus the BRITA-in-PuBs requirements could be carried through. The resulting U-value of the roof is 0,13 W/m²K compared to 0,2 W/m²K which is required in the Danish Building Regulations. For a detail see fig.7.

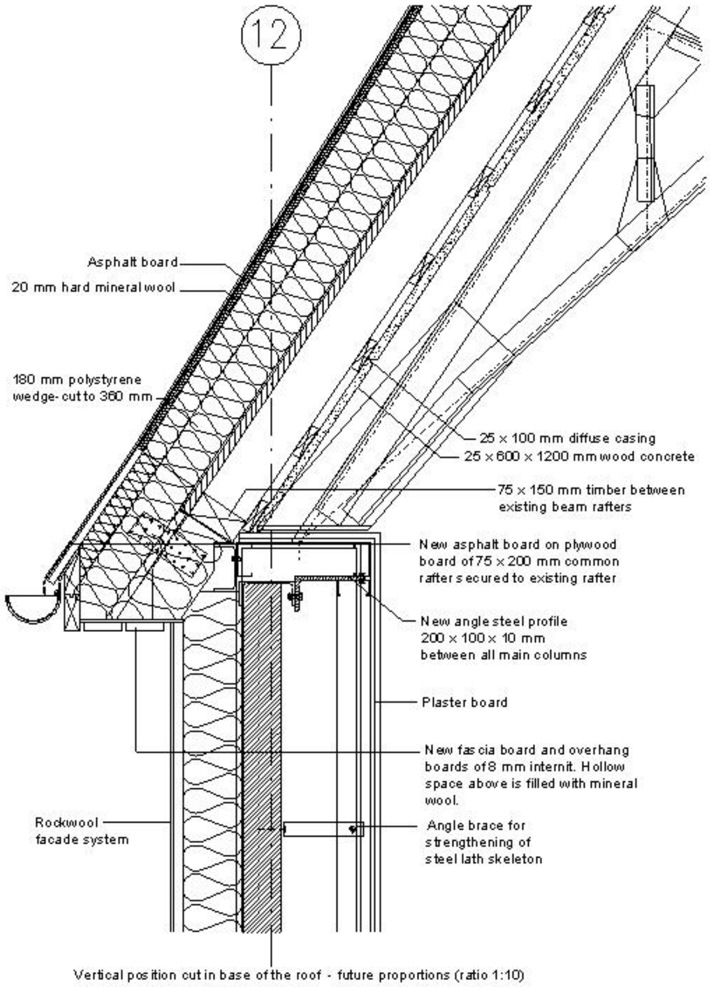


Fig. 7. Cross section of wall and roof construction details.

Wall:
As stated above the external walls had to be insulated on the outside. This did not create any additional problems. The following U-value was specified: 0,18 W/m²K – the corresponding requirement in the Danish Building Regulations is 0, 3 W/m²K. Fig. 7 below shows the details of roof and wall insulation.

Windows:
The new windows had to be designed in the same way (with the same look) as the existing windows. This meant that the subdivision of the larger windows had to have the same shape and size as before. The size of these are approximately 30 x 42 cm². The main part of the design process was therefore to search for a window product that both aesthetically and thermally could live up to the requirements. The system selected is from a renowned Danish company called HS Hansen – generally they are very expensive, but they gave a special offer and won the order. With a center U-value of the glazing of 1,1 W/m²K the overall U-value of the windows became 1,56 W/m²K.
What is required in the Danish Building Regulations is 1,8 W/m²K.

5.4.2. Heating / ventilation

5.4.2.1. Heating

The design of the heating system was straightforward – the additional feature was the control of the system by the BEMS system.

5.4.2.2. Ventilation

The ventilation system is described under 3.3 above. Strategies for the demand controlled ventilation had to be worked out for both the naturally ventilated parts and the mechanical ventilated part. The mechanical ventilation system was designed under both a cost constraint and a requirement agreed to by the design team, that it should be reliable, and easy to maintain, which meant that it could not be too complicated in layout. The design work of the mechanical ventilation system also included the ventilation unit suitable for the BEMS system control.

5.4.3. Solar PV & Solar PV/Thermal (PV/T)

As explained in paragraph 3.4 above a the originally planned PV system on the roof had to replaced by a PV-system on the gable wall and a PV/T system where the PV/T collectors are placed on a neighbour building. The systems are described below.

5.4.3.1. Solar PV/Thermal (PV/T)

6 kWp of PVT are placed on the roof of an adjacent building –as where the solar collectors originally planned for. They will be placed towards south with an optimal slope of 40-45 degrees from horizontal.

The solar collectors will be cooled by a heat pump and the heat delivered to the heating plant of Proevehallen. The idea of the solar energy system for DHW for Proevehallen is to utilise an innovative Photovoltaic/Thermal (PV/T) solar collector which both produces electricity and heat. A PV/T component, developed by the Danish PV company Racell will be mounted by the solar heating company Batec Solar Heating, see fig. 8.

Fig. 8. Photo of PV/T solar collector from Racell.

The efficiency of the PV – cells in dependence of different absorber temperatures are accounted for in the appendix: SE123W-PVT-Thermal-module-data.pdf. In this document is also -accounted for the thermal efficiency of the PVT – panels working as solar collectors.

Prior to the demonstration of the PV/T system at Proevehallen development work has been carried out in a Danish RTD project, named “PV-Optiroof”. The basic idea in this project was to utilise a PV/T solar collector absorber without a glazing system and combine this with the operation of a heat pump which cools the PV/T array and transfers the heat to produce DHW. This means that the typical operation temperature of the PV/T absorber and the solar cell will be around 5-10°C. This temperature range shall be compared to normal operation conditions of unglazed solar cells which will often be around 40°C.

With the stated temperature influence on the electrical output of 0.44% per °C and operation temperature of the PV/T solar cells of 10°C this will mean an extra solar electricity production of 0.44 x 30 = 13%, while for the 5°C operation temperature it is an additional 15%. At the same time a quite high solar thermal yield will be obtained due to the near ambient operation temperature.
The PV cells are connecting according to the Danish net-metering system, which means that the electricity production by the PV cells will first be used in the building and if it exceeds the demand of the building it is send to the grid. In this way the cells are integrated in the overall energy management of the building.

A high efficiency heat pump will be used to take heat out of the PV/T solar collectors and then transfer the heat into DHW heating boiler for Proevehallen (see Fig. 9). The proposed system has gained support and interest from both the local energy company, Copenhagen Energy and the electricity production controller Elkraft System. This is due to the fact that there exist problems in Denmark concerning electricity surplus production in winter, and here heat pumps in combination with renewable energy systems are seen as a very interesting option with a considerable potential for replication.

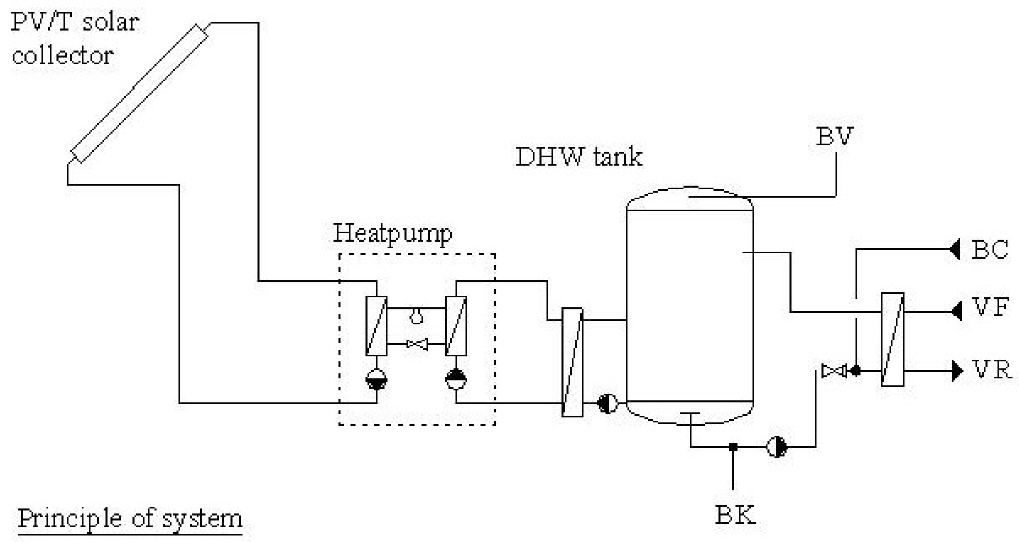


Fig. 9. Sketch of PV/T heat pump assisted energy system for DHW-production.

Compared to individual PV and solar DHW systems there are cost savings on the combined use of a PV/T system, but the overall payback is more or less the same. However, one of the interesting aspect is that although the heat pump uses electricity for its operation, this can be covered by the PV electricity production – in this case considering the electrical output of 1.25 kWp of the PV array a completely CO2 neutral DHW solution on a yearly basis will be the result.

5.4.3.2. Solar PV

As mentioned above the main part of the solar cells was shifted to the south gable wall. The additional bearing for the solar cells was mounted while the external insulation was added and is already in place. This was necessary to allow the mounting on the existing wall – these bearings are used for the normal mounting system of the cells. Furthermore the gable solution makes the solar cells more visible – as explained: the gable can be seen from the local subway-train which passes close by and everyday transports 400.000 of people to and from work.

It has therefore been necessary to get acceptance from the Chief Architect of Copenhagen, who has agreed on the condition that the integrated solution for the placement of the solar cells proposed by the artist is carried out. This means that the project will get a “light-house effect” for PV-cells in Denmark.

Fig. 10 Mounting racks for the PV-panels on the south gable wall

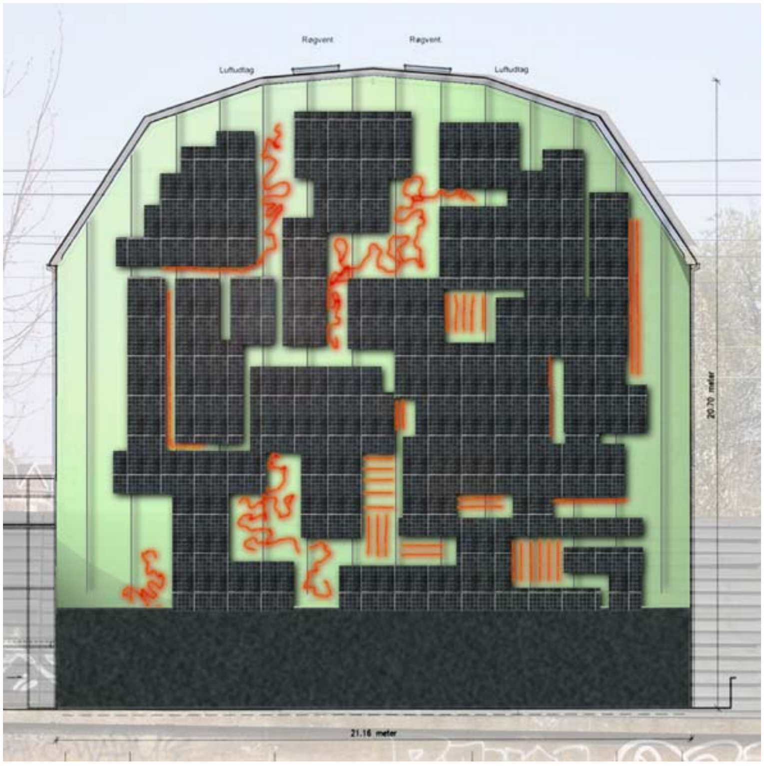


Fig. 11 The artist design of the PV panels on the gable wall.

5.4.4. BEMS

The specifications for the BEMS systems were worked out by the consultant. Then these were transferred into an implementation document by the company that delivered the system – TAC A/S – the details were clarified i.e. sensor locations and control algorithms. The type and location of the onsite display was discussed and agreed to – and the capabilities and limitations of these (in principle it provided access to the internet, but it was not the intentions that the project should provide that). The main feature of the TAC system and also a main reason for selecting this system is that the system is accessible anywhere from the internet.

The screen dumps shown in the figures 11-13 illustrate the user interface of the system.

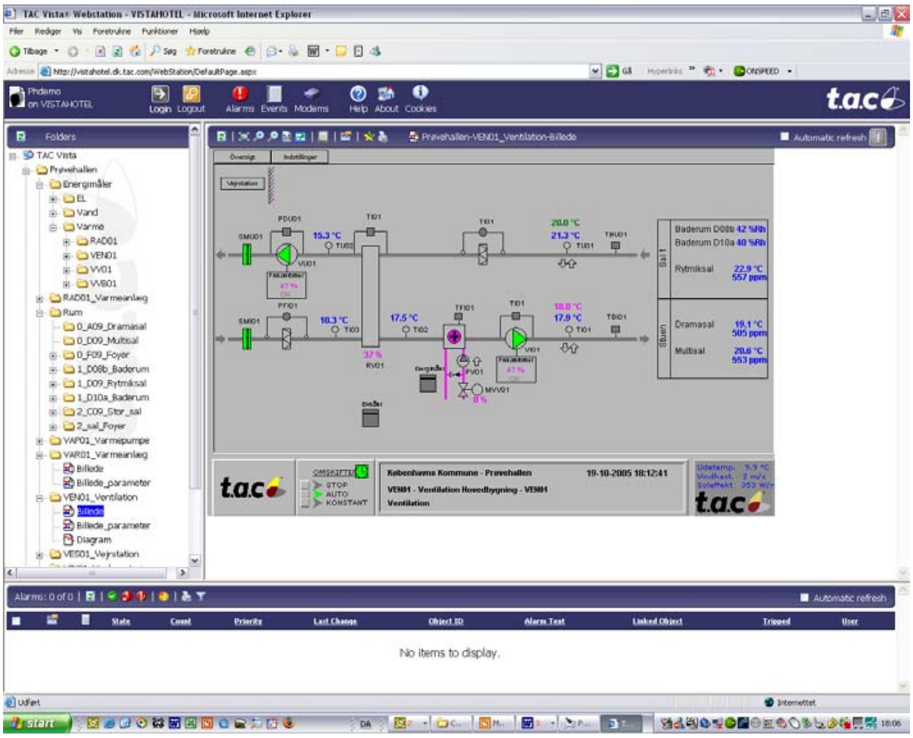


Fig. 11 Screen dump from BEMS system showing part of the ventilation control setup

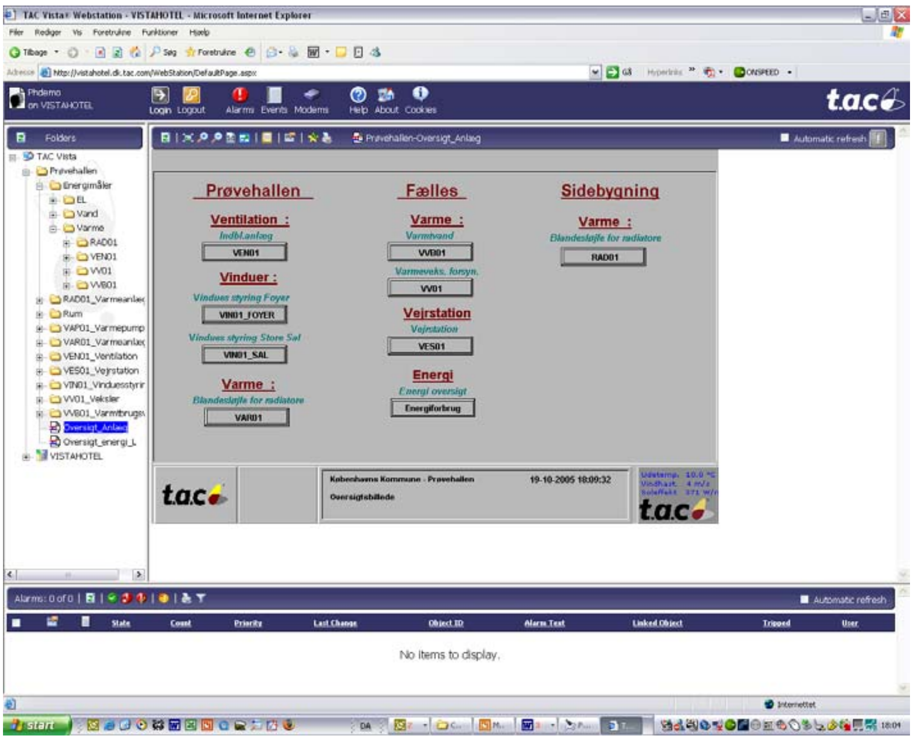


Fig. 12 BEMS screen dump – overview screen for entering into different parts of the BEMS

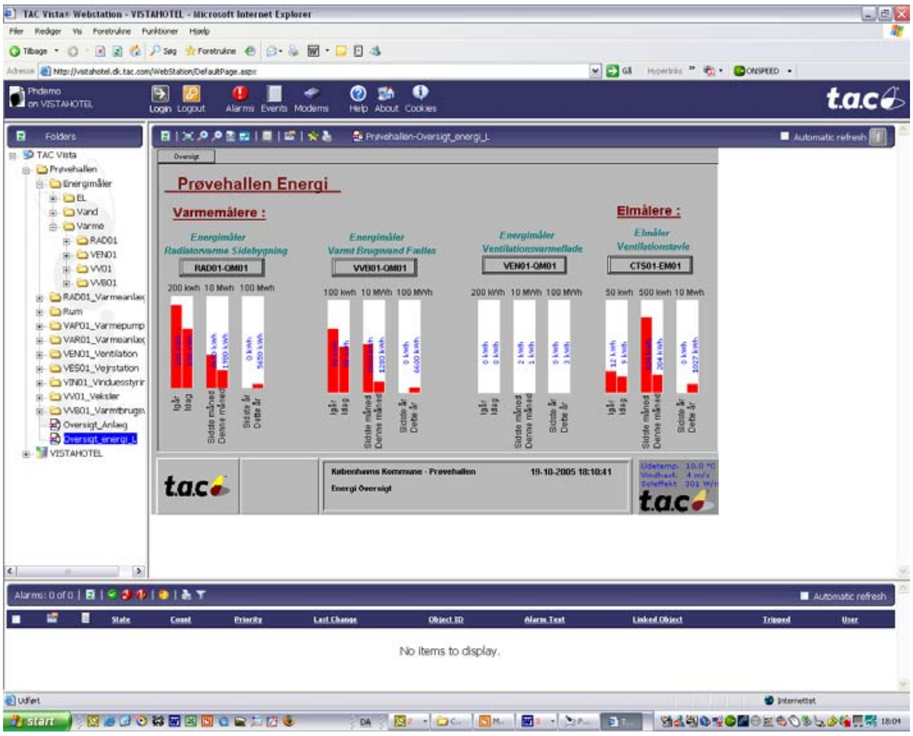


Fig.13 BEMS screen dump – showing a metering presentation.

5.5. Predicted energy savings

Energy saving measures, heating, cooling, ventilation	[kWh/m^{2}a]	Total [kWh/a]
High efficient ventilation	47,2	118000
Improved insulation of façade and roof	*6,0*	*15000*
Low-e windows	8,0	20000
Heating energy savings (lower water use)	9,2	23000
BEMS	12,0	30000
Combined PV and Thermal heating system	6,6	16500
Total heating energy savings	**89,0**	**222500**

Energy saving measures, electricity	[kWh/m^{2}a]	Total [kWh/a]
High efficient fans in the ventilation	12,4	31000
BEMS	4,0	10000
Electrical output of PV/T cells	2,4	6000
PV-cells, 19 kWp	6,4	16000
Total electricity energy savings	**25,2**	**63000**

Water saving measures	[m^3/m^{2}a]	Total [kWh/a]
Water savings (toilets, showers, taps)	0,25	625
Total water savings	**0,25**	**625**

5.6. Predicted costs and payback

Energy saving measure/investment	Total costs [EUR]	Saving [EUR/a]	Pay-back periods [a]
High efficient ventilation	33.557	8.870	3,8
Improved insulation	60.403	1.128	53,6
Low-e windows	26.376	1.503	17,5
Heat savings (water use)	6.711	1.729	3,9
BEMS (heating savings)	20.134	2.255	8,9
PV/T w. HP - thermal + electrical	102.500	2.595	39,5
High efficient fans	13.423	5.326	2,5
BEMS (el. savings)	20.134	1.718	11,7
PV-cells, 19 kWp	136.800	3.351	40,8
Water savings	6.711	2.148	3,1
Total	**426.749**	**30.623**	**13,9**

Energy costs used for the payback calculation:
Thermal : 0,075 Euro/kWh (0,55 DKK/kWh)
Electric: 0,21 Euro/kWh (1,55 DKK/kWh)

The cost for the additional bearings for the PV-panels on the gable wall was 2119 euro/kWp. The cost will be further increased because of artwork placing of the PV-panels. These additional cost are not included in the cost presented in the table – as they include other expenses, for example the fee to the artist. Furthermore this solution requires the use of new, totally black solar cells, at a higher cost than conventional solar cells.

5.7. Lessons learned during

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

- The finding 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 the 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 from the contractors is that “this is too expensive”. In the actual situation it was the BEMS system. But by negotiations it finally got through the process.

Appendices

1: SE123W-PVT-Thermal-module-data

6. The Brewery – students' social and cultural center

Authors: M. Jicha, P. Charvat

6.1. General data

6.1.1. General information

Year of construction: 1770s
Year of renovation (start): 2004

Total floor area before retrofitting (m^2): 2300
Total floor area after retrofitting (m^2): 2660
S/V ratio: 0.355
Number of storeys: 2 and 4
Window/glass areas (m^2): 145.5 m^2

6.1.2. Site

The "Brewery" is located in the north-west part of the city of Brno. The city of Brno is the largest city in the province of Moravia (the south-east part of the Czech Republic). The population of Brno is around 370 000 people. The city of Brno lies in the basin of the Svratka and Svitava rivers, surrounded by wooded hills on three sides and opened to the South

Moravia lowlands on the south. The altitude ranges from 190 to 425 meters. The coordinates of Brno are 49.2 N, 16.4 E.

Fig. 1 Location of the city of Brno

The "Brewery" is located in one of the old parts of the city. There are only low-rise buildings in the vicinity of the "Brewery", many of which are more than a century old. The altitude of the site is 227 m. The winter design temperature is -12 °C. The summer design conditions are: temperature 32 °C and enthalpy 62 kJ/kg. The annual mean air temperature (for the period 1961 - 1990) was 8.4 °C. The sunshine duration (in the same time period) was in average 1680 hours/year and the average precipitation 494 mm/year.

6.1.3. Building type

The Brewery is an old industrial-type building in a historical area that is under reconstruction for the use of the Faculty of Information Technologies of the Brno University of Technology (Fig. 2). The building was originally used as a brewery, but in the recent past it served as a warehouse. The retrofitting of the Brewery involves a complete change of the user profile. The former Brewery has to be transformed into a modern social and culture center for students and academics. This had a huge impact on the design phase, because all building services had to be designed from scratch.

6.2. Before retrofit

6.2.1. Building construction

The oldest part of the Brewery was built in 1770s. The building has been extended and rebuilt several times during more than 200 years of its history. The Brewery currently consists of two parts. The four-storey part of the building contains the original core dating back to the eighteen century. The two-storey part was build later, but also has a historical value, especially cast iron columns supporting the ceilings. Another two storey part of the building was torn down just before retrofitting. The elevations of the Brewery before retrofit are shown in Fig. 3. The floor plans of the four-storey and two-storey part of the building can be seen in Fig. 4 and Fig. 5. Fig. 6 shows four sections the building before retrofit.

Fig. 2 Arial view of vicinity of the Brewery

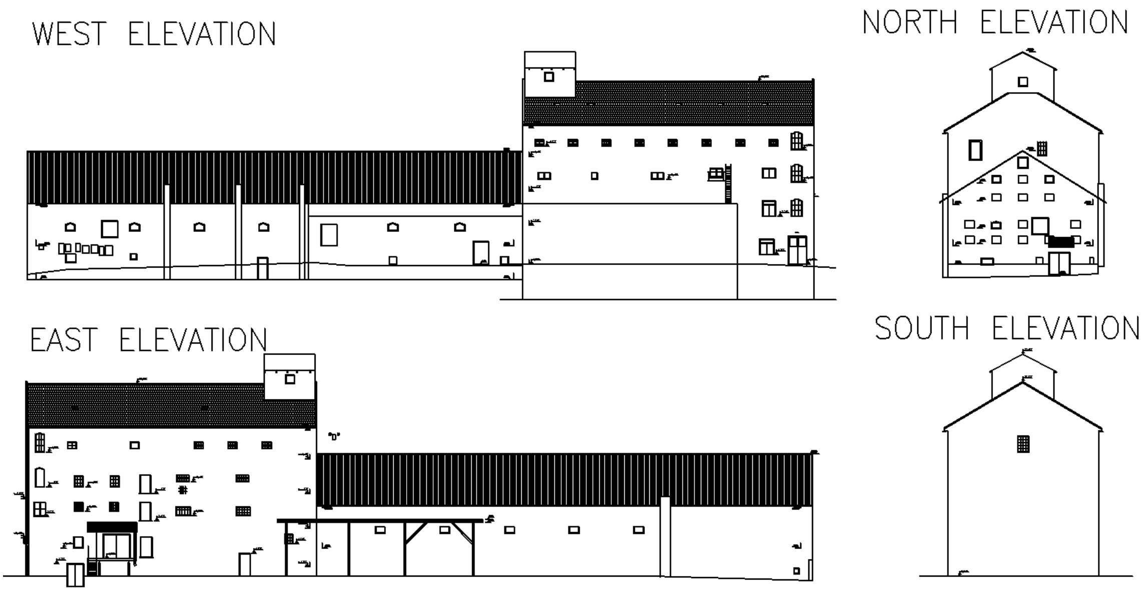


Fig. 3 Elevations – situation before retrofitting

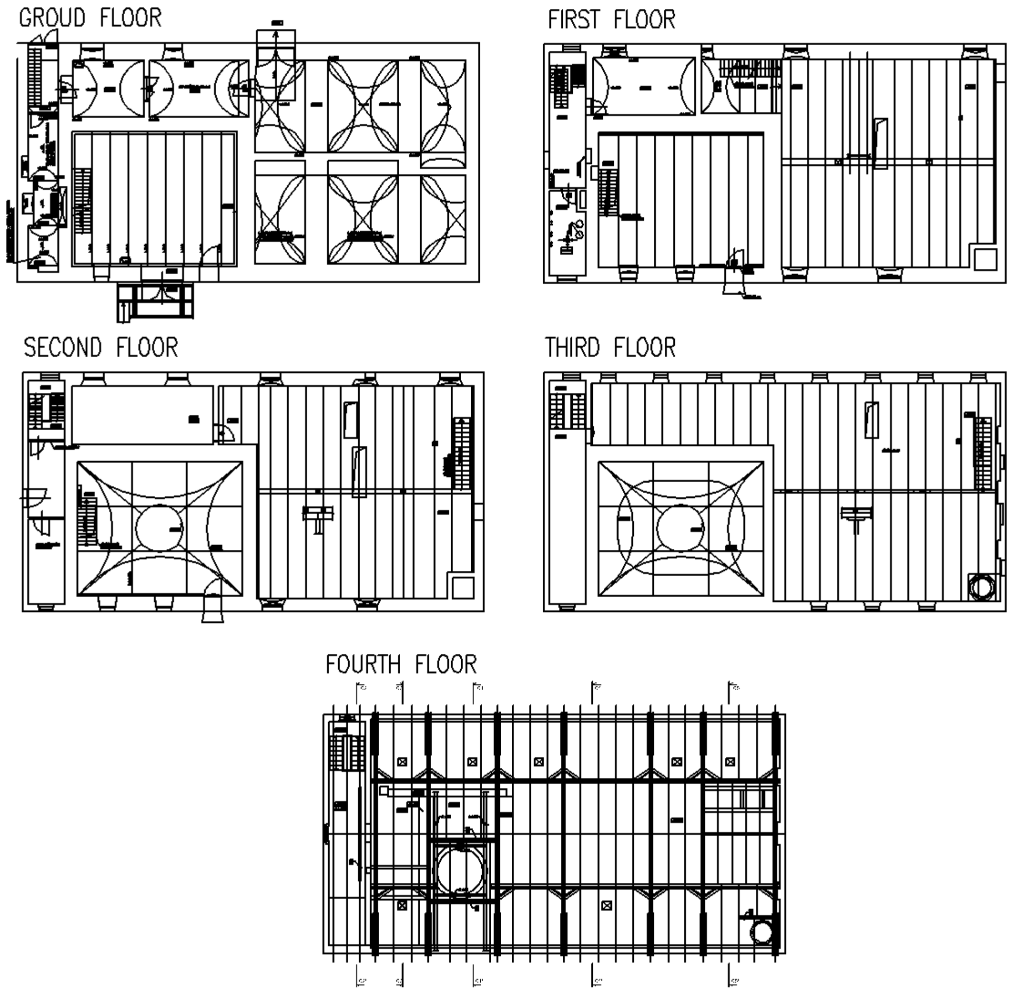


Fig. 4 Floor plans - situation before retrofitting (five-storey part of the building)

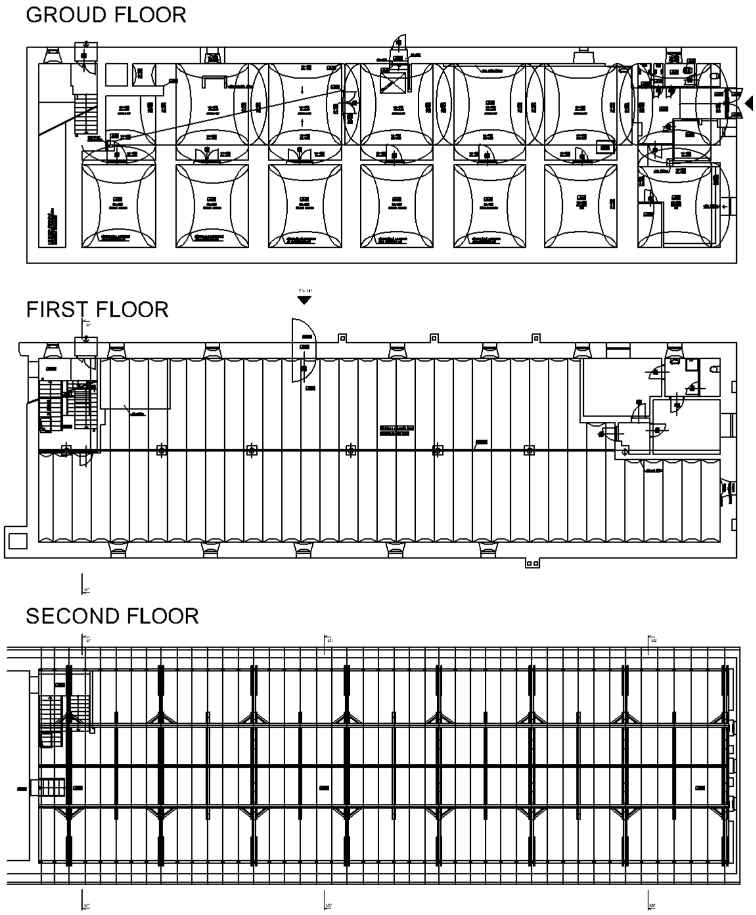


Fig. 5 Floor plans – situation before retrofitting (two-storey part of the building)

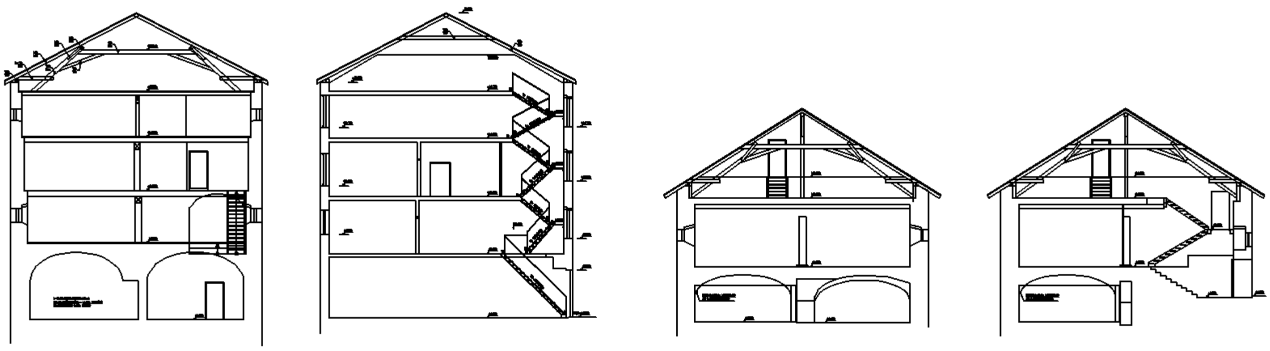


Fig. 6 Sections – situation before retrofitting

The walls of the building are made of burnt bricks. The external walls are 1 meter thick. The foundations of the building are very old and the foundation pressure exceeded the bearing capacity of the foundation soil. The reinforcement of the foundations was the first step, which had to be done before retrofitting. The vertical load-bearing constructions and brick vaults also needed some fixing.

The timberwork of the roofs was in relatively good shape, but some beams had to be replaced. The ceilings are of various constructions. There are brick vaults on the ground floor (Fig. 7a). The upper floors have either beam ceilings (Fig. 7b) or combined beam and riveted girder ceilings supported by cast-iron columns (Fig. 7c).

a) b) c)

Fig. 7 Ceiling types in the Brewery

6.2.2. Existing heating, ventilation, cooling, lighting systems

The building served as a warehouse for many years and so there was no usable heating system in the building before retrofitting. The coal fired heaters (stoves) were used for heating in the past, but these were not in operation since the building became a warehouse.
The building was naturally ventilated, but there were no purpose provided openings for the air supply, except of the windows. The old buildings were usually so leaky that no purpose provided opening were needed even to bring in combustion air for coal heaters.
There was no cooling system in the building, but there were spacey cellars for beer storage close to the building. The ice was used in these cellars as a cooling medium, when the building operated as a brewery. The cellars were flooded with water and an idea arose to use the flooded cellars as a heat reservoir for water-to-water heat pumps.

6.2.3. Energy and water use

Since the building had not been used for many years in recent past, no measured data about the energy consumption was available. An estimation of the energy consumption for the brewery profile was made. This estimation, however, did not seem to be relevant as a baseline in order to ascertain energy savings. Another estimate for the social centre profile, taking into account breaks in academic year, was made. The results of this estimate are shown in Table 1.

Table 1 The estimate of energy and water consumption before retrofitting

	Pre-retrofitting estimate for the students' centre user profile	**Total for the whole building**
Space heating	287 kWh/m^2 a	660 kWh/a
Electricity	71 kWh/m^{2}a	164 kWh/a
Water	5.5 m^3/m^{2}a	12 650 m^3/a

6.3. Energy saving concepts

Both passive and active measures have been present in the energy saving concept. Passive measures like additional insulation or replacement of windows represent more or less a "traditional" approach to retrofitting of building in the Czech Republic. Active measures, like the installation of a Building Energy Management System or integration of photovoltaic modules in a building structure, are innovative and have not been used in a mass scale yet.

6.3.1. Building construction

The building of the Brewery has 1-meter thick brick walls. The heavy mass of walls dampens the impact of the fluctuations of outdoor air temperature on the indoor air temperature.
One of the ideas at the beginning of the project was to employ the heavy mass of the walls as heat storage mass. The double skin facade was supposed to be placed on the south wall of the building. The facade would contain semi-transparent PV modules and the air gap in the double facade would work as transparent insulation in winter and a solar chimney in summer. The solar chimney would be employed for passive cooling and even night cooling, because solar heat absorbed by the south wall during day could be released at night and thus support the chimney effect. Unfortunately, the university decided to reserve the place in front of the facade for further development of the campus. It was very likely that another building would be build close to the south facade in future. The double-skin facade/solar chimney would be shaded by this building most of the time, and so the all means of solar energy utilization on the south facade had to be abandoned. The part of the east wall was also supposed to be covered with the double skin facade, but this was more or less for the aesthetic reasons in connection with double skin on the south wall, and this idea was abandoned as well.
Therefore, only a traditional energy saving measures remained. The low-E windows (glazing with the U-value = 1.1 $W.m^{-2}K^{-1}$) will replace the old ones. Some of the external walls will be thermally insulated on the outside by 100 mm of polystyrene. The roof of the two-storey building will be insulated with 160 mm of mineral wool in order to create a habitable attic with guest rooms. The floors adjacent to the ground will get additional insulation of 60 mm of polystyrene, and the ceilings under the loft in the four-storey building will be thermally insulated with 160 mm of mineral wool.
The U-values of the building constructions before and after the retrofitting are listed in Table 2.

Table 2 U-values of the building constructions

	U-value [$W\ m^{-2}\ K^{-1}$]	
	before retrofitting	after retrofitting
windows	5.2	1.3 (overall) 1.1 (glazing)
external walls (not to be insulated)	0.7	0.7
external walls (to be insulated)	1.8	0.36
ceilings (under the unheated lofts)	1.3	0.22
roofs (attic converted into habitable space)	5.0	0.25
floors adjacent to ground	3.5	0.6

6.3.2. Heating

The building did not have a heating system before retrofitting. The coal fired heaters (stoves) used to be used for heating, but these were not in operation when the building served as a warehouse. Therefore, the design of the heating system started from scratch.
A heating plant fitted with condensing gas boilers was chosen as the most suitable option. The individual control of heating enables to reflect the actual need for heating in each room

separately. The windows are fitted with sensors and the heating in a room shuts down when a window is opened. The VRV air-conditioning system in guest rooms will be used for heating when it is economical. An air-to-water heat pump will be used for DHW heating when the central heating plant is shut down.

6.3.3. Ventilation

The Brewery as a students' social and cultural centre involves several facilities with different kind of operation and therefore the different requirements on a ventilation system. The cafeterias and kitchens will operate only on weekdays and only for about six hours a day. The ventilation demand, however, will be quite high during the operation hours. A mechanical ventilation system with heat recovery will be installed in cafeterias and kitchens, because it fulfils the requirements best. The similar situation is in the clubs, where mechanical ventilation with heat recovery will be used as well.
The accommodation services will be used all year round and the occupancy of rooms, and therefore the ventilation demand, will vary significantly in time. The CO_2 controlled ventilation system will be installed in the guest rooms, because it is able to reflect the actual ventilation needs.

6.3.4. Cooling

The cafeterias and kitchens need cooling in summer because of the high internal heat gains. The air-handling unit will be fitted with cooling coils in order to provide cooling for these areas. Chilled water for the cooling coils will be supplied from the central cooling plant, which is located in the campus. The central cooling plant has the cooling capacity of 600 kW and provides chilled water for the new built premises, where the most of the cooling demand is concentrated. The lecture halls, laboratories, and classrooms in the new premises as well as the cafeterias and kitchens in the Brewery will only operate during academic year. The main cooling loop supplying cold water to these parts will be shut down for a couple of month in summer, because there will be now demand for cooling.
Some of the guest rooms are located in the attic directly beneath the roof and people staying there would suffer from overheating in summer. In order to maintain acceptable thermal comfort in the guest rooms (which will be used all year round) a Variable Refrigerant Volume (VRV) air-conditioning system will be used. The consumption of electricity of the VRV air-conditioning system will be compensated by the PV modules installed on the roof.

6.3.5. Lighting systems

The Brewery has relatively small window area. The ratio between the total area of windows and the total floor area is around 5.5 %. Because of that the artificial lighting in cafeterias, kitchens, clubs and multipurpose halls will be used most of the time when these are in use. The fluorescent tubes will be used for artificial lighting in these areas.
Better situation is in the guest rooms where dormers provide sufficient lighting during the day. The use of the light pipe skylights was considered in the corridors with no windows. Unfortunately, this idea had to be abandoned, because there was not enough space for the light pipes. The sensor controlled lighting will be installed in the corridors instead.

6.3.6. BEMS

The Building Energy Management System (BEMS) in the Brewery will be a part of the Building Management System (BMS) of the campus of the Faculty of Information Technologies. Beside the control of heating, lighting, ventilation and air-conditioning the BMS involves the access and security system, fire alarm system, CCTV, etc. It is not really possible to separate BEMS from the BMS because some information, like presence of people obtained from the access system (BMS), is used for the control of heating and cooling (BEMS).

6.4. Overview of design process

6.4.1. Building construction

The main problem in case of the building construction was overloading of the foundation soil. The Brewery has very shallow foundations and the foundation pressure was too high. This had a consequence in cracking of the load bearing walls. A new building with an underground parking lot was to be built just a few meters from the Brewery (Fig. 8). The big hole, which had to be dug for the underground parking lot, threatened to affect the stability of the foundations. The foundation soil could slide down towards the hole or its bearing capacity could be affected by variation of underground water level (underground water tending to flow into a hole). The sensors were installed in the walls in order to monitor the behaviour of the cracks during the digging. Some reinforcement of the foundation has also been done and this way the problem has been overcome.

Fig. 8 The underground parking lot

The usable floor area of the Brewery will be increased by retrofitting, because the attic of the two-storey building and a part of the attic in the four-storey building will be converted into habitable space (guest rooms). The progress of this work, with the first dormer erected is in Fig. 9.

Fig. 9 Conversion of the attic into habitable space

The sections of the building can be seen in Fig. 10. A tunnel at the level of the first floor will connect the Brewery with the adjacent building.
The floor plans of the complete building after retrofitting are in Fig. 11. There will be a cafeteria for the faculty staff and two multipurpose halls on the ground floor. On the first floor there will be a cafeteria for students and two student clubs. The accommodation services (guest rooms) will be on the third and the fourth floor. One two-store apartment (with skylights) will be located on the fourth and the fifth floor.

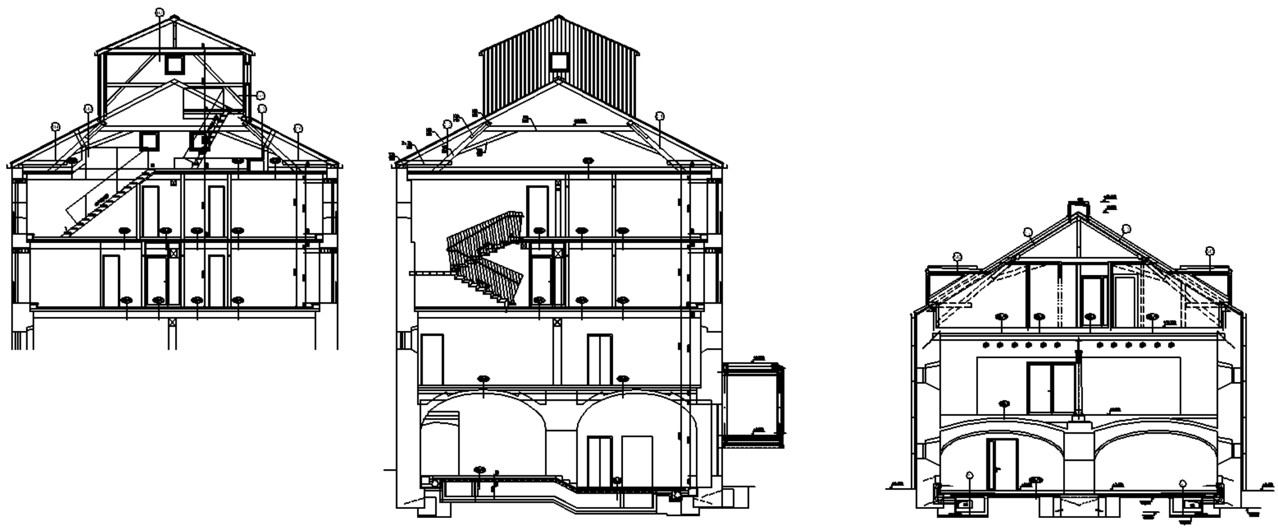


Fig. 10 Sections – situation after retrofitting

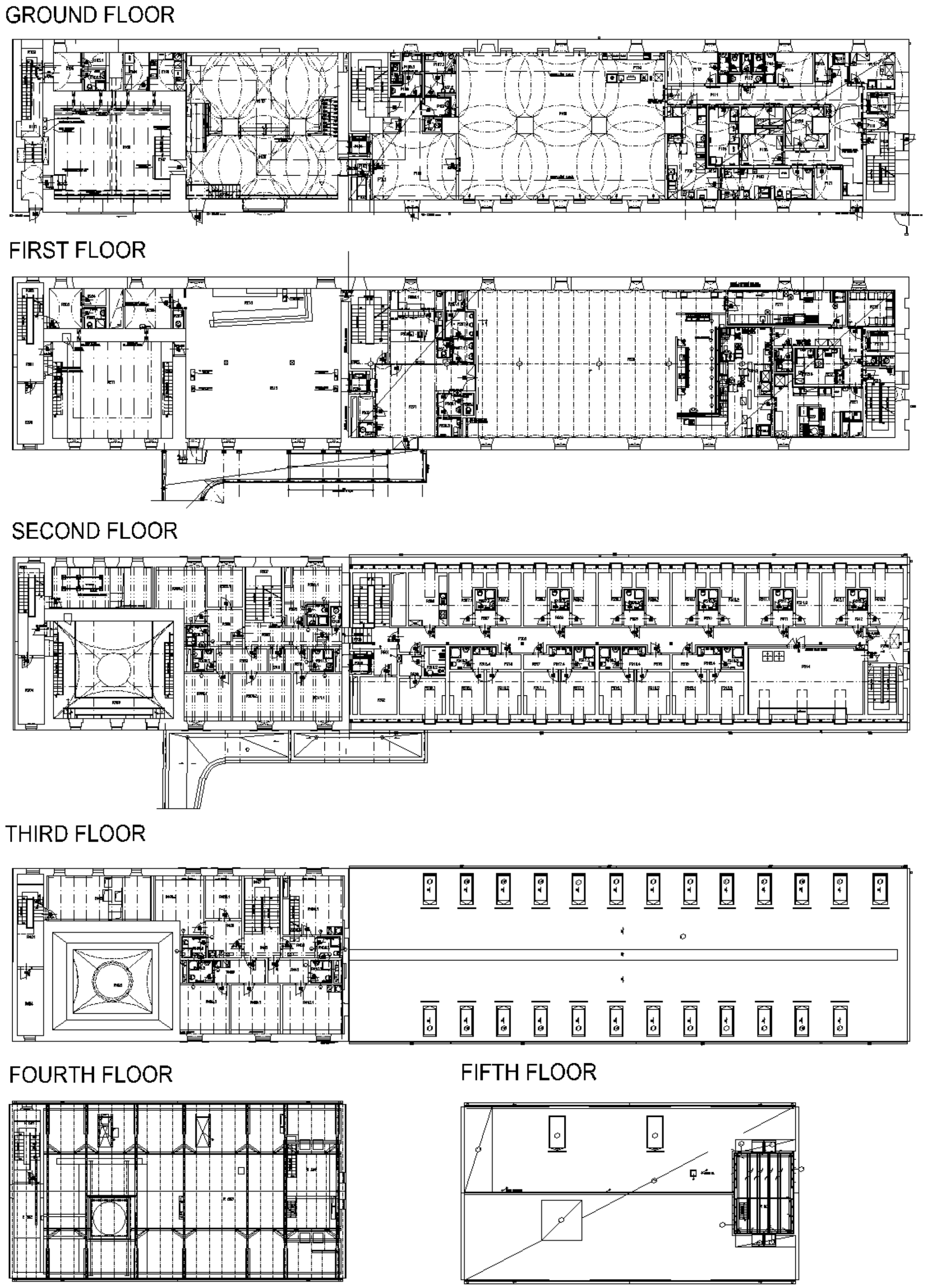


Fig. 11 Floor plans – situation after retrofitting

6.4.2. <u>Heating / ventilation / cooling and lighting systems</u>

The heating, ventilation, cooling and lighting systems were designed from scratch. To start a design from scratch offers usually some advantages in comparison to modification of an existing system. There had been no system in the Brewery before retrofitting, which could be modified. Even then the design was not an easy task because the complete change of the building use was involved, and the building construction itself limited possible options.

6.4.2.1. Heating

The Czech Republic has quite a developed system of district heating in cities and bigger towns. The cost of heat from the district heating, however, increased so much in the last decade that the district heating lost its competitiveness. The main reason for this is probably the condition of the infrastructure (pipelines). The infrastructure is quite old and has tremendous heat losses. The customers are not willing to pay for the heat that gets lost in the pipelines, and so the newly build building usually have their own heating plants.

In case of the Brewery a water-to-water heat pumps using flooded cellars as a heat reservoir were considered in the early stage of the design process. The pumping test showed that the cellars had a very small water inflow; not sufficient in order to provide heat for space heating of the whole building. Moreover, this solution, however interesting, would hardly be replicable in other buildings.

Another considered option was the CHP (combined heat and power). The Brno University of Technology already has two installations of the CHP units, one at the Faculty of Mechanical Engineering and the other at the dormitories. The CHP unit at the Faculty of Mechanical Engineering only operates between 8 A.M. and 4 P.M. on workdays outside the heating season, when there is a demand for domestic hot water. The CHP units at the dormitories, where 3000 students are staying, and where some cafeterias and restaurants are opened till late hours in the evening, have much better conditions for operation, because the hot water is demanded throughout the day. The demand for hot water in case of the Brewery is quite small in summer, and so the CHP showed not to be a good solution, because they would effectively operate only during the heating season.

A heating plant fitted with gas boilers was suggested as the most suitable option. The condensing boilers with higher investment costs, but higher efficiency than non-condensing boiler were chosen for the heating plant. In this stage a problem with the air-handling units arose. There was not much space for the air-handling units in the Brewery, and so the size of the units had to be kept as small as possible. It meant that the compact water-to-air heat exchangers with the high inlet water temperature were used. This had a consequence of high water temperature returning to the heating plant and therefore decreased the efficiency of the condensing boilers. Some changes in the layout of the heating system were made in order to bring the return water temperature down. The overall efficiency of the heating plant was increased this way.

There will be two condensing boilers in the central heating plant, each with the nominal output of 350 kW. Low temperature boilers convert about 93% of the calorific value of gas into usable heat. The condensing boilers employed in the heating plant can achieve as much as a 15% increase in the amount of usable heat. The average increase of 5 % is estimated to be achieved with normal operation of the heating system in the campus. If the heating system is operated in a way to maximize the effect of condensing boilers, the increase of 10% is achievable.

As mentioned before the condensing boilers are more expensive than non-condensing ones, but the payback time of four of five years in case of the Brewery is quite favourable.

Very important changes were made on the side of the control of the heating system. The original project expected only three zones for the control of the heating system (1. cafeterias and kitchens, 2. clubs and multipurpose halls, 3. accommodation services). This approach was based on the assumption that these three main areas of the building operate independently, but rooms and spaces within these areas would be used more or less at the same time. This is not really true and such approach could costs quite a lot of energy. For example, if one of the clubs is used then both clubs and the multipurpose halls are heated to the same temperature,

unless someone changes manually the settings of the thermostatic valves on the radiators in the club not used and two halls to lower temperature. The situation in the guest rooms would be even worse. If only one guest room was occupied then the all guest rooms would be heated to the same temperature (unless the settings of the thermostatic valves in the non-occupied rooms was manually adjusted to lower temperature).
The new approach to the control of heating adopted within the framework of the BRITA in PuBs project divides the building into more then 50 zones with the possibility of individual control of temperature. The heating of guest rooms will take into account occupancy (card access to the rooms), opening of the windows (window sensors) and ventilation (the heat output of the radiator will increase when an air supply inlet in the room opens).

6.4.2.2. Ventilation

Two different ventilation systems were suggested for two parts of the Brewery in order to meet the differences in ventilation needs. The cafeterias, kitchens, clubs and multipurpose halls have a high ventilation demand when in use. This ventilation demand can only be met by means of mechanical ventilation. The balanced ventilation with heat recovery was chosen for this part of the building as the most suitable solution. The air handling units of the ventilation system are located in the attic as can be seen in Fig. 12.

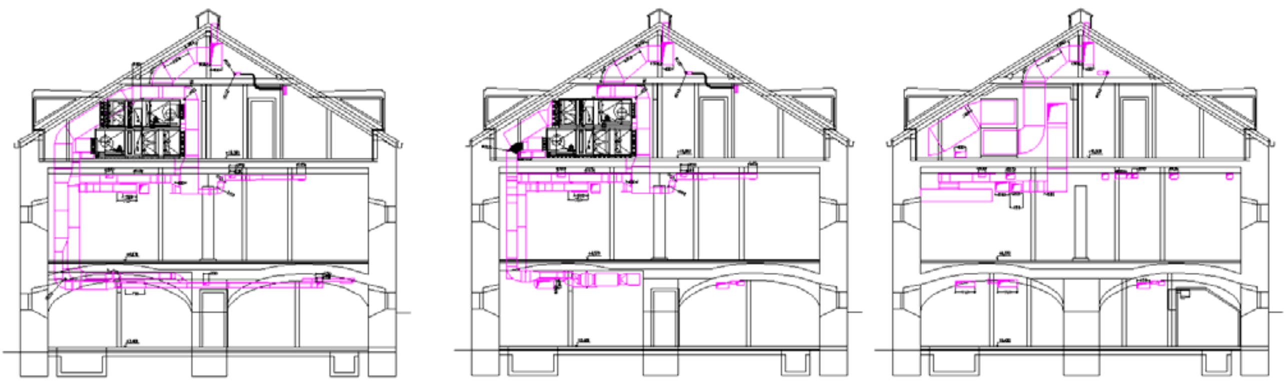


Fig. 12 Balanced mechanical ventilation system

The occupancy of guest rooms changes significantly in time. In such a situation a demand controlled ventilation system meets the requirements much better than the central mechanical ventilation system. A demand controlled hybrid ventilation system was designed for the guest rooms. The control of ventilation is based on monitoring of CO_2 concentrations measured in each room. There will be an air supply inlet above the window in each room and a hybrid exhaust in the bathroom. The configuration of the hybrid ventilation system is shown in Fig. 13.

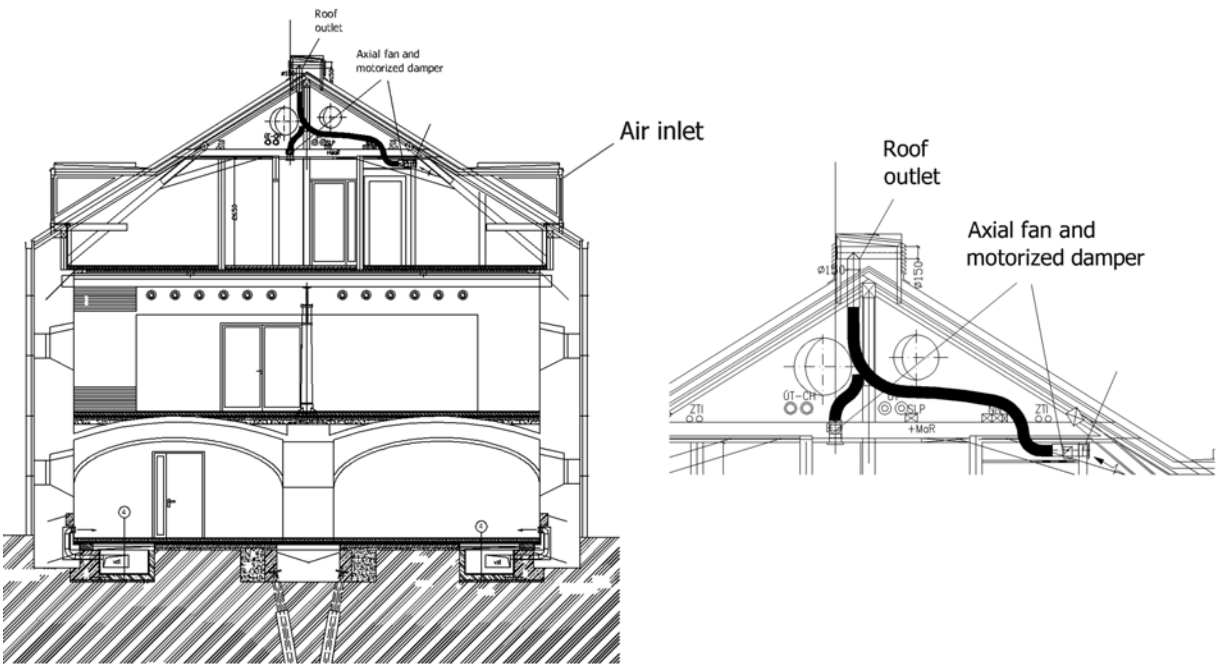


Fig. 13 Hybrid ventilation system

The air supply inlets are located in the window frames of the dormer windows. The hybrid air exhaust consists of a fan, a motorized damper and a roof outlet. The T-shaped roof outlet, located in a roof ridge of a special construction, will employ wind in order to increase the stack effect. The main objective of having a rather special construction of the roof ridge was to minimize the number of penetrations through the roof. All exhausts of hybrid and mechanical ventilation systems are located in the roof ridge, because it is rather difficult to seal the opening for a duct in the fibre-cement corrugated roofs used in the Brewery.

6.4.2.3. Lighting

The Brewery as an old building has quite small windows and a very small ratio between the window/glass area and the floor area. This ratio after retrofitting will be around 5.5 %. It was not really possible to increase the window area since the building has 1 meter thick brick walls. There are no lintels or beams above the windows but only brick arcs/vaults as can be seen in Fig. 14

Fig. 14 Windows in the Brewery

The artificial lighting will probably be used all the time in cafeterias and kitchens when these are in use. The better situation is in the guest rooms located in the attic, where dormer-windows provide sufficient amount of daylight during day.

There will be a separate measurement of consumption of electricity for lighting in the Brewery in order to ascertain the impact of small window area. The fluorescent tubes will be used for artificial lighting in order to keep energy consumption low.
The use of the light pipe skylights was considered in the corridors with no windows. This idea, however, had to be abandoned, because there was not enough space for the light pipes. The sensor control lighting will be installed in the corridors instead.

6.4.2.4. Cooling

Two separate cooling systems will be used in the Brewery. As mentioned in the previous paragraph the Brewery has very small windows, and so the direct solar heat gains will also be small. The heavy walls represent an advantage as far as cooling is concerned. The problems represent internal heat gains in kitchens and cafeterias and solar heat gains in guest rooms located in the attic of the two storey building. The roof is well thermally insulated, but it is of a timber frame construction, and does not have thermal mass to dampen the impact of solar radiation in summer.
The cooling of the cafeterias and kitchens will be provided by means of the ventilation system. The air handling units of the ventilation system will be fitted with cooling coils. The cold water for the cooling coils will be supplied from the central cooling plant located in the campus.
The pumps for the main cooling loop will be shut down in summer, because most of the buildings in the campus (including the cafeterias in the Brewery) are not used during student vacation. This excluded the use of fan coil units in the guest rooms, which will be used all year round. Therefore, a Variable Refrigerant Volume (VRV) air-conditioning system was chosen for cooling in the guest rooms. The VRV system will also be used for heating, when it is economical.
The VRV system consists of 3 external units and 35 internal units. The cooling capacity of the external units is 2 x 28 kW and 1 x 40 kW. The COP in the cooling mode is 3.11 in case of 28 kW units and 2.8 in case of the 40 kW unit. The heating capacity of external units is 2 x 31.5 kW and 1 x 45 kW. The COP in the heating mode (at air temperature of 7°C) is 3.38 in case of smaller units and 3.49 in case of the bigger one. Each of the internal units has the cooling capacity of 2.2 kW and the heating capacity of 2.5 kW.
The external units are (for esthetical reasons) located in the attic of the four-storey building as can be seen in Fig. 15. The outdoor air enters the attic through the opening in the facade and is blown out through the vertical ducts.

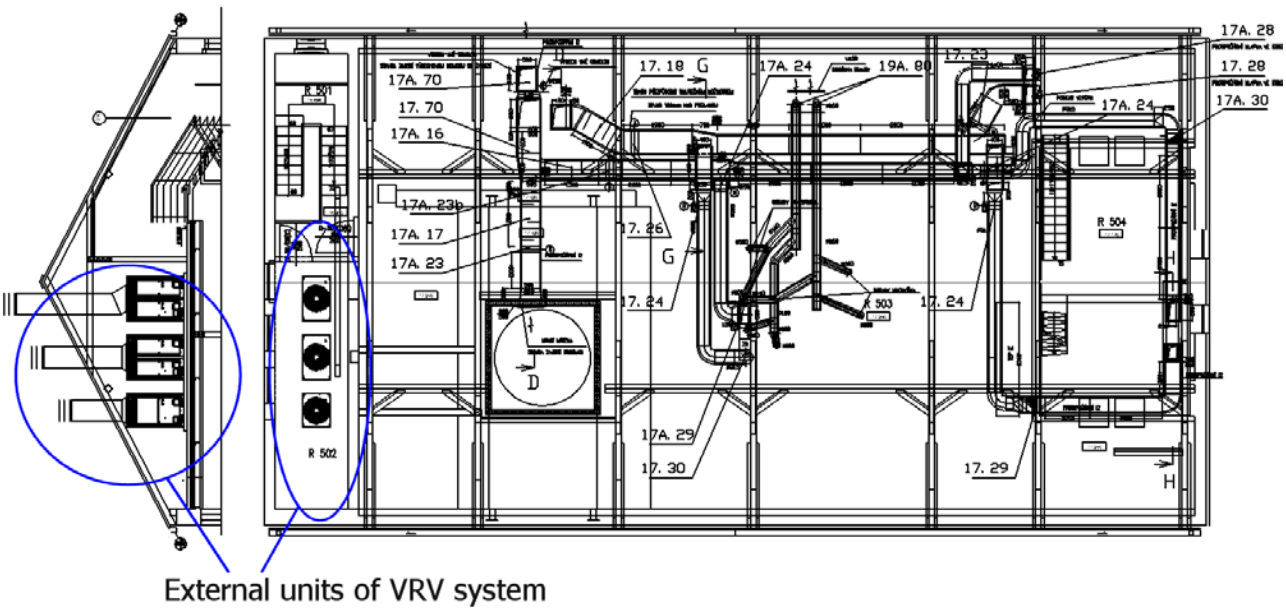


Fig. 15 Location of the external units of the VRV system

6.4.3. Solar PV

The PV modules represent an option how to compensate the energy consumption of air-conditioning (mechanical cooling) in buildings. The Czech Republic, when implementing the EU Energy Performance of Building Directive, decided to use the reference building approach. When a building is build or retrofitted a calculation of energy consumption for a reference building will be done together with the calculations of the energy consumption of an actual building. The reference building will have the same geometry as the actual building, but it will have “reference” properties. In order to comply with the requirements the energy consumption of the actual building will have to be lower than that of the reference building. Air-conditioning (mechanical cooling) will not be considered in the reference building. If designers decide to use air conditioning (mechanical cooling) in a building, they will have to save energy somewhere else, or to compensate the consumption of mechanical cooling by means of utilization of renewable energy sources. The PV modules might be a good option, since there is usually a good match between the high demand for mechanical cooling in buildings and high output of the PV modules.
The total area of photovoltaic modules in case of the Brewery was reduced several times because there was not enough suitable space for the installation. The south facade of the building could be completely covered with the PV modules, but another (five storey) building is supposed to be built close the south facade in the future. This building would shade the PV modules most of the time and hence decrease the yield. The only possible option was to install the modules on the west roof of the four-storey building. Fig. 16 shows the location of the PV modules on the roof. The peak power of the cells is 14 kW.

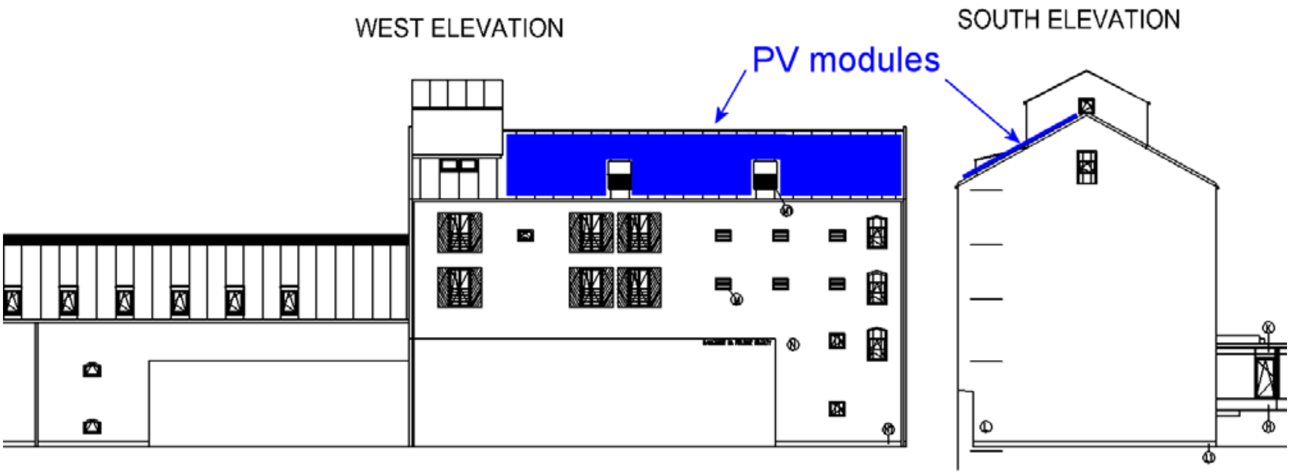


Fig. 16 Location of the PV on the roof of the Brewery

The dimensions of the modules are 1310 x 654 mm. There will be 132 modules connected in an array. The details of the mounting of the modules on the fibre-cement corrugated roof, which is used on the Brewery, can be seen Fig. 17.

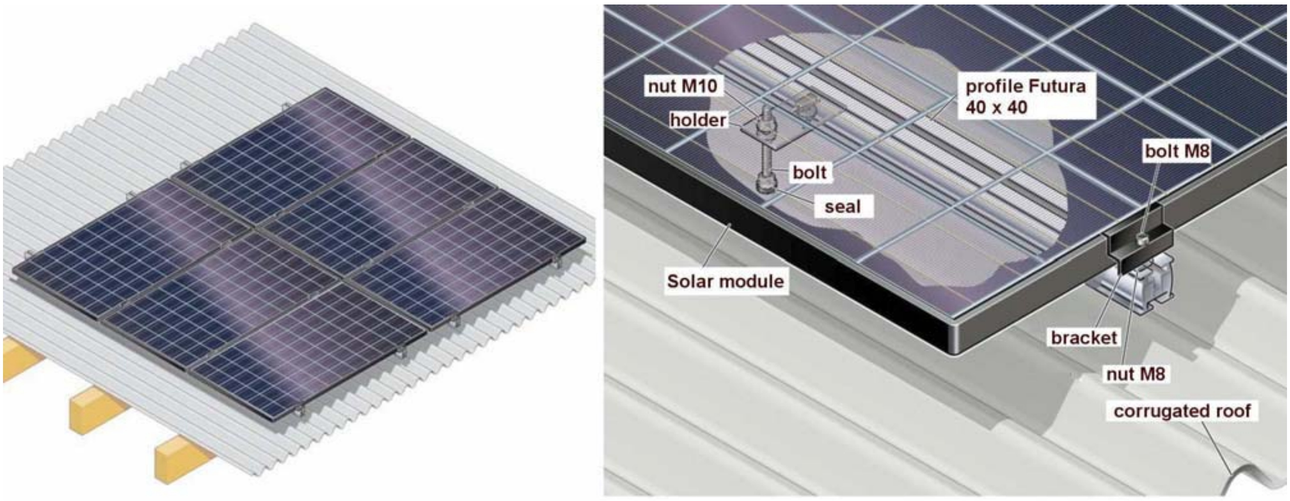


Fig. 17 Detail of the mounting of the solar modules (Donauer Solartechnik Vertriebs GmbH)

Each PV module consists of 72 cells with the cell size of 4 inches. The parameters of the modules are as follows:

Module short-circuit current at reference conditions: 3,25A
Module open-circuit voltage at reference conditions: 43,2V
Reference temperature: 25°C
Reference insolation: 1000Wm^{-2}
Module voltage at max power point and reference conditions: 34,8V
Module current at max power point and reference conditions: 3,05A
Temperature coefficient of I_{sc} at (ref. cond): +0,054%/°C
Temperature coefficient of V_{oc} (ref. cond.): -0,37%/°C
Module temperature at NOCT [°C]: 45°C
Ambient temperature at NOCT [°C]: 20°C
Module area [m^2]: 0,857 m^2
The modules will be connected in three sub-arrays; two consisting of 42 modules and one of 48 modules. The sub-arrays will be arranged horizontally one above another and each sub-array will use a separate inverter. This configuration offers better performance in winter when the lower part of the roof is covered with snow. The surface of modules has a very small friction and precautions had to be made in order to prevent snow from sliding off the roof.
The estimated power production for the modules positioned on the west roof is shown in Fig. 18. The facades of the Brewery are not oriented to due north, east, south and west, but deviate from these orientations by 11degrees. It means that the “west” roof actually has an azimuth of 259° and not 270°.

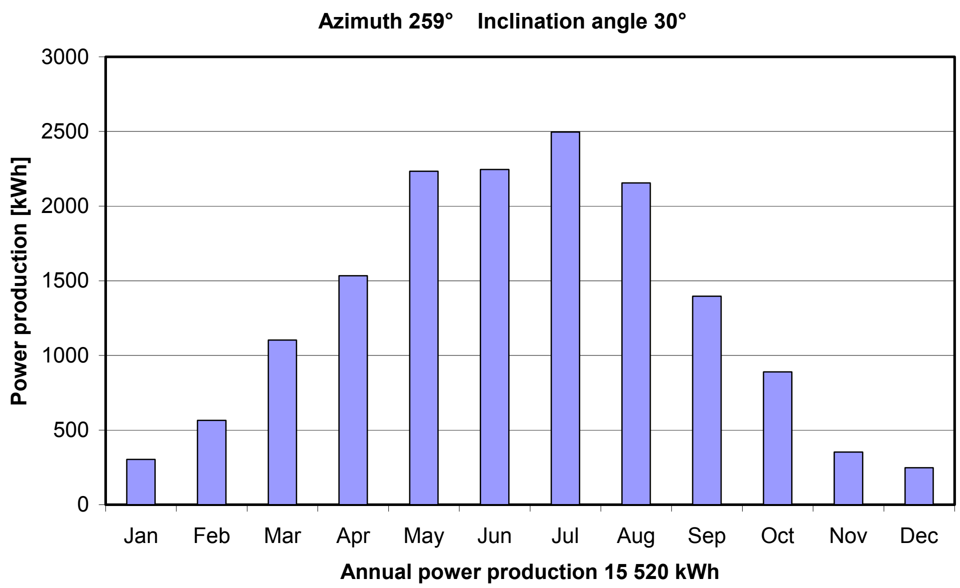


Fig. 18 Estimated yield (the west roof)

If the system with the same configuration was installed on the south facade of the building the estimated yield would be lower than in case of the west roof as can be seen in Fig. 19.

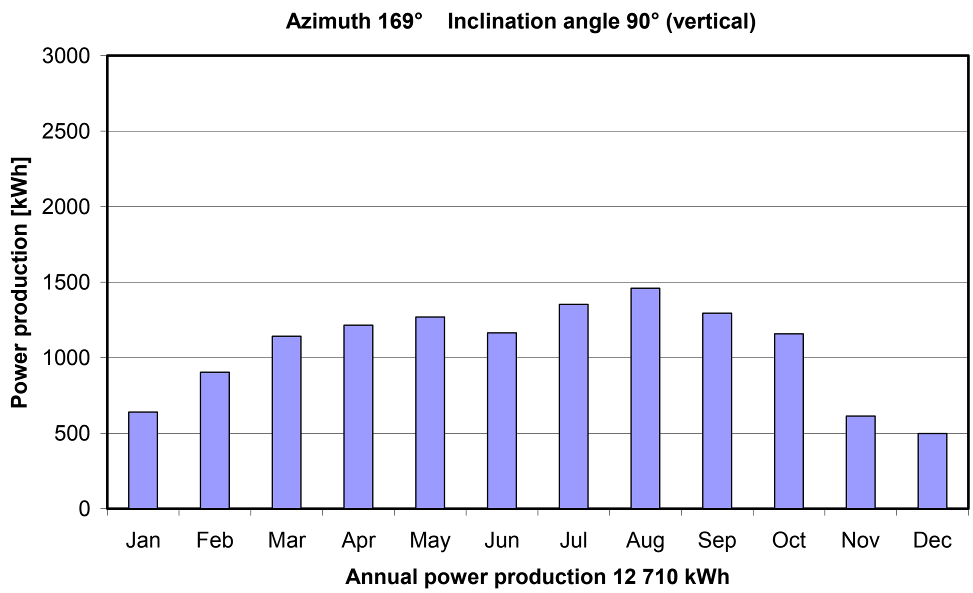


Fig. 19 Estimated yield (the south facade)

6.4.4. BEMS

The Brno University of Technologies requires integration of control and monitoring of the building systems into the Building Management System, whenever a new building is built or an old building undergoes retrofitting. This approach usually brings problems with the compatibility of the BMS and building systems. These problems have to be overcome in the design process.
In case of Brewery the integration involved:

- control and monitoring of heating, ventilation and air-conditioning
- monitoring of heat consumption
- monitoring of consumption of electricity
- monitoring of water consumption

- monitoring of natural gas consumption
- monitoring of indoor air temperatures
- electronic security system
- fire alarm system
- access system
- CCTV

Another requirement on the BMS arising from the BRITA in PuBs project was the implementation of the central control system of the "smart" building type in order to:

- Achieve thermal comfort of the occupants in an energy efficient way
- Control and monitor energy flows in order to optimize energy consumption

The schematic of the Building Management System is in Fig. 20. Two main communication protocols are used in the system – TCP/IP and LONWORKS®.

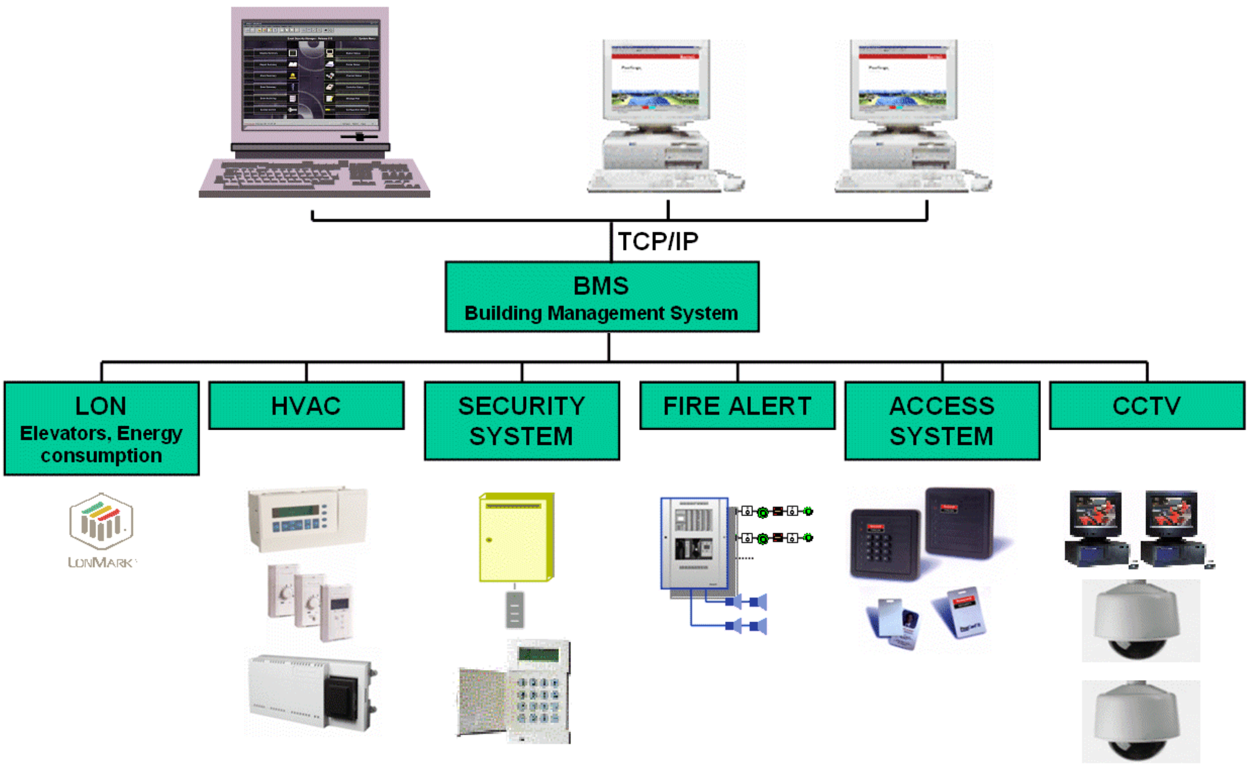


Fig. 20 The BMS system

The data acquisition is based on the LONWORKS® technology. With this approach it is possible to acquire data from heat meters, water meters, electricity meters, and other devices that use this communication protocol.

The above mentioned philosophy of having one BMS in the whole campus had a huge impact on the energy saving measures implemented within the framework of the BRITA in PuBs project. It was not possible to design building systems as "stand alone", but it was necessary to integrate their control and monitoring into the BMS. This did not have a negative impact on the costs of the systems themselves, but caused some delays in the design process and also increased the design costs.

The main problem was the control of a hybrid ventilation system. The manufacturer offers an interface for the communication with a "superior" control system (BMS), but this interface does not allow direct control of the ventilation system by that "superior" control system. This was not acceptable, and so the hybrid system was designed from scratch.

The central control and monitoring also brought some advantages. The individual control of heating in nearly all room in the Brewery means that there are temperature sensors in all of those rooms. With all the sensors connected to the BMS monitoring of temperatures will be an easy task, which does not require extra monitoring equipment.
In order to get more representative data about the consumption of electricity a decision was made to measure separately the consumption of electricity for lighting and for the VRV air conditioning system. The separate measurement of the consumption of the VRV air conditioning system enables real time comparison of this energy consumption with the electricity produced by PV modules (which is anyway measured separately). The PV modules used for the compensation of electricity consumption of air-conditioning systems seem to represent a good option, because the peaks in the production usually match the peaks in demand for cooling.

6.5. Predicted energy savings

Energy saving measures, heating, cooling, ventilation	[kWh/m^{2}a]	Total [kWh/a]
Insulation of roofs and facades	24.3	56 000
Low-e windows	32.5	74 750
Condensing boilers	45.3	104 100
Individual control of heating	9.3	21 400
Waste heat recovery (mech. ventilation)	29.9	68 850
CO_2 controlled hybrid ventilation	8.6	19 900
BEMS (heating saving)	15.4	35 500
Total heating energy savings	**165.4**	**380 500**

Energy saving measures, electricity	[kWh/m^{2}a]	Total [kWh/a]
Photovoltaic modules	14.3	33 000
Daylighting system	2.4	5 600
Heat pump for DHW	1.7	3 900
BEMS (electrical saving)	3.9	9 000
Total heating energy savings	**22.4**	**51 500**

6.6. Predicted costs and payback

Energy saving measure/investment	Area [m²]	Total costs [EUR]	Saving [EUR/a]	Pay-back periods [a]
Insulation of roofs and facades	1360	100 000	3 472	28.8
Low-e windows	154	72 000	4635	15.5
Condensing boilers		28 000	6 454	4.3
Individual control of heating		47 000	1 327	35.4
Waste heat recovery (mech. ventilation)		15 500	4 269	3.63
CO_2 controlled hybrid ventilation		90 000	1 234	72.9
BEMS (heating saving)		35 000	2 201	15.9
Photovoltaic modules	140	110 000	6 160	17.9

Daylighting system		4 200	616	6.8
Heat pump for DHW		2 500	429	5.8
BEMS (electrical saving)		15 000	990	15.2
Total		**519 200**	**31 786**	**20.2**

Energy costs used for the payback calculation:
Thermal: 0.062 Euro/kWh
Electric: 0.11 Euro/kWh (0.44 for the PV system)

6.7. Lessons learned

- The application of Building Management Systems brings a potential of significant energy savings even in the retrofit of very old buildings.
- The monitoring of occupancy, while being a very effective energy saving measure, is not easy to implement in a cost-effective way.
- Even a very old building in a really bad condition can after retrofitting exceed the requirements of contemporary building codes. The cost of such retrofitting can represent only a fraction of cost of a new building with similar parameters.

7. Vilnius Gediminas Technical University (VGTU), the Main Building

Authors: A Kaklauskas, S. Raslanas

7.1. General data

7.1.1. General information

Year of construction: 1971
Year of renovation (start): 2004
Total floor area (m^2): 8484.20
Surface/Volume ratio: 0.33
Number of storeys: 7
Window/glass areas (m^2): 1089

7.1.2. Site

The site of the Main Building of Vilnius Gediminas Technical University (VGTU) is in the suburb. Nearby VGTU there is Vilnius university (VU), also residential buildings and forest (Fig 1.).

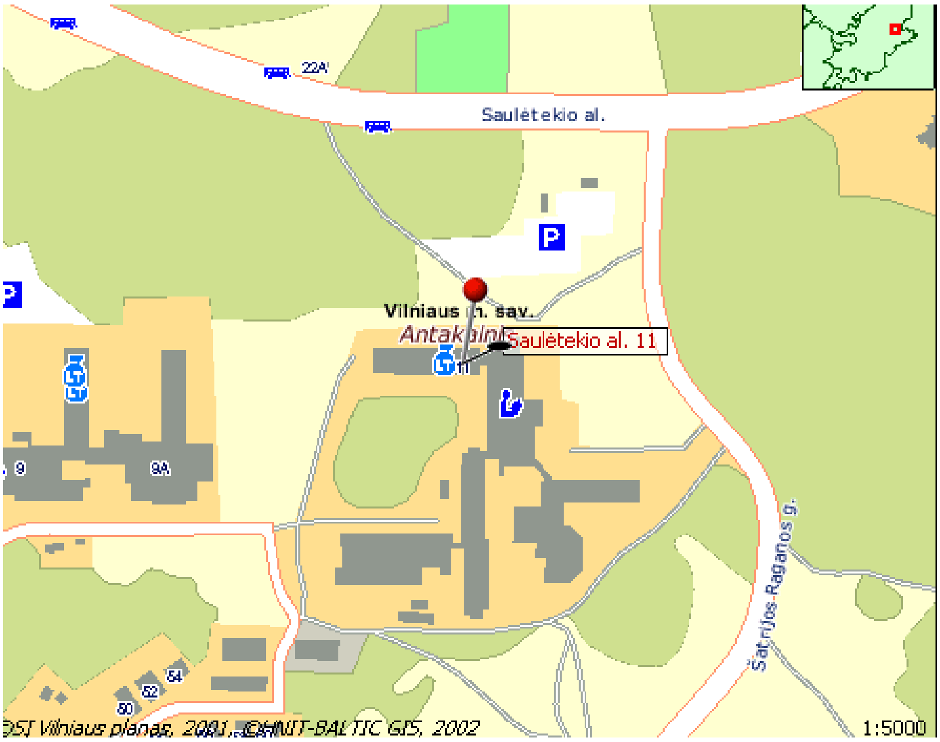


Fig 1. Location of the Vilnius Gediminas Technical University (VGTU)

Lithuanian climate is maritime/continental. The highest temperature in July is +30.1°C and the lowest temperature in January is -22.7°C. The Lithuanian climate is temperate. From May to September daytime highs vary from about 14°C to 22°C (57°F to 72°F), but between November and March it rarely gets above 4°C (39°F). July and August, the warmest months, are also wet, with days of persistent showers. May, June and September are more comfortable, while late June can be thundery. Slush under foot is something you have to cope with in autumn, when snow falls then melts, and in spring, when the winter snow thaws. Average annual precipitation 717 millimetres on coast and 490 millimetres in east.
The geographic position of Vilnius (latitude - 54°41' N., longitude - 25°17' E., altitude - 140-150 m above sea level) (Fig 2.). The mean annual temperature - 6.4°C, the mean winter temperature -4 °C.

Fig 2. Location of the Main Building of Vilnius Gediminas Technical University (VGTU) in Lithuania

7.1.3. Building type

The main building is public building and the first one that everyone can see after taking the turn-off from Sauletekio Avenue towards Vilnius Gediminas technical university. The configuration of a rectangular comprises the shape of the building with the measurements 74,30 x 17,22 m. The floor area totals 8484,20 m2. The main building was built up in 1971. It includes several departments and lecture halls seating from 50 to 100 students.
Number of storey – 7.
Number of occupants – 1084,
number of rooms – 219,
average area per user - 7.83 m^2 .

7.2. Before retrofit

7.2.1. Building construction

The substructure of the building is made from frame pillar with columns of UK type. The walls of the building have the ferroconcrete frame and three-layer ferroconcrete panels (60/90/90) (Fig. 3, 4). The thermal transmittance of walls U_w = 1.07 W/m^2K. During thirty years of exploitation, both sun and rainfall have impacted on external sectors partitioned off. Somewhere, connection junctures of three-layer panels are already partly crumbled. Such sealing junctures are easily blowable and pervious to moisture. Juncture in damaged places of the external sectors partitioned off is sealed with warm sealing material and stopped up with a sealant.

Fig 3. Photos of the Main Building of Vilnius Gediminas Technical University (VGTU) before retrofit

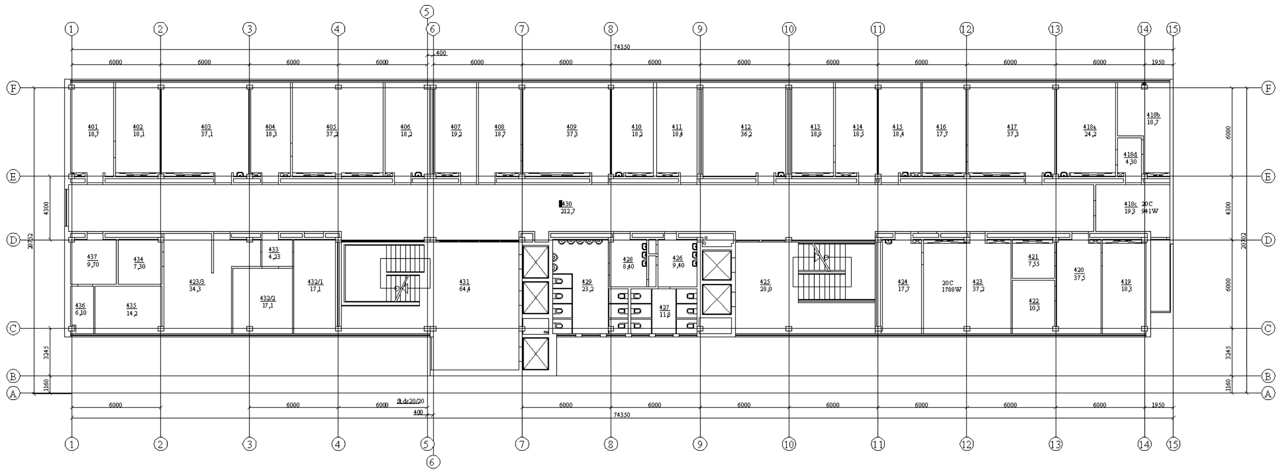


Fig. 4. The plan of 4nd floor the Main building of VGTU

The biggest part of the external sectors partitioned off in the main facades is occupied by glass area. All window glass is placed in wooden or aluminium profile frameworks. The windows of the main building are very old. Closing windows and lack of tightness are the biggest inconveniences. Current construction of the windows does not correspond to the modern window requirements and does not ensure proper inside comfort conditions. The thermal transmittance of existing windows is $U_{wi} = 2.5$ W/m^{2}K.
Lateral entrance doors in the Main building are old, unsealed and very insecure as well. The thermal transmittance of doors is $U_d = 2.3$ W/m^{2}K.
All roofs of the building are flat, and the covering is made from the roll. In October 2002, the roof of the Main building was repaired. After unwrinkling all blowholes and other roughness of the old covering, new hydroisolating roofing was fit up. While renovating the roof, due to a shortage of financing, current old parapet tins were changed only in these places where they were very rusty. The thermal transmittance of roof is $U_r = 0.8$ W/m^{2}K.

7.2.2. Existing heating, ventilation, cooling, lighting systems

Heating system of the Main building VGTU has been working for already thirty years. The heating system is connected to the central heating system according to the independent scheme of connection. Since the Main building VGTU is pretty long, facade regulation of the heating system was carried out in the new thermal unit. Both filiations of heating system were connected to the Central heating system with the help of tabular heating elements, circulating pumps of heating system, and automated regulation of heat quantity as well, which depends on outside temperature. Besides, the regulation of heat quantity may work within diminished temperature work regime in respect of twenty-four hours and days of week. Heating system works according to the diminished temperature schedule from 4 p.m. until 4-5 a.m. as well as on Saturdays and Sundays. With the aim to heat up the main building, the single-pipe heating system of lower distribution is designed and installed. Heating devices are sectional radiators M-140 AO, and convector heaters in lobbies. Mostly heating devices are covered (Fig. 5). In case there is no basement and the ground floor is on

Fig. 5. The sectional radiators M-140 AO and convector heaters in lobbies of the Main building of VGTU

the ground, then trunk pipelines are installed in the pathless underground canals. Additionally, in socle floor premises these pipelines are installed openly near the floor (Fig. 6). Therefore, the old and covered heating devices, the old and a little permeable pipelines as well as hardly controlled reinforcement cannot fulfill heating functions of the building even having renovated thermal unit and facade regulation.

Fig. 6. The view of pipelines

During heating season, when the windows are not tight, an inside temperature is approximately 14ºC - 16ºC.

Earlier there was an elevator unit. In 2000 VGTU has renovated the unit and instead of it the new automated thermal unit for building needs has been installed (Fig. 7). It prepares the thermal carrier with the help of tubular heat exchangers. . In the thermal unit façade regulation of building heating systems is installed. Closing valve, filter, indicator of temperature of initial t_1 temperature and recursive temperature t_2, two thermal transmitters, pumps, expansion vessels and façade indicators are equipped in the thermal unit. Hot water in the Main building is only in several points of hot water as is prepared with the help of electric volumetric thermal transmitters. DHW is prepared with the help of boilers.

Fig. 7. View of the thermal unit in the Main building of VGTU

Ventilation system. In the Technical project of VGTU, mechanical air supply/removal systems were foreseen to install in the Main building VGTU. Air paths were installed in particular facilities (between walls) and in the suspended ceiling as well. At the moment, the old mechanical air supply/removal systems are not in use in the Main building because they need a lot of electric power (Fig. 8). Besides, the old systems are too noisy for the building having a particular purpose.

Fig. 8. View of the old mechanical air supply/removal systems in not use in the Main building

Illumination and electrical engineering.

When visiting and talking to Computation centre specialists, there were some complains about electrical engineering for computers and other electrical needs of the building are connected from the one point. Especially, it is relevant in cold period of the year when some additional heating devices are being connected and protectors cut out the electric power. In addition, the computers are also disconnected. In all the departments there was a wish expressed to install new lines of electric power supply designed only for computers. The installation for computers should be connected to earth. Additionally, illumination engineering is also out-of-date and does not meet the modern requirements. There are old luminescential illuminators without covering in some offices or auditoriums (Fig. 9).. The level of facilities illumination is insufficient as well.

Fig. 9. View of the old luminescential illuminators without covering in the Main building

7.2.3. Energy and water use

	Measured year (..)	Total for the whole building
Space heating	178 kWh/m^2 a	1510188 kWh/a
DHW	* kWh/m^2 a	* kWh/a
Electricity	36,04 kWh/m^{2}a	305737 kWh/a
Water	0,364 m^3/m^{2}a	3088,25 m^3/a

* the DHW data is not available.

7.3. Energy saving concepts

Having in mind that the Main building is in use more than thirty years, it was suggested the following:

- renovation of facades will have a very important impact on energy saving
- replacement of current windows will have a very important impact on energy saving too
- renovation of roof will increase the effect to energy saving
- change of entrance doors will be very important too
- to correct a little bit the operation of renovated thermal unit and complement a part of its automatics, still better effect should be reached.
- Renovation of heating system will increase the effect of energy saving

The efficiency level of the Main building's VGTU refurbishment depends on a great many of factors, including: cost of refurbishment, annual fuel economy after refurbishment, tentative pay-back time, harmfulness to health of the adopted materials, aesthetics, maintenance properties, functionality, comfort, sound insulation and longevity, etc. Solutions of an alternative character allow for a more rational and realistic assessment of economic, ecological, legislative, climatic, social conditions, traditions and for better satisfaction of architectural, comfort, functional, maintenance and other customer requirements. They also enable one to cut down on refurbishment costs. The developed Multiple Criteria Decision Support System for Building Refurbishment will allow to perform the alternative design of the Main VGTU building's refurbishment, multiple criteria analysis and make the selection of the most efficient versions, etc. The more alternative of refurbishment versions are investigated before making a final decision, the greater are the possibility to achieve a more rational end result. Basing oneself on the collected information and the Multiple Criteria Decision Support System for Building Refurbishment (BRDS) system will be perform a multiple criteria analysis of the VGTU building refurbishment project's components and select the most efficient versions (see http://dss.vtu.lt). After this, the received compatible and rational components of a refurbishment will be joined into the projects. Having performed a multiple criteria analysis of the projects in this way, one can select the most efficient projects (Annex 1 and 2).

7.3.1. Building construction

Retrofit concept for the Main VGTU building:

Building part	Structural unit	U-value [W/m²K]	
		before retrofit	after retrofit
(1)	windows	2,5	1,16
	walls	1,07	0,296
	roof	0,8	0,2
	doors	2,3	1,5

Table 2. Heating energy consumption [kWh/m²a] for the Main building of VGTU according to the conclusions of energy audit (performed in 2002))

Building	Heating energy consumption [kWh/m²]		
	Before retrofitting (2002)	After retrofitting	
		(2005/06)	(2006/07)
((8484.20 m²))	178	157	88

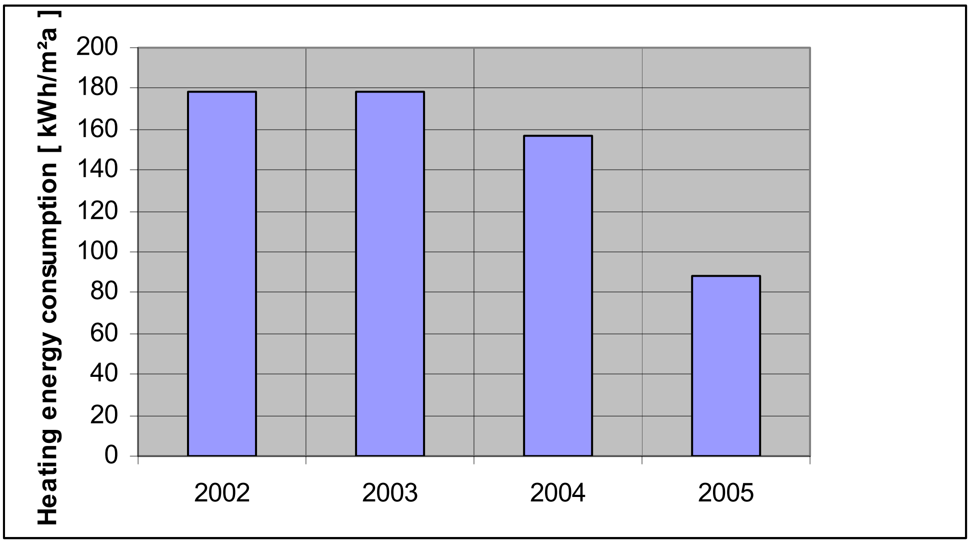


Fig. 10. The diagram of heating energy consumption [kWh/m²a] for the Main building of VGTU according to the conclusions of energy audit (performed in 2002)

7.3.2. Heating

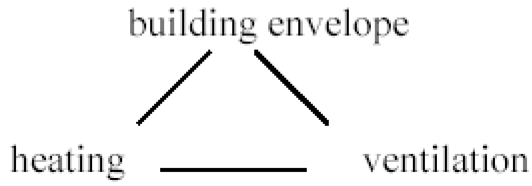
It was suggested to carry out renovation of current morally and physically out-of-date heating system of the main building. It would include three stages of this process:

1. A technical project regarding heating system will foresee new, fully automated heating system, automated compensation valves designed for the stands of the heating systems, new closing reinforcement, installation of thermostatic valves for heating equipment, change of trunk pipelines and co-ordination of the project as well.
2. Implementation of the heating system renovation according to the technical project.
3. Coordination and operation of the renovated heating system. An act regarding the heat effect.

During the partial renovation of the thermal unit, the electromagnetic indicator "Katra" SKM-1M for heat and water quantity is planning to be installed. With the help of indicator the heat quantity for the Main building VGTU is determined, the quantity of flowing water, instantaneous debit, initial and recursive temperature, initial and final pressure. Data of indicator may be transmitted by internet and the indicator managed by computer programs.

7.3.3. Ventilation

The original idea of the Main Building renovation of Vilnius Gediminas Technical University (VGTU) was to replace windows, to renovate thermal unit, roof, heating system, to insulate facades and to change entrance doors. These renovation implements (renovation project based on medium investments) for the proposal were written according to the conclusions of audit (performed in 2002). In the process of renovation the balance between the three components must be kept:



Renovation of mechanical air supply/removal systems foresees:

1. A technical project, in which it is suggested to replace current old ventilation system with the new one, fully automated. Ventilation should be mechanical, with 50-70 percent recuperation. In addition, new pipelines of air supply/removal and equipment should be installed.
2. Implementation of air supply/removal systems renovation according to the Technical project.
3. Installation and co-ordination of renovated ventilation systems. Acts regarding installation and co-ordination works of the systems.

7.4. Overview of design process

7.4.1. Building construction

Energy audit recommended to change all current windows having old construction as well as sectors partitioned off in lobbies. They should be replaced with the new windows or glass surface. The selection of a low-e windows was made by the MCDM method COPRAS and using DSS, developed by authors (see http://dss.vtu.lt) (see Table 1).. A new window has to be glazed with 4/16 Ar/4 Kms double glass unit. The thermal transmittance of glass unit U_g = 1,1 W/m^{2}K, weighed sound reduction index R_w = 33 (-2, -6) dB. A new window is foreseen to fit up with the third opening position or with closing infiltration airhole in order to keep inside microclimate.

Table 1. The data obtained in multiple criteria analysis of five contractors' bids in pre-qualification for window replacement in the Main building of VGTU

PQC	Units of measu-rement	*	Weights of criteria	Ltd 1	Ltd 2	Ltd 3	Ltd 4	Ltd 5
Mechanical strength and stiffness	**	+	0.06875	1	1	1	1	1
Reliability	Cycles	+	0.07275	10000	10000	10000	10000	10000
Thermal transmittance U_p of profile	W/m^{2}K	–	0.091	1.2	1.4	1.4	1.4	1.4
Thermal transmittance U_g of double glazing unit	W/m^{2}K	–	0.108	1.1	1.2	1.1	1.1	1.14
Emission ability of low emissive glass coating ε	***	–	0.0575	0.05	0.1	0.05	0.05	0.05
Weighed sound reduction index R_w	dB	+	0.08275	34	33	34	33	32
Air permeability, when pressure difference Δp = 50 Pa	(m^3/m^{2}h)	–	0.0615	0.18	0.15	0.18	0.3	0.31
Water-tightness	Pa	+	0.0755	600	300	600	250	250
Warranty period	Years	+	0.0755	10	5	5	5	5
Longevity	Years	+	0.07725	35	30	50	40	30
Light transmittance τ_v of double glazing unit	%	+	0.055	81	78	81	79	78
Duration of works	Days	–	0.05625	60	50	60	60	60
The number of windows with two opening positions (horizontal and vertical) (in percent of the total area of windows)	%	+	0.05375	78.5	100	37	100	27.43
The number of windows with closing infiltration air vent or the third opening position (in % of the total area of windows)	%	+	0.0645	78.5	100	37	100	27.43

* The sign z_i (+/–) indicates that a higher/lower criterion value satisfies a client

** - Does it meet the specification requirements (if so, =1)

*** - There is no particular unit for criterion measurement.

The windows were selected with the following technical characteristics: thermal transmittance of the profile U_p = 1.2 W/m^{2}K, thermal transmittance of double glazing unit U_g = 1.1 W/m^{2}K, emission ability of low emissive glass coating ε = 0.05, weighed sound reduction index R_w = 34 dB, light transmittance of double glazing unit τ_v = 81 %, water-tightness p = 600 Pa, warranty period 10 years, longevity 35 years, duration of works – 60 days, the number of windows with the third opening position (in % of the total area of windows) 78.5 % (see Fig 11)..

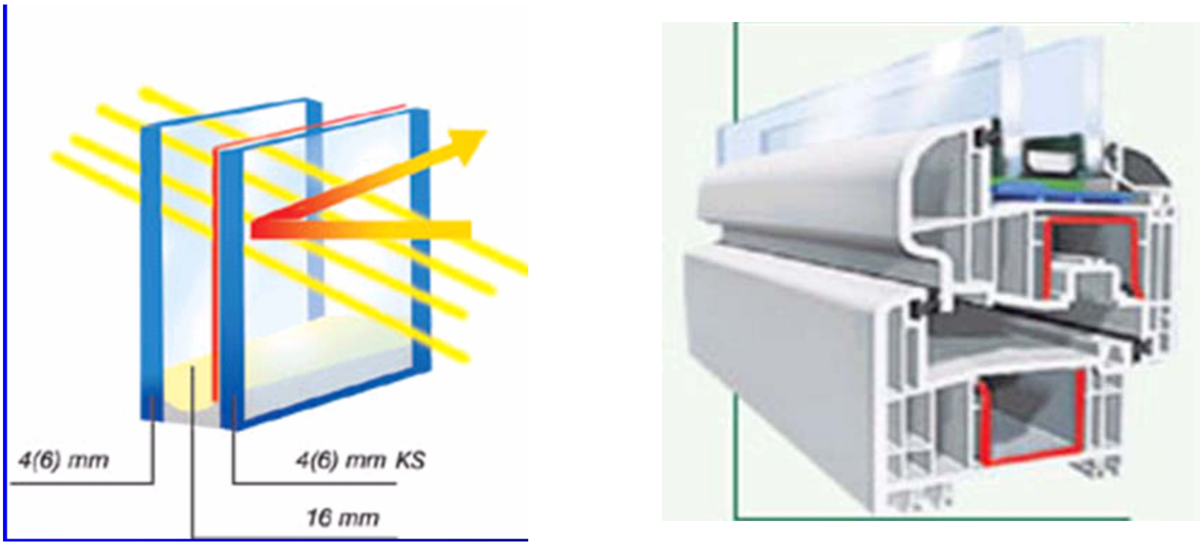


Fig. 11. The sketches of new windows glass units and profiles

Before placing thermal insulation on external façade walls, it is necessary to:

1. Clean the old cracked surface of façades until the solid basis is reached and to restore the cracked places.
2. To remove the existing tins of parapets and windowsills.

Stone wool will be used for thermal insulation of walls, and façades will be finished with patterned daub and façade decoration panels. For thermal insulation of the part of façade between the axes „5 – 8", material of 100 mm will be used (70 mm heating insulation of stone wool (ρ = 30 kg/m^3) and 30 mm heating and wind insulation of stone wool (ρ = 90 kg/m^3)). Façade decoration panels will be used for finishing (see Fig 12). Z type profiles will be used for insulation fastening; the profiles will be placed every 600 mm (see Fig 13). The remaining part of the façade will be covered with thermal insulation of 130 mm: stone wool (ρ = 140 kg/m^3). This part will be daubed with patterned daub, which will be placed on levelling grout with a reinforcement net glued to the heat insulation, and painted with good quality façade painting twice (see Fig 14). 30 mm stone wool (ρ = 140 kg/m^3) will be used for heat insulation of window edges. They will be daubed and painted white. Windowsills will be covered by tin with pural covering.
A 100 mm thermal insulation (polystyrene foam rubber EPS 150, M25) will be attached on flashing of the semi-basement using bituminous glue; the insulation will go into the ground by more than 60 cm. Special humidity-resistant semi-basement panels will be attached to the insulation using special profiles. 30 mm stone wool (ρ = 140 kg/m^3) will be used for heat insulation of window edges, and semi-basement panels will be used for finishing. Windowsills will be covered by tin with pural covering.

Fig. 12. The main façade of renovation

The area of walls of the central building of VGTU for external thermal insulation by using thin daub for finishing is 2900,4 m^2 and by façade decoration panels 656,2 m^2.
Several different materials are offered for finishing of façades: patterned daub and façade decoration panels. Façades will be daubed with patterned daub and painted with good-quality façade painting (twice). Since existing plastic windows and spaces between windows are white, it is offered to paint façades with several shades of grey: dark grey for the semi-basement, grey for the largest surfaces of the façade and light grey for daubed spaces between windows and external walls of the technical floor. Window edges will be daubed and painted white.
Façade decoration panels are offered for finishing of the projected barrier of metal ventilation shaft and for finishing of lift shafts in the main façade and the foyer (between axes „6-8“). The panels have magnolia colour (matched to the existing natural stone finishing of facades).
Parapets and windowsills of the building will be covered with zinc tin covered with plastic. Windowsills will be white, and parapets will be grey.
The flat roof of the central building of Vilnius Gediminas Technical University in Saulėtekis is being reconstructed by placing additional heat insulation using materials of 120 mm thickness (80 mm semi-hard and 40 mm hard stone wool) and using two layers of new roll roofing (see Fig 15). A slope will be formed using expanded clay layer of 0...150 mm thickness in order to grant good water diversion to funnel. The existing parapet will be heightened to a height of 60 cm. The parapets will be covered by profiled zinc tin with pural; the tin will be attached to the frame made from wooden beams covered with antiseptic, and their external side will be daubed with patterned daub. The old tin of parapets and ventilation shafts will be replaced by new (zinc tin covered with pural). The funnels will also be replaced, and ventilation chimneys will be mounted.

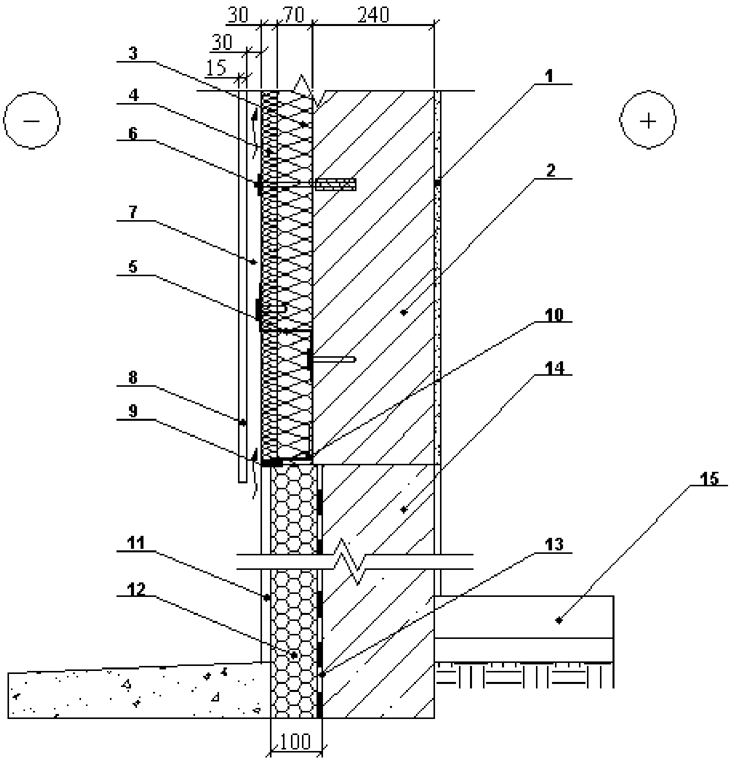


Fig. 13. Thermal insulation of walls by using façade decoration panels

1. Internal daub
2. Existing wall
3. Heat insulation: stonewool ($\rho = 140\ kg/m^3$)
4. Glue
5. Additional plugs for stonewool fastening with the core from stainless steel
6. Grout for levelling with the reinforcement net
7. Daub
8. Façade decoration panels
9. Band for seam sealing
10. Special profile
11. Special humidity-proof panel for semi-basements
12. Heat insulation for semi-basements; goes into the ground >60 cm (polystyrene foam rubber EPS 150, (M25))
13. Hydro insulation
14. Existing floor
15. Façade decoration panels

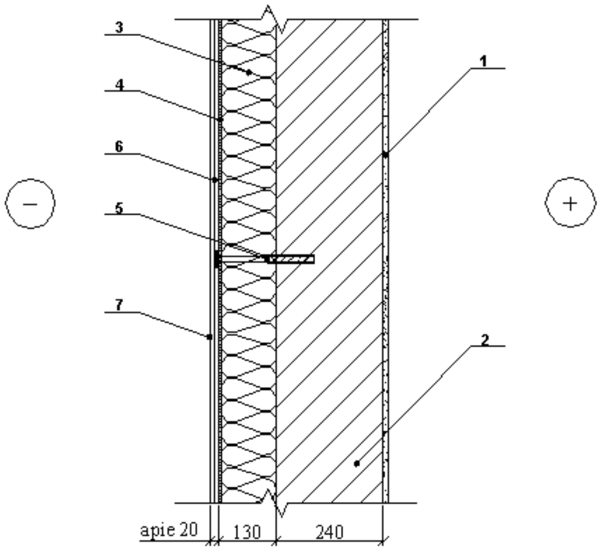


Fig. 14. Thermal insulation of walls by using thin daub for finishing

1. Internal daub
2. Existing wall
3. Heat insulation: stonewool ($\rho = 140$ kg/m^3)
4. Glue
5. Additional plugs for stonewool fastening with the core from stainless steel
6. Grout for levelling with the reinforcement net
7. Daub

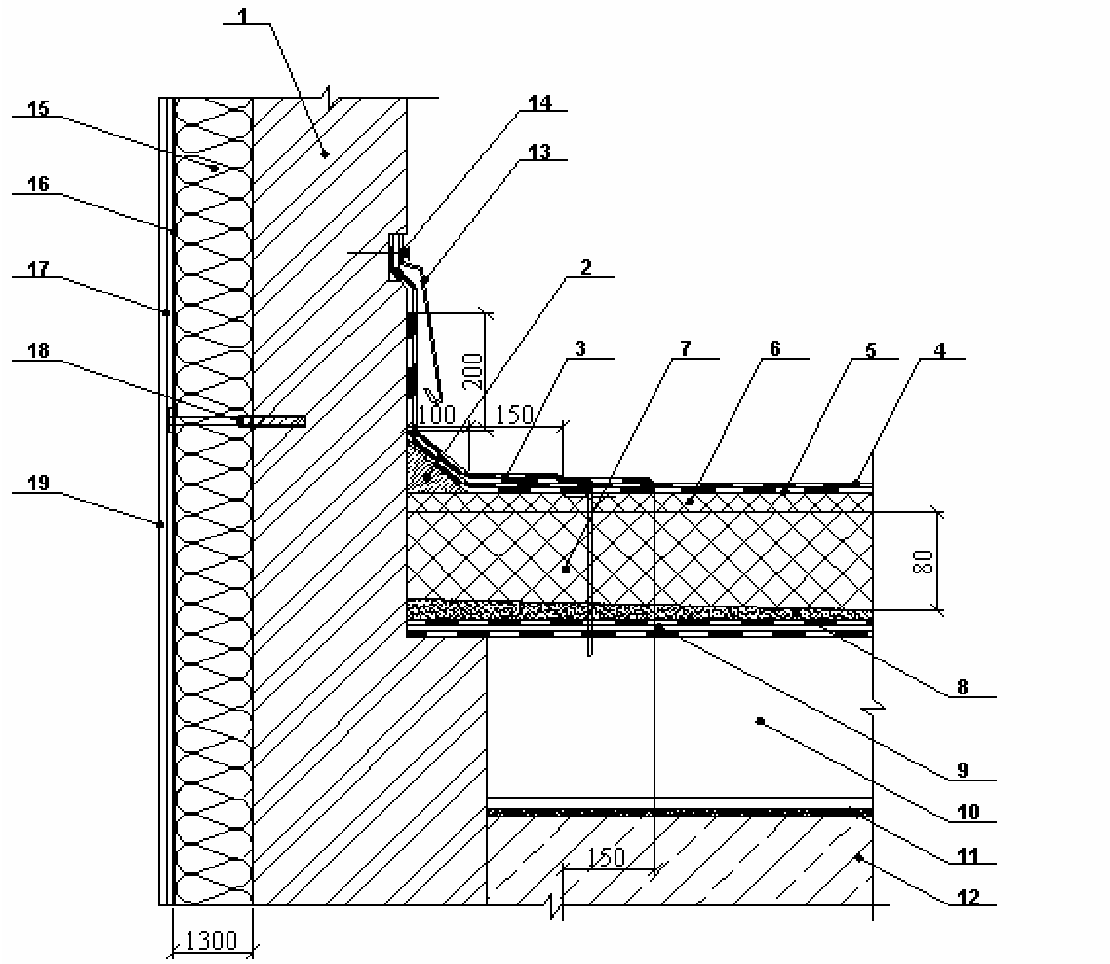


Fig. 15. Renovation of roof

1. Existing wall .
2. Wooden side with antiseptic covering
3. Additional two hydro insulation layers
4. Upper hydro insulation layer
5. Lower hydro insulation layer
6. Hard heat insulation ($\rho = 160\ kg/m^3$)
7. Semi-hard heat insulation ($\rho = 110\ kg/m^3$)
8. Layer for slope formation
9. Existing hydro insulation
10. Existing heat insulation
11. Existing vapour insulation
12. Existing supporting ferro-concrete panel
13. Zinc tin covered with pural
14. Nails for brick walls
15. Heat insulation: stonewool ($\rho = 140\ kg/m^3$)
16. Glue
17. Additional plugs for stonewool fastening with the core from stainless steel
18. Grout for levelling with the reinforcement net
19. Daub

Time-schedule

Original Time schedule																
Year	1				2				3				4			
1. Integrated architectural, energy and environmental design	←	—	—	→												
2. Construction			←	—	—	—	—	→								
4. Commissioning								←	—	→						
5. Monitoring and Evaluation										←	—	—	—	—	—	→

Revised Time schedule																
Year	1				2				3				4			
1. Integrated architectural, energy and environmental design	←	—	—	—	→											
2. Construction	←	—	—	—	—	—	—	→								
4. Commissioning								←	—	→						
5. Monitoring and Evaluation										←	—	—	—	—	—	→

7.4.2. Heating / ventilation / cooling and lighting systems

7.4.2.1. Heating

This list of normative documents have been used in designing plants:

1. STR2.05.01:1999 “Heating technology for surfaces of buildings”
2. STR2.09.04:2002 “Power of the heating system in a building. Energy consumption for heating”
3. STR2.09.02:1998 “Heating, ventilation and air conditioning”
4. Instructions for installation of heat insulation on equipment, 2005
5. Instructions for construction of heating supply networks and heating plants, 2005
6. STR2.01.01(6):1999 “Essential requirements for a building. Energy saving and heat preservation”
7. RSN 156-94 “Constructional climatology”

A heating plant is constructed in the Main building of VGTU where reconstruction of the heating system is being performed; the plant receives heat from the central heating system. Separate nodes for façades, i.e. the southern side and the northern side, will be mounted in the heating plant of the central building. A node for ventilation will be installed in this plant as well. Nodes in the heating plant will be mounted according to the new parameters of heating systems.

The heating system will be reconstructed. Systems with bottom distribution will be replaced by two-pipe systems with upper distribution in order to avoid channels under floors. Separate heating systems for the northern façade and the southern façade will be constructed. Baseboard heating systems are designed. Only the hall of the ground floor with windows reaching the floor will have branches going from frames mounted in a channel under the floor.

In the technical floor (7th floor), the systems of frames will be constructed, i.e. distribution from frames to radiators with side connections.

Plastic pipes are used in the baseboard system. Trunk pipes and frames will be made from steel. Distribution to frames is planned near the ceiling of the 6th floor. Closing fittings and balancing valves will be installed in branches leading to frames and also in branches leading to the technical floor. Closing fittings will be installed in the supply line and the return line, and balancing fittings only in the return line.

Fixed supports and compensators will be installed in the main pipelines. The planned compensators are made from steel and have axial expansion for space saving purposes. Frames will also have compensators and fixed supports. However, the pipeline compensation is checked or, to be precise, solved in the work project. T-form fastening plates will be fixed at each heating device in the baseboard system. Also pipelines will be fastened using plastic fastening elements every 0.5 m.

Closing fittings are also planned in the supply line for branches going from frames, and balancing fittings in the return line. The solutions on hiding of the fittings or leaving them in open are presented in the work project.

Trunk pipelines and frames are insulated; the insulation used for frames will be thinner for space saving purposes. Plastic pipes that will be laid in floor constructions will have a protective shell, i.e. this way frames will be moved and laid from other premises to narrower ground floor and the basement.

Steel radiators of various height (mostly of 30 cm) and size will be used as heating devices (see Fig 16). The projected radiators will have legs and bottom connections with T-forms allowing connecting to the baseboard system. All these heating devices will have thermostatic valves of advanced positioning and thermostatic heads. Side connections will be used only in the technical floor and for one unit in the basement. Therefore, additional thermostatic and return flow valves are planned for them. Radiators that will be mounted near windows have legs. Others will be attached to walls. Joints of plastic pipes are pressed, non-demountable and suitable for use in wall or floor constructions under a layer of daub or concrete without preparation of primary shafts in advance. Before mounting, all steel pipes will be cleaned till shining and covered by anticorrosive varnish. Water release taps will be installed in the lowest parts of pipelines, and automatic air releasers in the highest.

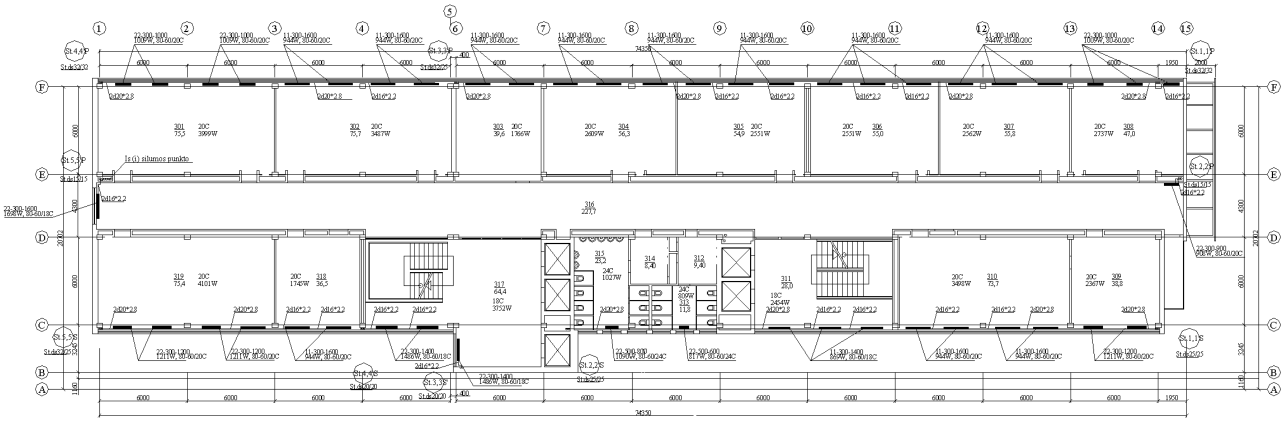


Fig. 16. Renovation of heating system (plan of 1st floor the Main building of VGTU)

Temperature parameters of the heating systems: T_{supply} 80ºC, T_{return} 60ºC
Heat demand of the southern heating system: 226 kW (with the coefficient 1.1 according to STR2.09.04:2002).
Heat demand of the northern heating system: 210 kW (with the coefficient 1.1 according to STR2.09.04:2002).
Pressure loss in the southern heating system: 13
Pressure loss in the northern heating system: 12.4
The calculatable outside air temperature: -23ºC.
Heat carrier: water.
Heat loss in the premises was calculated when heated air was supplied to the premises through a mechanical ventilation system.
Pipes for heating ventilation are laid in the channel under floor from a separate ventilation node in the heating plant and divided to two branches near the basement ceiling, i.e. for calorifer nodes of ventilation cameras in the basement and for calorifer nodes of ventilation cameras in the technical floor. Mixing nodes are installed at each calorifer.
Temperature parameters for the heating for ventilation system: T_{supply} 80ºC, T_{return} 60ºC
Heat demand for ventilation: 377 kW.
Pressure loss: 11
Heat carrier: water.
Closing taps and balancing valves will be installed in distribution branches of the main pipelines. Compensators will be installed and fixed supports will be constructed in the straight sections of the main pipelines; the compensators will be made from steel and will have axial expansion. Steel pipes will be cleaned to metallic shining, covered by anticorrosive covering twice, fastened and insulated.

7.4.2.2. Ventilation

Mechanical air supply and removal systems are designed for the main building of VGTU for maintenance of sanitary and hygiene conditions in the premises. Air amounts are calculated according to norms set for the creation of air exchange in the premises and removal of diffused pollutants. On the basis of the General Requirements, the following was planned for the reconstruction of ventilation in the building located in Saulėtekio al:

1. Air supply and removal ventilation with heat retrieval is designed for auditoriums and workrooms.
2. To make the most of the existing special ventilation premises.
3. Management of ventilation systems: from a single location specified for each block and local.
4. Striving to reduce additional repair work: to lay pipelines instead of the existing systems to the possible extent.
5. Systems of blocks must be separate/independent.

THE MAIN VENTILATION INDICATORS

BUILDING NAME	TOTAL AREA, m^2	EXTERNAL TEMPERA-TURE, ºC	HEAT/COLD DEMAND, kW		PLANNED ELECTRIC LOAD
			FOR VENTILATION	COLD DEMAND	
FOR PUBLIC NEEDS	8,484.08	IN WINTER -23 IN SUMMER 26.1	kW *395	-	kW ~ 76*

* note: heat and electric loads are corrected after selection of supplier's aggregates.

EXPLANATORY NOTE

While preparing the ventilation section in the project for the central building of Vilnius Gediminas Technical University in Saulėtekio al. 11, Vilnius, the following material was used:
Heating, ventilation and air-conditioning "Regulation on Technical Requirements for Construction"; STR 2.09.02.1998; STR 2.09.02.2005;
Hygiene norm. Acoustic noise HN 33-2001;
Fire safety. Main requirements. RSN 133-91;
Hygiene norm. Marginal values for concentrations of harmful chemical substances in the air of work premises. General requirements. HN 23-2001;
Hygiene norm. Heat comfort and sufficient thermal environment in work premises. Limited values of parameters and measurement requirements. HN 69-1997;
Hygiene norm. Microclimate in residential and public buildings. HN 42:1999;
STR 2.05.01:2005 Thermal equipment for walls, roofs and floors of buildings.
Hygiene norm. Institutions of vocational training. HN 102:2001

In order to maintain sanitary and hygiene conditions, mechanical air supply and removal systems are designed for premises. Air amounts were calculated for the determined norms to form air exchange in premises and to remove pollutants.
Positions of ventilation systems and air amounts are designed in order to form negative pressure in WC premises, to avoid distribution of unpleasant odours to work rooms. Optimal conditions for air exchange are created.
On the basis of Appendix 3 (A. General requirements), the following was planned for the ventilation section in the reconstruction of the building in Saulėtekio al.:
Ventilation for air supply and removal with heat recovery for classrooms and offices will be designed. Systems for classrooms and offices will be separate where possible.
Maximal use of the existing ventilation chambers.
Operation of ventilation systems: from a single specified place for each block and local.
In order to reduce additional repair works, pipelines will be laid in the place of the existing to the possible extent.
Systems for each block must be separate/independent.

- in work rooms: 3.6 m^3/h for 1 m^2 (no visitors);
- in work rooms: 5.4 m^3/h for 1 m^2 (open for visitors);
- in conference rooms: 14.4 m^3/h for 1 m^2;
- in classrooms: 10,8 m^3/h for 1 m^2;

- WC: exhaustion of 108 m^3/h per one toilet bowl/urinal and of 75 m^3/h per one shower;
- utility premises: exhaustion of 7.2 m^3/h for 1 m^2 ;
- air exchange once an hour is planned in the halls;
- canteen: 18 m^3/h for 1 m^2;
- ventilation in the kitchen according to the existing technology;
- library and reading-room: 7.2 m^3/h for 1 m^2;
- storeroom and auxiliary premises without work places: 1.3 m^3/h for 1 m^2;
- one time exchange is planned in the ventilation chambers.

Amounts of the supplied and removed air are specified on a separate sheet "Technical characteristics of ventilation systems".

THE LIST OF NORMATIVE DOCUMENTS USED FOR THE PREPARATION OF THE PROJECT

STR 1.01.06:2002. Specific buildings.
STR 1.01.07:2002. Simple buildings (temporary among them).
STR 1.01.08:2002. Construction type of a building.
STR 1.01.09:2003. Classification of buildings according to their purpose.
STR 1.04.01:2002. Research of the existing buildings.
STR 1.05.06:2005. Designing of a building.
STR 1.14.01:1999. Calculation of area and volume.
STR 2.01.01 (1): 1999. Essential requirements for buildings. Mechanical permanence and durability.
STR 2.01.01 (2): 1999. Essential requirements for buildings. Fire safety.
STR 2.01.01. (3): 1999. Essential requirements for buildings. Hygiene, health and environment protection.
STR 2.01.01. (4): 1999. Essential requirements for buildings. Use safety.
STR 2.01.01. (5): 1999. Essential requirements for buildings. Noise protection.
STR 2.01.01 (6): 1999. Essential requirements for buildings. Energy saving and heat retention.
STR 2.01.03:2003. Declared and projected thermal technical values of construction materials and goods.
STR 2.01.04:2004. Fire safety. Main requirements.
STR 2.02.02:2004. Public buildings.
STR 2.05.01:1999. Thermal equipment for walls, roofs and floors of buildings.
STR 2.05.02:2001. Buildings' constructions. Roofs.
STR 2.05.03:2003. Introduction to designing of building constructions.
STR 2.05.04:2003. Effects and loads.
STR 2.05.05:2005. Designing of concrete and ferro-concrete constructions.
STR 2.05.07:2005. Designing of wooden constructions.
STR 2.05.09:2005. Designing of brick constructions.
STR 2.09.01 :1998. Heat supply networks and heating stations.
STR 2.09.02:1998. Heating, ventilation and air conditioning.
RSN 156-94. Constructional climatology.
HN 69:2003. Heat comfort and sufficient thermal environment in work premises.
RPST-01-97. State fire safety regulations. Main requirements.
HN 33-1:2003. Acoustic noise. Allowed levels in residential and work premises.
RSN 134-92. Public buildings. Fire protection requirements.
BPST 01-97. General fire protection regulations.
RSN 138-92*. Fire protection automation in buildings.
HN 42:2004. Microclimate in residential and public buildings.

RSN 99-87. Instructions for covering of wood with anti-septic and increasing of fireproof qualities.

The air exchange scheme. Aggregates of the systems TI-1, TI-2, TI-3 and TI-4 are planned in the technical floor of the building, in the former ventilation compartment where the existing old equipment will be already dismantled and the premises cleaned. Aggregates of the above-mentioned systems are mounted on a floor insulated with *AKUSTO* or other sound absorbing plates. The systems TI-1 and TI-2 serve auditoriums in the 6th and 5th floors. It is planned to mount air-ducts in the existing shafts between the corridor and auditoriums. Only those parts that hinder construction of new air-ducts leading to the premises are dismantled in shafts of the building. Aggregates of the systems TI-3 and TI-4 serve workrooms in 6th, 5th, 4th and 3rd floors. Air-ducts of these systems are installed in a vertical shaft designed along axes A-F/15 of the building. Air-ducts installed in a brick shaft are insulated with stone-wool and aluminium foil of 100 mm, also fixed with adhesive tape and metal holders. Air-ducts are fixed to the wall of the building. In order to avoid noise, noise silencers are planned together with ventilation aggregates of 2,000 mm in length. The systems TI-3 and TI-4 are considerably big; therefore, it is possible to install noise silencers in each floor additionally. Air is removed through the roof by air-ducts protruding at 1 m and by installed elbows with a net. Air is supplied using metal grid with regulators. Air is supplied using diffusers in the corridors where hanging ceilings are planned.
It is planned to mount the systems TI-5, TI-6, TI-7, TI-8, TI-9, TI-10 and TI-11 in the former ventilation compartments in the basement. Old equipment is dismantled, premises cleaned and painted. Air collection grid through a wall is installed for the air supply, and the air from systems TI-5 and TI-6 is removed through a former air collection shaft where the grid is replaced. The system TI-6 serves the hall in the ground floor and rooms in the basement. Since it is not allowed to connect to old channels without inspection (they may be dirty, cracked and leaky), it was decided to lift air-ducts to the ground floor through rooms and then „hide" them in the walls. High capacity air releasers of type CS500 are planned for air ventilation in the hall. The system TI-5 serves rooms in

TECHNICAL CHARACTERISTICS OF VENTILATION SYSTEMS

SYSTEM MARKING	NO. OF SYSTEMS	SERVICED PREMISES	FILTER	VENTILATOR			ELECTRIC ENGINE			AIR HEATER/ COOLER				NOTES
				TYPE	AIR AMOUNT L, m^3/h	PRESSURE P, Pa	POWER N, kW	REV NUMBER N/min	EMITTED NOISE LEVEL dB	TYPE	AIR TEMPERATURE FROM	AIR TEMPERATURE TO	HEAT AMOUNT, kW	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T1 I1	1 1	CLASSROOMS, 5th & 6th FLOORS	EU5 EU3	Centrifugal Centrifugal	4,052 4,052	350 350	3 3	1,700 1,700	60	water	-23	+18	30	Rotary recuperator
T2 I2	1 1	CLASSROOMS, 5th & 6th FLOORS	EU5 EU3	Centrifugal Centrifugal	2,668 2,668	350 350	1.7 1.7	1,900 1,900	59	water	-23	+18	16	Rotary recuperator
T3 I3	1 1	OFFICES, 5th & 6th FLOORS	EU5 EU3	Centrifugal Centrifugal	6,623 6,229	680 700	3 3	1,600 1,600	52	water	-23	+18	50	Rotary recuperator
T4 I4	1 1	OFFICES, 3rd &4th FLOORS	EU5 EU3	Centrifugal Centrifugal	9,386 8,504	800 800	6 6	1,425 1425	60	water	-23	+18	70	Rotary recuperator
T5 I5	1 1	OFFICES, 1st FLOOR	EU5 EU3	Centrifugal Centrifugal	2,088 1,647	350 350	1.8 1.5	1,850 1,850	29	water	-23	+18	18	Rotary recuperator
T6 I6	1 1	PREMISES IN THE BASEMENT AND THE GROUND FLOOR	EU5 EU3	Centrifugal Centrifugal	3,285 2,916	350 350	2.6 1.9	1,200 1,200	42	water	-23	+18	46	Rotary recuperator
T7 I7	1 1	CLASSROOMS AND OFFICES, 2nd FLOOR	EU5 EU3	Centrifugal Centrifugal	5,476 4,975	550 550	3.5 3.1	2,400 2,400	29	water	-23	+18	45	Rotary recuperator
T8 I8	1 1	CLASSROOMS, 1st FLOOR	EU5 EU3	Centrifugal Centrifugal	5,538 5,538	700 700	3 3	1,475 1,475	30	water	-23	+18	46	Rotary recuperator
T9 I9	1 1	CLASSROOMS, 2nd FLOOR	EU5 EU3	Centrifugal Centrifugal	3,106 3,106	550 550	2.3 2.3	1,900 1,900	55	water	-23	+18	30	Rotary recuperator
T10 I10	1 1	LIBRARY AND READING-ROOMS, GROUND FLOOR	EU5 EU3	Centrifugal Centrifugal	634 634	200 200	0.5 0.5	1,900 1,900	54	water	-23	+18	4	Rotary recuperator

TECHNICAL CHARACTERISTICS OF VENTILATION SYSTEMS

SYS-TEM MAR-KING	NO. OF SYS-TEMS	SERVICED PREMISES	FILTER	VENTILATOR			ELECTRIC ENGINE			AIR HEATER/ COOLER				NOTES
				TYPE	AIR AMOUNT L, m³/h	PRESSURE P, Pa	POWER N, kW	REV NUMBER N/min	EMITTED NOISE LEVEL dB	TYPE	AIR TEMPERATURE FROM	AIR TEMPERATURE TO	HEAT AMOUNT, kW	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T11 I11	1 1	CANTEEN, GROUND FLOOR	EU5 EU3	Centrifugal Centrifugal	4,381 2,560	350 400	3 2.2	2,730 1,800	49	water	-23	+18	40	Plate recuperator
I12	1	WC, GROUND, 1ST & 2ND FLOORS	-	Centrifugal .	3,564	400	2.5	2,400	44					In insulated casing or on the roof
I13	1	WC, 3rd, 4th, 5th and 6th FLOORS	-	Centrifugal .	4,752	450	3.5	2,800	52					In insulated casing or on the roof
I14	1	WC, 3rd, 4th, 5th and 6th FLOORS	-	Centrifugal .	3,888	400	2.5	2,400	48					In insulated casing or on the roof
I15	1	WC GROUND, 1ST & 2ND FLOORS	-	Centrifugal .	2,916	400	2.5	2,400	42					In insulated casing or on the roof
I16	1	FROM THE KITCHEN HOOD WITH FAT FILTERS	-	Centrifugal .	2,000	500	2.5	1,850	47					Special fat-resistant with Teflon vanes

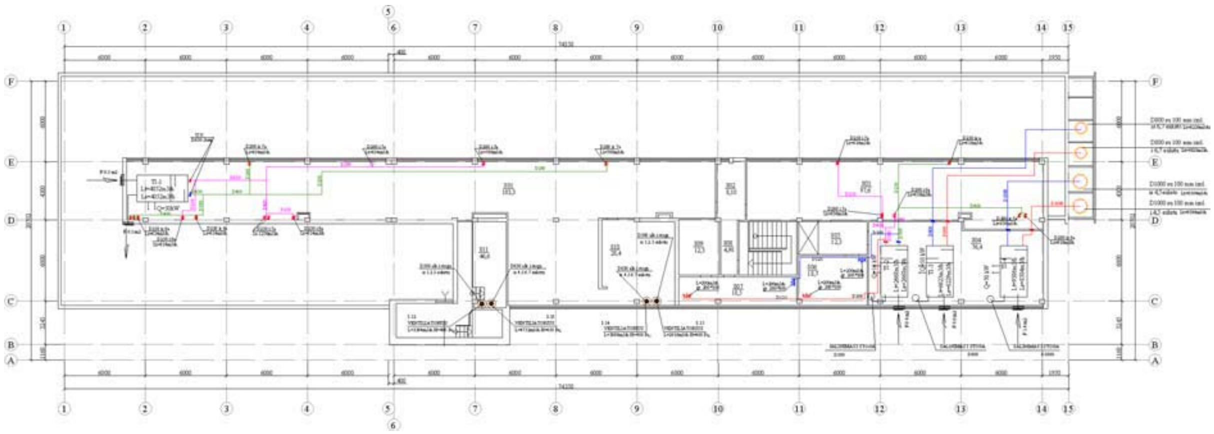


Fig. 17. Renovation of ventilation system (plan of technical floor the Main building of VGTU)

Patalpos Nr.	Patalpos pavadinimas	Patalpos plotas, m2
801	Ventiliatorinė	183,3
802	Koridorius	8,10
803	Ventiliatorinė	97,6
804	Ventiliatorine	76,4
805	Koridorius	12,3
806	Dailininko kabinetas	18,7
807	Dailininko kabinetas	18,5
808	Koridorius	4,98
809	Pagalbinė patalpa	12,3
810	Krovininio lifto patalpa	28,4
811	Keleivinio lifto patalpa	46,6

the 1st floor. The system TI-7 serves premises in the 2nd floor, mainly auditoriums. The system TI-8 serves auditoriums in the 1st floor. The system TI-9 serves auditoriums in the 2nd floor. The system TI-10 serves the library and the reading hall located in the ground floor.

The air from the systems TI-7, TI-8, TI-9 and TI-10 is removed to the joint air-duct, which goes through a brick shaft to a wall without windows. A reverse valve is installed on air-ducts of each system. The air of the above-mentioned systems is collected 2 m above the ground and removed through a wall without windows. Air-ducts in the shaft are insulated with a layer of stone-wool of 100 mm (thickness) and also fixed with the adhesive tape and metal holders. Ventilators are planned in the technical floor for WC ventilation. The systems I-12 and I-15 remove air from ground, 1st and 2nd floors, and the systems I-13 and I-14 remove air from 3rd, 4th, 5th and 6th floors. Two systems are planned for each floor. Since the amount of the removed air is quite large, it is planned to supply 1/3 of aspirated air amount to the wash-hand premises due to possible large overpressure in WCs. Then the aspiration will be more effective and doors will open easily. Metal regulated diffusers aspirate the air. The ventilator has a protection against overheating. The highest noise emitted to the environment is 47-52 dBA.

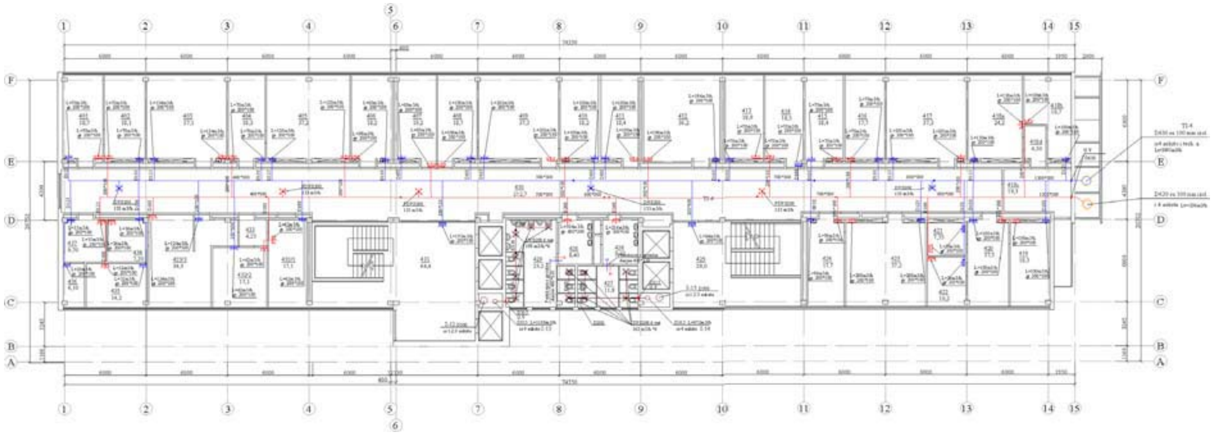


Fig. 18. Renovation of ventilation system (plan of 4 st the Main building of VGTU)

Patalpos Nr.	Patalpos pavadinimas	Patalpos plotas, m2
401	Buhalterës pavaduotojos kabinetas	18,7
402	Vyr. buhalterës kabinetas	18,1
403	Ekonomikos direkcija	37,1
404	Reikalø tvarkytojos kabinetas	18,3
405	Ûkio direktoriaus kabinetas	37,2
406	Pastatø eksploatacijos valdyba	18,2
407	Pastatø eksploatavimo valdyba	19,2
408		18,7
409	Statybos technologijø ir vadybos katedra	37,3
410	Statybos technologijø ir vadybos katedra	18,2
411	Statybos technologijø ir vadybos katedra	18,4
412	Spec. lëðø buhalterija	36,2
413	Ekonomikos direkcija	18,9
414	Ekonomikos direkcija	18,5
415	"Inþinerijos" redaktoriaus kabinetas	18,4
416	Statybos fakulteto prodekano kabinetas	17,7
417	Statybos fakulteto metodinis kabinetas	37,3
418a	Statybos technologijø ir vadybos katedra	24,2
418b	Statybos technologijø ir vadybos katedra	18,7
418c	Statybos technologijø ir vadybos katedra	19,3
418d	Koridorius	4,30
419	Statybos fakulteto prodekano kabinetas	18,3
420	Statybos fakulteto prodekano kabinetas	37,5
421	Statybos fakulteto prodekano kabinetas	7,55
422	Statybos fakulteto prodekano kabinetas	10,3
423	Statybos fakulteto dekano kabinetas	37,2
424	Statybos fakulteto dekanatas	17,7
425	Laiptinë	28,0
426	Prausykla	9,40
427	San. mazgas	11,8
428	Prausykla	8,40
429	San. mazgas	23,2
430	Koridorius	212,7
431	Fojë	64,4
432/1	Buhalterija	17,1
432/2	Buhalterija	17,1
432/3	Buhalterija	34,3
433	Koridorius	4,23
434	Kasa	7,30
435	Buhalterija	14,2
436	Buhalterija	6,10
437	Buhalterija	9,70

Aggregates for air supply/aspiration are with rotary recuperators, except TI-11. TI-11 is provided with a plate recuperator. All compartments consist of: filters (EU 5 and EU 3 class), ventilators, water heating calorifers, terminator and automation. Thermal capacity is planned with a reserve; VGTU at the request could install aggregates with a plate recuperator. All air-ducts in ventilation compartments and going through floors and in shafts are insulated with a heat insulation of 100 mm (thickness). The forecasted air movement speed in the premises is 0.2 m/s.

7.5. Predicted energy savings

Energy saving measures, heating, cooling, ventilation	[kWh/m²a]	Total [kWh/a]
High-efficient windows	26	220589
insulation of roofs and facades	27,9	236672
heating system	36	305663
Ventilation system (heating recovery system)	42,2	297000
Total heating energy savings	132,1	1059924

Energy saving measures, electricity	[kWh/m²a]	Total [kWh/a]
N.A.		
Total heating energy savings		

Water saving measures	[m³/m²a]	Total [kWh/a]
N.A.		
Total heating energy savings		

7.6. Predicted costs and payback

Energy saving measure/investment	Area [m²]	Total costs [EUR]	Saving [EUR/a]	Pay-back periods [a]
Insulation of facades	2425	105.349	8.166	12,9
Windows	1000	109.696	8.295	13,2
Roof	1306	17.020	633	26,88
Change of entrance door	25	6.154	145	42,4
Renovation of the thermal unit		2.298	1.354	1,7
Heating system	8484.20	185.026	11.364	16,2
Ventilation system		42.606	11.028	42,4
Total		462.000	40.840	19.8

Energy costs used for the payback calculation:
Thermal : 36,14 €/MWh.
Electric: 85,15 €/MWh.

7.7. Lessons learned

Because of the financial shortages the attention was not paid to the third renovation component, i.e. ventilation and in consequence the ventilation system was not foreseen to be refurbished.

In the renovation process economical reasons have lead to the development of 1 project modification. This has been done in close cooperation with the builder and VGTU authorities. The 1 modification is described below. As we saved total 42605,61 €, we suggest if it is possible to use that money for ventilation of the building. In the project proposal ventilation was not foreseen as the mean of renovation. Then the authorities of university are planning to retrofit ventilation system.

8. Evonymos Ecological Library

Author: E. Triantis, E. Athanassakos

8.1 General data

8.1.1. General information

Year of construction: 1890
Year of renovation (start): (i) 1955, (ii) 2006

Total floor area (m^2): 1000
S/V ratio: 0.55
Number of storeys: Three storeys plus one mezzanine
Window/glass areas (m^2):

8.1.2 Site

The building is located close to the central archaeological spaces in Athens, which are being united and enhanced by pedestrian roads. This location is ideal for dissemination purposes as the whole area is very popular and widely frequented by Athens citizens and visitors throughout the year.

Building location

Geographic position

Latitude: 37^{o} 58’ N
Longitude: 23.43’ E
Altitude: 50 m.

Climate Conditions

Total Annual Sunshine hours	2818
Annual Heating Degree Days (18 ^{o}C)	1110
Temperature	
Winter Average	11.6
Winter av. min	7.6
Summer Average	25.1
Summer Av. max	29.7

8.1.3 Building type

It is a listed building of the 1890 ‘s used as a public library.

8.2 Before retrofit

8.2.1 Building construction

The building construction is characteristic of its era. It has 60 cm thick stone walls, and single pane 3,5 m high windows and balcony doors. At present there is no insulation on walls and roofs and there are serious humidity problems in the building. Currently it extends on three floors, a basement, and terrace. The ground floor housed commercial activities while the 1st floor originally a residence, is now used as a library.

The building has a total floor area of 910 m^2, to which two covered terraces will be added, bringing the total usable surface to 1000 m^2 approximately. Another serious problem is the building facade whites is gravely deteriorated and is in urgent need of renovation.

Figure 1: The building interior

Figure 2: Characteristic details of the building

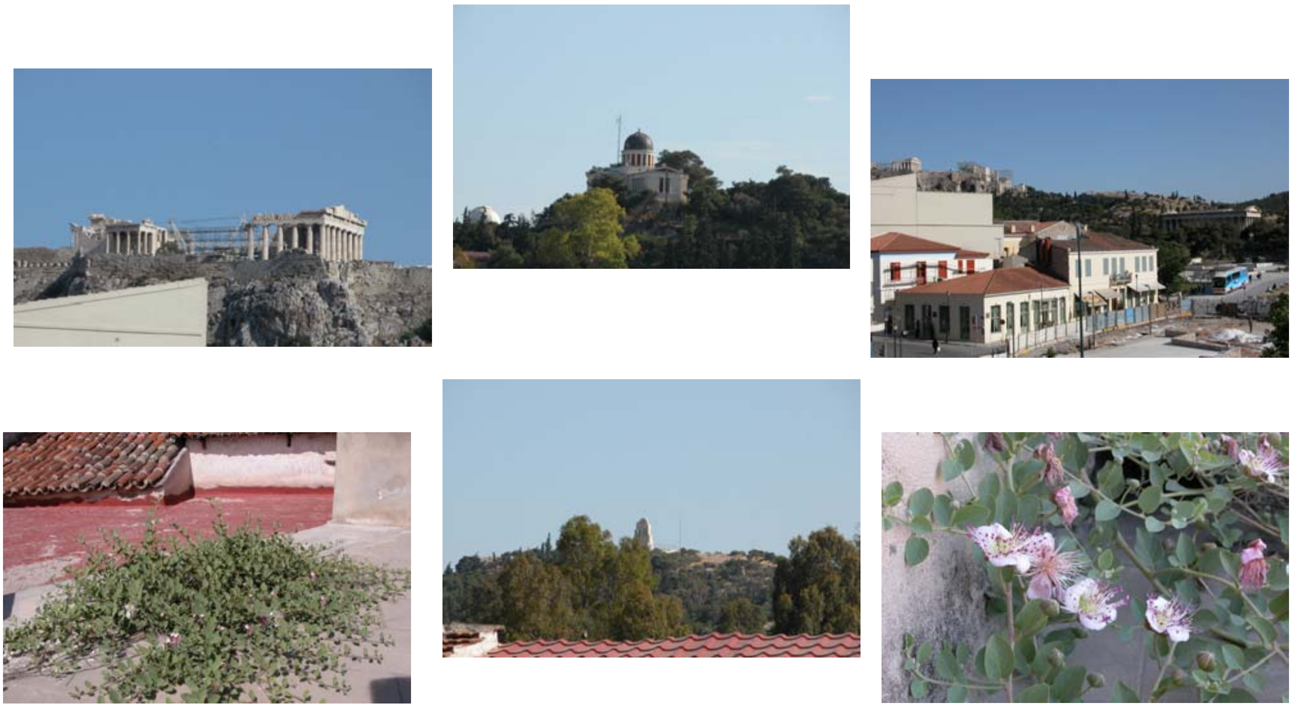


Figure 3: Main views from the building terrace

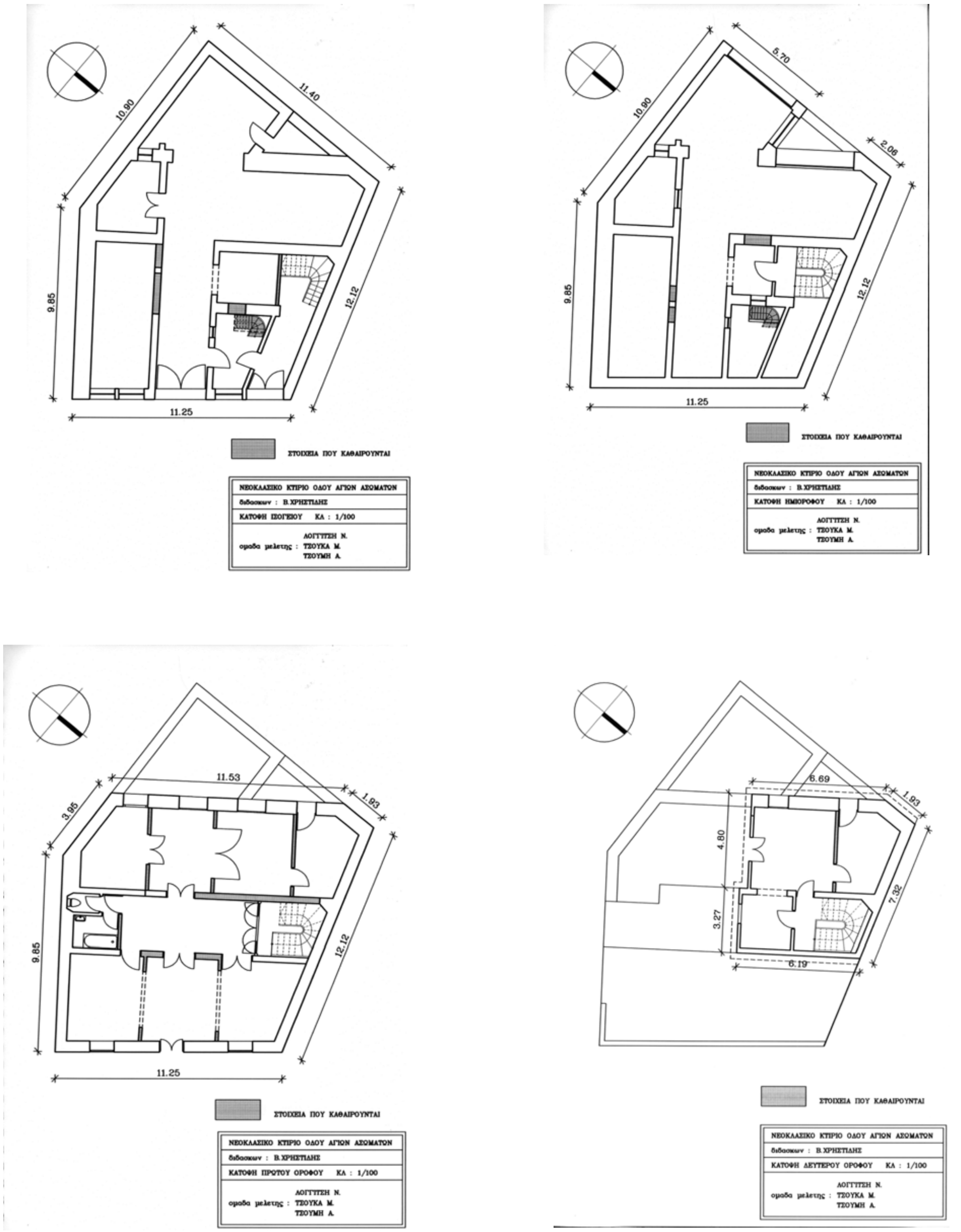


Figure 4: Existing plans of the building: the four levels

8.2.2 Existing heating, ventilation, cooling, lighting systems

Currently the building is heated locally with portable small stoves burning liquid gas. In order to reduce heating expenses, both in equipment and fuel, the stoves serve only the places that are continuously occupied. The remaining building is quite cold. This gives rise to cold drafts and unpleasant cold zones that the users are exposed to when they circulate to non-heated areas. Furthermore, the temperature regime is strongly fluctuating with room door opening. During the very cold days the capacity of the stoves does not suffice to keep the internal temperature within comfort levels. Overall the space has strong thermal asymmetries and quite often is under-heated.

Window opening provides ventilation, for both hygienic and cooling purposes. Although this may be in principle a sufficient mechanism for a high percentage of building operating time, the cold drafts in winter and the street noise especially in summer, give rise to uncomfortable conditions. Furthermore, the speed of the incoming air that often exceeds the comfort level and the lack of effective mechanisms to control it, give rise to annoying conditions for the users. These problems result in reducing the potential of ventilation to provide cooling. Properly designed ventilation openings are needed in order to remove the warm air without causing any annoyance at the working level.
In summer, because the building remains closed during nighttime, for safety reasons, the heat absorbed by the high thermal mass during the day cannot be dissipated to the outside but remains in the building elements causing overheating. Thus night ventilation could be very beneficial for cooling off the building mass.
Cooling is provided by portable and ceiling fans. Currently this cooling type is quite sufficient for the limited space and activities of the library.

Lighting is provided by neon lumps as background lighting enhanced with task lights. The space that houses currently the bookstands and the reading facilities is satisfactorily daylit. However, special daylight design is needed for the circulation space, and the new uses to be housed in the first floor and the mezzanine.

8.2.3 Energy and water use

The energy and water consumption tabulated in Table 1 is estimated based on national consumption levels. The actual consumption is reported in Table 2 but relates to the current limited use of the library. As mentioned in above, the energy consumed does not suffice to provide comfort conditions to the library resulting in underheated spaces in winter and overheated ones in summer.

Table 1

	Estimated year (2003)	**Total for the whole building**
Space heating	112 kWh/m^2 a	112000 kWh/a
DHW	3.2 kWh/m^2 a (included in electricity consumption)	3200 kWh/a
Electricity	140 kWh/m^2a	140000 kWh/a
Water	1.1 m^3/m^2a	1100 m^3/a

The above tabulated values are estimated based on typical consumption levels for offices and raised by 40% to account for longer working hours and different needs of certain uses the building will house (such as material recycling labs, coffee shop etc.). Correspondingly the water consumption has been increased by 7%.

Table 2

	Measured year (2003)	Total for the whole building
Space heating	82 kWh/m^2 a	14350 kWh/a
DHW	0 kWh/m^2 a	0 kWh/a
Electricity	3.1 kWh/m^{2}a	435 kWh/a
Water	0.8 m^3/m^{2}a	60 m^3/a

8.3 Energy saving concepts

The purpose of the project is to renovate the building and turn it into an ecological library devoted to demonstration, education, and dissemination of low energy and environment friendly technologies in building construction and renovation. This will include traditional and modern techniques of energy and water conservation, ecological building materials, renewable energy systems, and recycling of water, paper etc.

Besides the main function of the library where open shelf reading spaces will be formed there will be conference and seminar rooms as well as workshops on paper recycling, book making and photography, an electronic library and an internet cafe where information on ecological subjects can be obtained. A special open monitoring space will be created, where energy conservation technologies used in the building will be demonstrated to the public.

The whole building will be completely renovated in the interior. Key features of the renovation is the addition of new useful spaces, that is:

a) a mezzanine between the ground and 1st floor, in order to take advantage of the double height of the ground floor (nearly 6 m)
b) the conversion of an existing veranda on the first floor in to an open reading area,
c) the conversion of the terrace in to a sitting area. The outdoor spaces will be designed to ensure high quality thermal and visual comfort for the users in all seasons.

All internal spaces will be reformed and new spaces added to house diverse activities of the library such as laboratories of photography, CD and DVD production, book binding etc. Moreover an auditorium with a capacity of 80 people is foreseen on the mezzanine, whilst the book stands and reading areas will be located on the mezzanine and first floor.

First priority in the renovation curriculum is the minimisation of energy needs with the use of energy efficiency measures and integration of solar technology, ensuring simultaneously thermal and visual comfort conditions both indoors and outdoors. Key feature of the renovation design is to accommodate energy efficiency and RES systems and techniques in an integrated design without altering the facades of the building. The energy refurbishment design will follow the norms and restrictions foreseen by the General Building Code for listed buildings of this type.

Basic architectural design
An additional entrance and circulation core are included in the refurbishment design following a change in the design brief to enable the separation of library use from the other uses. This change seemed necessary for securing the building at times when only the library is in use. At these times only the personnel has access to the first floor and mezzanine.
The sanitary spaces, foreseen in the preliminary design, were judged insufficient to adequately service the users when the building is fully operated. Furthermore, the location of sanitary spaces was partly changed due to the addition of an extra fire escape exit.
Fire escape exits were re-established as in the initial construction. Specifically, during previous refurbishment that took place before the fifties, the auxiliary stair on the back façade

was limited to service only the upper two levels. During the proposed design the stair is extended down to the 1st floor in order to be used as escape exit for the mezzanine and upper floors. Similarly an exit door to the backside was added on the 1st floor.

Energy design
Following the results of a new redesign in scale, it was deduced that it is impossible to increase the thickness of the principal façade in order to accommodate 10cm insulation layer as initially foreseen. The maximum available space for insulation thickness is 4cm. The same is true for the flat areas of the roofs.
In order to enhance natural ventilation (day and night) without interfering with the use of spaces or reducing comfort (higher air speeds and noise outside of comfort zone), a new ventilation chimney is foreseen. It will be located in the light-well originally used to daylight the auxiliary spaces on the 2nd floor. Thus, the light-well will be redesigned to accommodate the ventilation chimney and simultaneously ensure efficient daylighting of both the auxiliary spaces and the main corridor on the 2nd floor.

8.3.1 Building construction

- Energy conservation:
- External insulation of walls and roofs (4 cm insulation thickness - all external architectural protrusions and balconies will be dismounted for the placement of the insulation and then put back).
- Air tight low–e double glazing and night insulation (insulated aluminium rollers)
- Reduction of infiltration with window stripping and tight window frames
- Shading varying according to the orientation of openings (horizontal, and vertical shades made of thin wooden openable fins)
- Shading of the South and Southwest façades with wooden pergolas supporting PV modules and sliding cloth shades
- Ecologically treated wood
- Insulation made of natural plant substances e.g. quark, wood fibres, or similar

8.3.2 Heating

- Renewable energy integration:
  - Integration of two sunspaces on the verandas/terraces with openable vertical and tilted glazing to eliminate any increase of building cooling load.
  - PVs integrated on the sunspace roofs as shading devices
  - Solar collectors for DHW
- Efficient energy supply: A gas fired water boiler system will supply the heating energy. The size of the boiler needed is 82 kW. It will be fuelled from the natural gas city network. Hydraulic networks will be common for both heating and cooling systems. A four-way valve is necessary at the boiler outlet to significantly lower the water temperature to the level needed by fan coil units (~45-50o C). Pumps will be driven by Variable Frequency Drivers (VFD), to account for pressure changes due to opening/closing of local valves. Hydraulic network will be common for both cooling and heating systems.

8.3.3 Ventilation

- Hybrid efficient ventilation: ceiling fans and earth pipes.
- A centrifugal fan (“fan section” type) with VFD drivers will assist natural ventilation. It will be installed at the top of the main stairs of the building to reject used air.

8.3.4 Cooling

8.3.4.1 Natural cooling

- Innovative solar chimney / light duct elements,
- Night hybrid ventilation for the warm months

8.3.4.2 Mechanical cooling

Air cooled water chiller. The chiller size for the building is 90 kW. The option of being reversible could be explored to exploit possible favourable electricity tariffs. In Greece off-peak low electricity tariffs apply in winter in general during the time intervals 15:00-17:00 and 23:00-05:00. Electricity during these intervals is usually cheaper than gas.
The decision of reversible or not will be taken close to the installation phase. Increase in price from a non-reversible to reversible chiller is quite small, of the order of 15%, and this will have to be compared with electricity tariffs at the time of purchase. The chiller will be based on rotary type compressors, which are more efficient than reciprocating ones.

Fan Coil Units (FCU) for the areas of the library. They will have to be mostly placed on the floor of the rooms due to the big clear height (5m) of each space and most importantly of the wall frescos. Each FCU will contain two thermostats, one for air and one for water temperatures. It will also carry a humidifier (water spray) downstream the heating-cooling element.

Air Handling Units (AHU) will be installed in the meeting-exhibition areas of the ground floor. Such units have higher cooling/heating capacity than FCU's. In addition they can be designed to provide ventilation through a mixing box. AHUs should have the capability to introduce a variable amount of fresh air to the room, and reject the equivalent amount of used air. The two currents will pass through a heat exchanger, so that heat of the used air will be recovered and supplied to the fresh air. The process of ventilation, quantity of air in-out and heat recovery will be controlled by the BMS.

8.3.5 Lighting systems

8.3.5.1 Daylighting

- Light shelves to enhance daylighting in reading areas
- Light duct (as part of the ventilation chimney)

8.3.5.2 Artificial Lighting

General lighting in the library areas will be provided by 3x14 W or 4x14W fluorescent light fixtures. Bulbs used will be T5 type which exhibit very low electricity consumption.
In areas close to openings the fixtures will contain dimmable ballasts (High Frequency Regulated – HFR) and will carry light sensors, so each fixture will adjust light output according to the incident light, using as criterion the maintenance of a preset light level on the working surface below it.
In special reading areas local user-operated table lights will be used.

8.3.6 BEMS

An intranet with PCs will be used for education and information purposes in order to present to students and visitors of the library the energy conservation and environmental systems used in the building and their operation.
Most of the systems installed in the building will be controlled by a Building Management system (BMS). The BMS will serve 3 distinct purposes:

- Control HVAC, lighting, passive cooling, RES and other systems installed in the building, optimizing their performance
- Collect system operation and energy consumption/production data for analysis and evaluation
- Demonstrate the usefulness of the system itself, as well as the entire energy conscious design of the building.

The BMS system will receive input and/or will control the following:

System	**Measurements & controls**
Weather station	Temperature, solar radiation, humidity, lighting level, wind
PV	Recorders, display
Boiler	Thermostats / valves, time
Heat Pump	Thermostats / valves, time
FCU	Temperature, Time, humidification
AHU (meeting rooms)	Temperature, Time, Heat recovery
Fans / Openings	CO_2 sensors, fans, openings, ambient conditions, Time, motors
Lighting	Local dimmer sensors, occupancy sensors, Time
Sunspace	Openings, shading, ambient conditions
Shading	Louvers (horizontal and vertical)
Glazing night thermal protection	Rollers (electric motors)
Fire protection	Fire sensors, alarms
-	Energy analysis

It will be connected via LAN (Ethernet) to the computer system in the library, to be used for demonstration and teaching purposes.
The sections to follow, will define the details of operation of the BMS.

8.4 Overview of design process

8.4.1 Building construction

- The building heating and cooling loads and the contribution of the sunspace, direct gain to reducing heating demand, as well as shading and ventilation to reducing cooling demand were investigated using SUNCODE PC – Building Load Simulation Program with Athens TMY.
- The areas in the rooms spanned by the incoming solar beam were computed and visualised using SOLAR2. This investigation supported the design of the space layout and location of equipment.
- Shading masks from neighbouring buildings and other obstacles were traced using the sun charts.
- The shading design efficiency was investigated using the software Helios W.

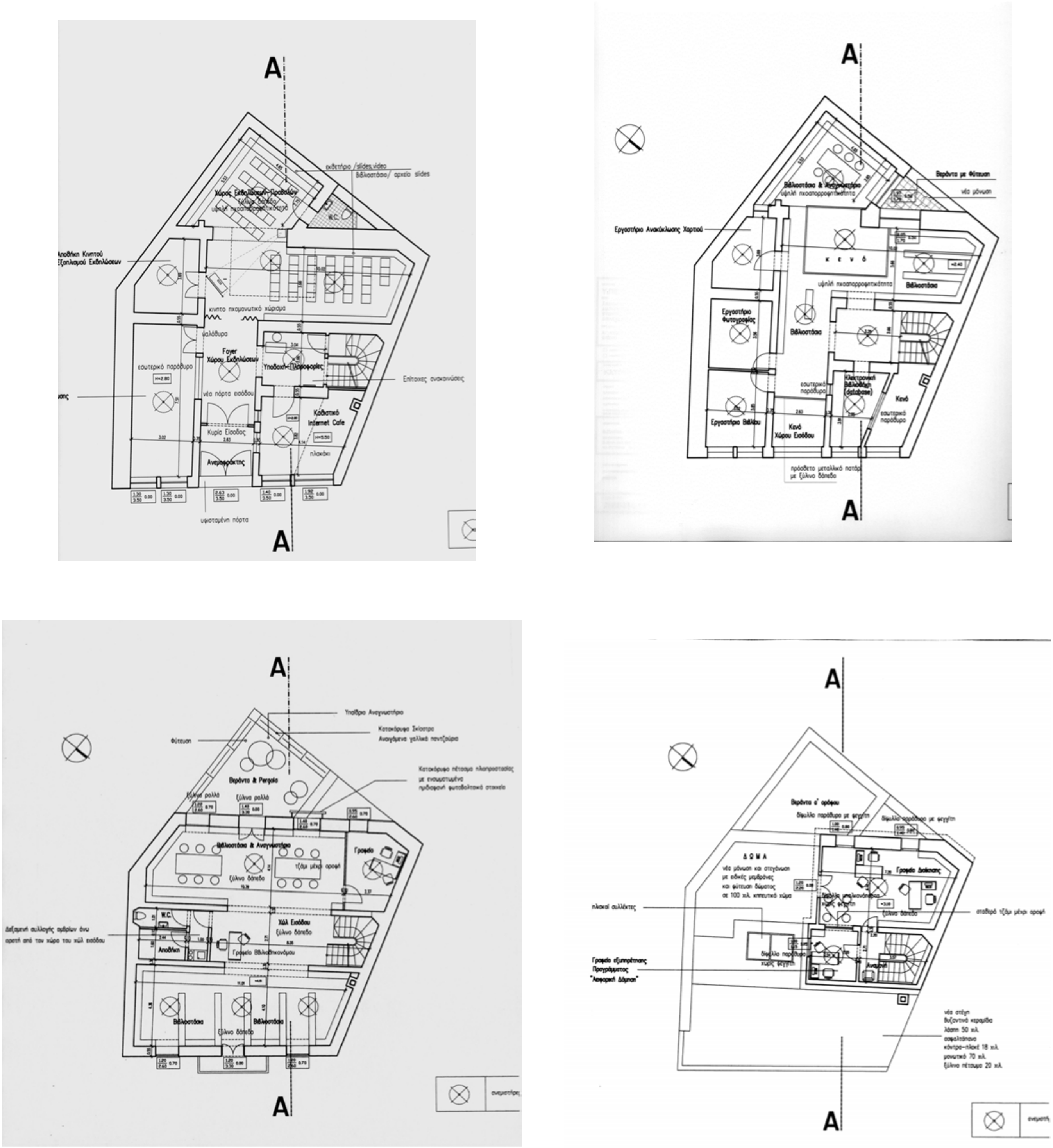


Figure 5: Technical design solutions: plans of the four levels of the building

8.4.2 Heating / ventilation / cooling and lighting systems

8.4.2.1 Ventilation

To be completed

8.4.2.2 Lighting

Daylighting levels were computed using SUPERLITE.

8.4.2.3 Solar thermal

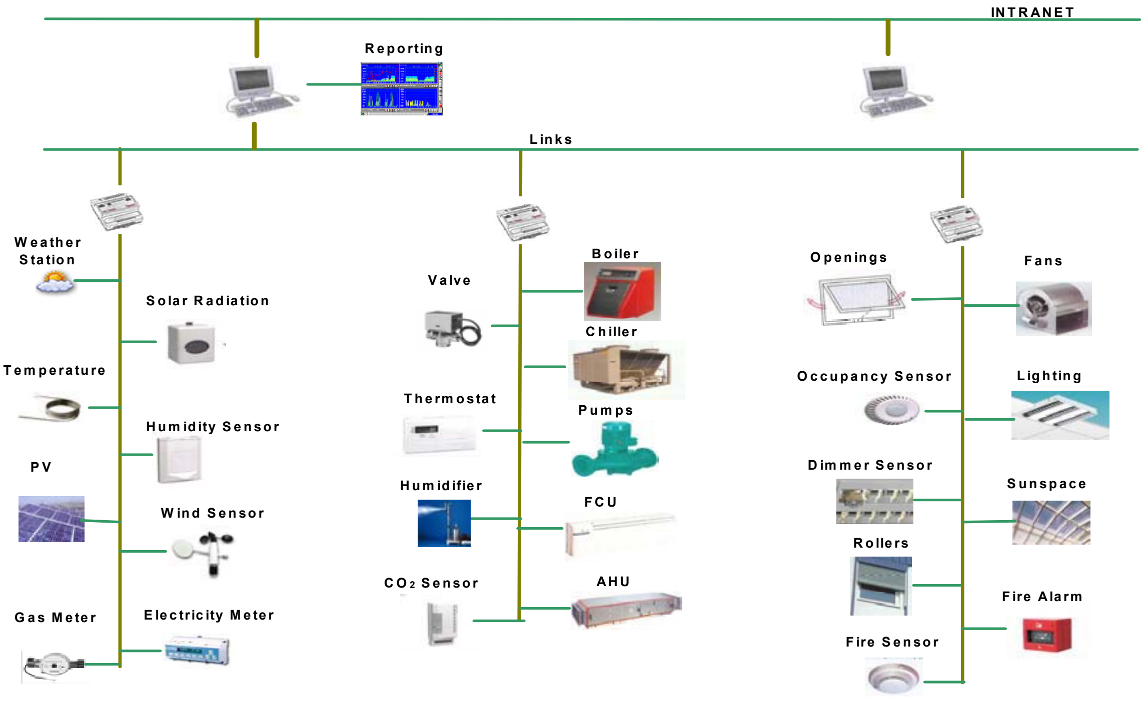
The DWH system was sized to suit the needs of the library.

8.4.2.4 Solar PV

To be completed

8.4.3 BEMS

The BEMS design has not been finalised as yet. Therefore the protocol and design details have not been decided. The structure of BEMS is depicted below.



8.5 Predicted energy savings

Heating energy saving	
kWh/m² floor area	Total [kWh]
195	**195000**

Electrical energy saving	
kWh/m² floor area	Total [kWh]
4.2	**4234**

Water saving					
Original measures	**Modified measures**	**Original water savings**		**Modified water savings**	
		m^3/m^2	Total [m^3]	m^3/m^2	Total [m^3]
Two sanitary spaces	Addition of two more sanitary spaces to service the users	0.16	175	0.16	175
Total		0.16	175	0.16	175

8.6 Predicted costs and payback

Eligible costs (€)	Payback time
484370	**23 years**

8.7 Lessons learned

To be completed