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AALBORG UNIVERSITY
DENMARK

CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 1

Heiselberg, Per Kvols

Publication date:
2016

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

Link to publication from Aalborg University

Citation for published version (APA):
Heiselberg, P. K. (Ed.) (2016). *CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 1*. Department of Civil Engineering, Aalborg University.

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Improving the Energy Performance in Existing Non-residential Buildings in Denmark Using the Total Concept Method

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Abstract
This project is a part of a joint European research project, "Total Concept", which is a method for improving the energy performance in existing non-residential buildings. The method focuses on achieving maximum energy savings in a building within the profitability frames set by a building owner, who plans to invest. The method differentiates from other refurbishment approaches by using a comprehensive energy audit plan, advanced energy simulation methods, a complex economic model and analysis of measures that may have a reasonable energy-saving potential. The aim of the demonstration project was to form a package of measures for an energy performance improvement in the building based on the Total Concept method.
This paper presents results from recently analyzed data on two renovated Danish buildings according to the rules of "Total Concept" method. According to the estimation done based on available information the identified measures in total lead to at least 22% and 37% energy saving, respectively for the building 1 and building 2.

Keywords - Energy renovation, Retrofitting, Energy measures, Total Concept method, Action package, Holistic approach, Energy efficiency, Energy reduction, Energy audit, Energy refurbishment, Energy renovation, Existing non-residential buildings

1. Introduction

Improving energy efficiency and reducing energy demand of existing buildings are considered as a key target area in European countries, since buildings account for about 40% of total energy demand in the EU [1]. In Denmark, the energy requirements for new buildings have been gradually tightened up and therefore the new buildings use less energy than old ones. But the main issues are existing buildings with lifetimes of 50 to 100 years or more. In Denmark, there is a strong focus on renovation of existing buildings, with a special focus on non-residential buildings. The government has developed a comprehensive strategy for the energy renovation of the existing building stock [2]. It is estimated that the initiatives in the Strategy will reduce the net energy consumption for heating and domestic hot water in the existing buildings stock by 35% until 2050 compared to today.

In order to reach the EU's 20% energy saving target by 2020 and being in line with the Danish government's strategy for the renovation of the existing building stock, it will be essential to increase the ambitions by the building owner´s to carry out major energy refurbishment projects in the non-residential building sector.

Total Concept method offers a method and a financial tool that can provide the information required by establishing a platform for decisions on investments in energy-saving measures. The Total Concept method have been developed and successfully applied on a number of non-residential buildings in Sweden, with the results showing that it is possible to achieve energy savings up to 50-60 % in the existing building within the profitability frames set by the building owner/investor. The prerequisite for attaining profitability is that the whole package of measures (action package) is implemented in its entirety. Additionally, achieving successful results requires careful analysis in the entire process, from planning until final commissioning. Therefore, during the development of this method the entire working process has been divided into detailed working steps and tasks with defined roles and responsibilities of all actors involved in the process. The Total Concept method is based on an economic model for profitability assessment and includes, in brief, the following steps:

- A thorough inventory is carried out in the building to identify all conceivable energy saving measures and from these an action package is created that as a whole fulfills the property owner's/client's profitability requirements.
- The implementation of an entire action package in the building.
- The follow up of the measures taken: the energy used after one year is compared with the energy used before implementing the action package.

The criterion for how many measures are to be included is that the internal rate of return for the complete package exceeds the approved cost of

capital. The property owner/client decides both the financial terms and the conditions on which the cost of capital is based.

2. Methods

The work process of Total Concept method has been structured into three main steps. Each Step includes a number of tasks to be carried out and requires a certain involvement from the specified stakeholders and key actors of the method implementation. The present study used Step 1 in order to create the action package and provide an information basis on which the owner of the building can make decisions. Step 1 of the Total Concept method starts with a detail technical assessment of the building in question. Basic information about the building is gathered and relevant technical data compiled. A comprehensive energy audit is carried out on site and possible energy saving measures identified in the building. It is not a question of only the apparently most cost-efficient measures, but all measures that may have a reasonable energy saving potential. Energy simulations are performed to verify the different energy end users as well as to estimate the savings achieved by the different identified measures.

The investment costs are assessed for each individual measure. The property owner/client stipulates the financial terms and conditions on which the investment cost calculations are made. The profitability calculations are carried out by using the Total Concept calculation tool, the Totaltool.

Afterwards all the single measures are ranked according to their profitability based on the internal rate of return method.

The final result of the profitability calculation is the internal rate of return which, from an energy savings perspective, corresponds to the most comprehensive action package that can be carried out and which meets the profitability requirements stipulated by the property owner/client.

This paper presents results from recently analyzed data on two Danish pilot buildings (Lyngby Port and Ballerup Town Hall) being renovated according to the procedure of the "Total Concept" method [3]. The method leads to the identification of a package of energy saving measures, which as a whole fulfills the property owner's profitability requirements. After implementation of the action package, it is planned to follow-up on the energy use and validate profitability of the action package.

3. Results and discussion

3.1 Assumptions for caculations

The information about building envelope, technical installations and building usage was used to form a 3D model. The model was created in the software IES VE 2014. The output of the energy simulations of the 3D model was calibrated with the use of energy measurements and results from energy labeling.

The calculated measures were graded according to profitability based on the internal rate of return method. The action packages for both buildings were created taking into account the effects that each of the individual measures had on each other.

The internal rate required by the property owner was 6%. The real calculation interest rate has been adjusted with a relative energy price increase of 2% above the inflation (the average price increase for the last 25years has been around 5% annually including inflation [4]).

3.2 Pilot building 1 – Lyngby Port

Lyngby Port (3D model in Figure 1) is a 20.000m^2, 7-storey building located in Lyngby (Denmark).The building was built in 1992 and apart from upgrading of the lighting system it has never been energy upgraded before.

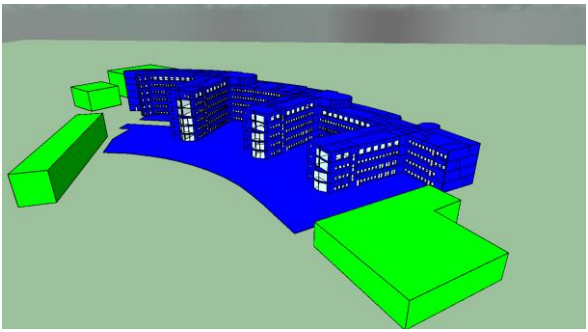

Fig. 1 Lyngby Port as a 3D model

Based on the energy audit an overall picture of the building was created:

Table 1. Summary of energy audit for Lyngby Port

Element	Description
Façade	Façade insulated according to standards from the beginning of 1990s (190mm insulation in sandwich elements, 300mm in the roof, 200mm in the ground deck).
Fenestration	Double-glazed windows mounted with inner manually controlled screening are estimated to have a U= 2,5W/m^{2}K.
Infiltration	Infiltration set to 0.25 l/s·m² of facade
Ventilation	6 VAV-systems with heat recovery (71-74%) and 6 exhaust systems with no heat recovery.
Heating	The main heating system consists of radiators served by two boilers of efficiency 93-94%.
Cooling	2 compressor-/water cooling-systems with 6 cooling units with an average COP=3.0 and is in very poor condition.
Lighting	Lighting in office area 6 W/m². There is no PIR or daylight control in offices, kitchens, technical rooms or bathrooms.

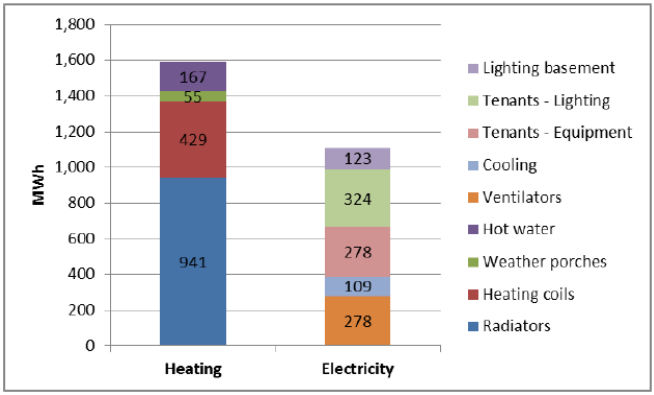

Figure 2 Simulated energy demand of Lyngby Port

After establishing of a baseline model (reference level with the current/measured energy use in the building, minimum indoor climate requirements, etc.), possible energy saving measures were analyzed. The sensitivity of the different estimations and calculations was studied. Figure 3 illustrates action package created for Lyngby Port.

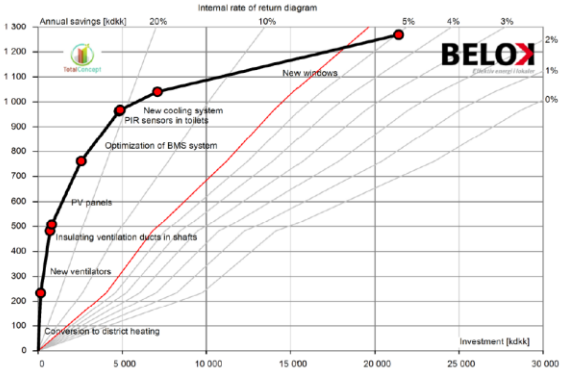

Figure 3 Action package created for Lyngby Port

Table 2 Identified energy saving measures for the pilot building 1 (Lyngby Port).

Identified measure
Measure 1 - Conversion from gas heating to district heating
Measure 2 - Replacing fans in existing air handling units
Measure 3 - Insulation ventilation ducts in shafts
Measure 4 - PV panels on the roof
Measure 5 - Retrofiting of BMS system for heating and ventilation
Measure 6 - PIR sensors in toilets and technical rooms

Measure 7 - Replacing cooling system
Measure 8 – Replacing of windows

In Step 1 of a Total Concept method, an action package of energy saving measures was identified which would create the biggest energy savings within the profitability range stipulated by the client. Replacing windows is a measure which does not fulfill the requirements about the internal rate.

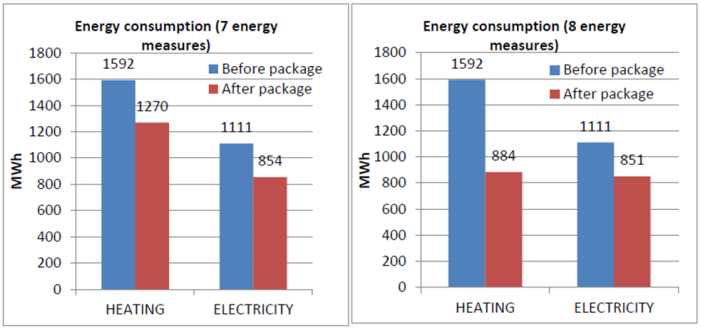

Figure 4 Energy use before and after carrying out the measures in the action package, kWh/m^2

The energy saving for the package that fulfills the owner internal rate of return is 20% for heating and 23% for electricity. The reduction for the building's electricity (excluding tenants' electricity use to lighting and equipment power) is around 50%. The electricity for tenant's energy consumption is a fixed value. For the package with 8 measures the saving is respectively 44 and 23%.

For forming the action package both the single cost-efficient measures and more costly measures were considered. The most economically profitable measures were conversion from gas heating to district heating and replacing fans in existing air handling units. The least profitable measures were PIR sensors in toilets and technical rooms and replacing cooling system. In this case the most economically profitable measures assisted the less profitable measures while the complete action package fulfilled the profitability frames set by the building owner.

3.3 Pilot building 2 – Ballerup Town Hall

The building Ballerup Town Hall owned by Ballerup Kommune is located in Ballerup, Denmark. The building is divided into 6 sections on 2 floors. The layout of ground and 1st floor consists of a mixture of mainly offices and meeting rooms. Basement is heated, and consists mostly of archives and depots. In the center of the building there is an atrium. The building was built in 1975 and it was partly renovated in 2009-2010. Figure 5 illustrates Ballerup Town Hall as a 3D model (red part of the complex is not a part of the project).

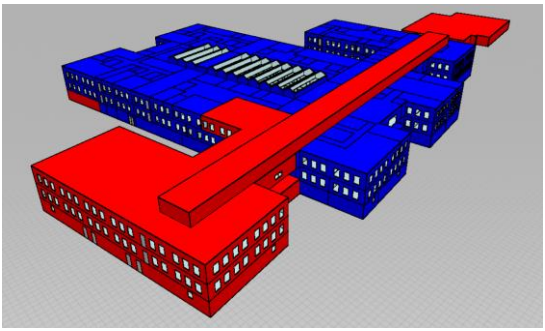

Figure 5 Ballerup Town Hall as a 3D model (red part of the complex is not a part of the project)

Based on the energy audit an overall picture of the building was created:

Table 3 Summary of energy audit for Ballerup Town Hall

Element	Description
Façade	Flat roof with 400 mm mineral wool on the renovated areas, and 200 mm on the smaller, non-renovated areas. Element walls are 250mm with 50mm insulation. Basement outer wall above and below ground with 300-350mm concrete without insulation. Basement floor is non-isolated concrete.
Fenestration	Windows/glass doors are 2-layer thermo windows with estimated U=2,9W/m^2K. Outside roller blinds with solar factor 0.4 are manually controlled and probably activated too late. Atrium skylights are with 2-layer energy glass.
Infiltration	Infiltration is not known. Based on the buildings age and façade, infiltration is set to 0.85l/(s·m² facade)
Ventilation	The building is fully mechanically ventilated. In 2009-2011 the ventilation units and ducts were replaced. 12 VAV-units with an average heat recovery of 81% and SEL 1.97 kJ/m³ are pressure controlled, with central cooling cooling coils.
Heating	Heating delivered by district heating. The main heating system consists of radiators with local manual thermostats. Pumps are of newer type. There are installed three hot water tanks, all insulated
Cooling	Comfort cooling delivered by chilled beams, which are connected to 9 units. The average COP (EER) value is 3.44 and the total cooling effect is approximately 700 kW.
Lighting	Lighting in offices, meetings, atrium and glazed corridors are with 28 W T5 tubes. Daylight control sensors are installed in Offices, Meeting Rooms, Corridors, Atrium, and renovated part of basement.

The model was created with a use of IES VE 2014 and the energy use was calibrated with measurements.

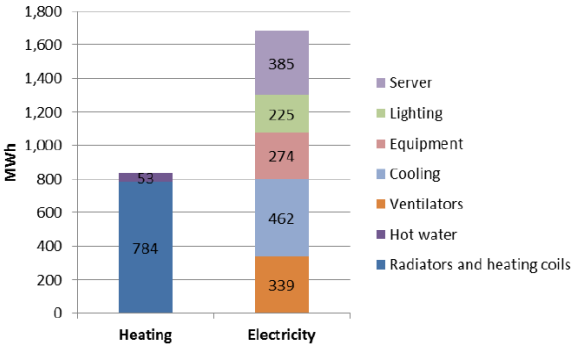

Figure 6 Simulated energy demand of Ballerup Town Hall

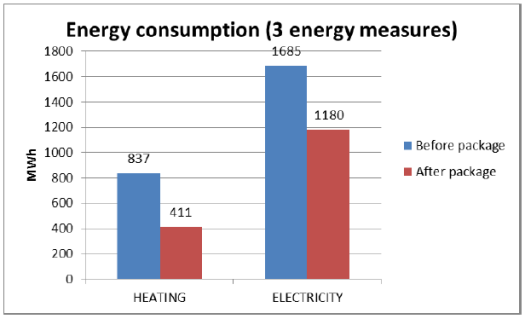

Figure 7 Energy use before and after carrying out the measures in the action package, kWh/m^2

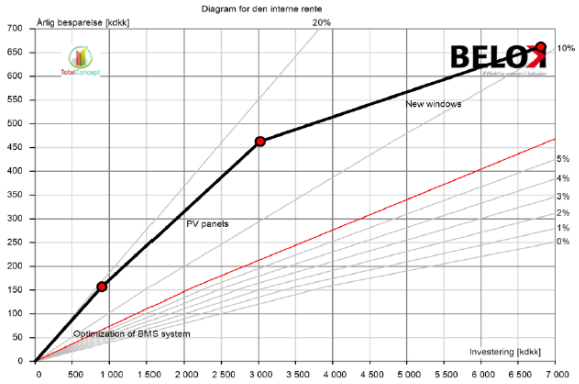

Figure 8 Action package created for Lyngby Port

Table 4 Identified energy saving measures for the pilot building 2 (Ballerup Town Hall).

Identified measure
Measure 1 - Optimizing of BMS system for heating and ventilation
Measure 2 - PV panels on the roof
Measure 3 - Replacing of windows

In Step 1 of a Total Concept method, an action package of energy saving measures was identified which would create the biggest energy savings within the profitability range stipulated by the client.

The calculations show that 3 energy measures are profitable and have a total internal rate of return of around 10%.

The upgrading of BMS system has a big impact on the future energy consumption. It is though crucial to design control strategy in the most optimal way so that simultaneous heating and cooling never occur. The control strategy should also include better use of cooling system – for instance supplying colder air instead of higher air volumes during warm periods. The third measure – replacing windows can be problematic because of employees' relocation during construction work. It would though result in a massive heating energy reduction, decreasing CO2 impact and improving indoor climate in the building.

The energy saving for the package that fulfills the owner internal rate of return is 50% for heating and 30% for electricity. Because of the very high cost of the package it is unclear now if the package will be carried out in its entirety.

The most economically profitable measure was upgrading BMS system and the least profitable measure was windows' replacement. In this case the most economically profitable measures assisted the less profitable measures while the complete action package fulfilled the profitability frames set by the building owner.

4. Conclusions

The purpose of the demonstration and evaluation projects was to form a package of measured for energy performance improvement in the respective buildings, based on the Total Concept method.

An energy audit was carried out for respective building in order to provide a comprehensive analysis of the studied installations.

Different energy saving measures were identified for both pilot buildings and the energy balance of the buildings was simulated. The energy calculation show that the heating (radiators and heating coils) takes majority of the total energy use for both building 1 (52%) and building 2 (31%). The difference in heating demand in analyzed building comes from different occupancy rate (much higher occupancy intensity for Ballerup Town Hall) and ventilation principle (CAV system in Ballerup Town Hall with much lower air intensity).

The calculation show that the biggest energy saving potential is in converting to district heating and replacing inefficient ventilators for building 1 and upgrading BMS for building 2. Because of low price for heating in Denmark (approx. 30% of electricity price), energy measures that reduce heating consumption are normally not profitable. The reason for high profitability of converting to district heating in Lyngby Port is a preferential price of connecting to district heating network and lower price of district heating comparing to natural gas.

According to the estimation done based on available information the identified measures in total lead to at least 22% and 37% energy saving, respectively for the building 1 and building 2.

The results from the demonstration buildings in Denmark show that with the Total Concept method, it may be possible to obtain a significant profitable energy reduction. The Total Concept method provides therefore an opportunity to access an essential part of the great energy savings potential in existing buildings by carrying out energy saving measures in a commercially profitable way - as one package of measures that fulfills the profitability requirement of the investor.

Step 1 of the method is an important part of the whole process and a precise calibration of the model, correct assumptions about the technical systems as well as proper assessments of proposed measures and their costs have direct influence on the future energy use of the building.

The main purpose of analyzed pilot project is to ascertain quality assurance the working method that supports property owners in minimising the energy use in their building stock in a profitable way.After implementation of the action package there will be a follow- up of the energy use and check of the profitability of the action package. There is always an uncertainty in both savings and investment costs assessments for different measures.

Acknowledgment

This work is a part of the project "Total Concept method for major reduction of energy use in nonresidential buildings" (EU- project IEE/13/613/S12.675832), funded by EU.

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