Ballerup Town Hall

Energy efficiency improvements according to Total Concept method

Ordered by:	Ballerup Kommune, Dan Kjærulf
Project carried out by:	Ramboll Denmark A/S
Date:	28.09.2015

This report template has been developed as part of the project "The Total Concept method for major reduction of energy use in non-residential buildings", supported by Intelligent Energy Europe Programme. Contract number: IEE/13/613/SI2.675832
Project webpage: www.totalconcept.info

Version 1.1- October 2014

Co-funded by the Intelligent Energy Europe
Programme of the European Union

Disclaimer

The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EACI nor the European Commission are responsible for any use that may be made of the information contained therein.

Table of content

1 Background

As part of a renovation project it is attractive to look at potential energy saving measures and thereby obtaining a better energy-attractiveness of the building.

The main objective of the renovation work for the property owner is to investigate the building, and the potential of changing the windows in façade and investigating the new technical systems.

2 Project scope and methodology

The aim of this project has been to carry out Step 1 of the Total Concept method[1] and form a package of measures for energy efficiency improvements in the Ballerup Town Hall building. The work is based on the following key activities included to the Step 1 of the Total Concept method:

- Gathering of basic information about the building and compiling technical data.
- Energy audit and identification of energy saving measures.
- Investment cost estimations.
- Energy calculations.
- Profitability calculations and the creation of an action package.

Following background information received from Ballerup Kommune: Dan Kjærulff and OBH Ingeniørservice A/S: Jes Bøgelund from the auditing on site has been used in this project:

- Building drawings (architectural drawings, structural drawings, HVAC drawings)
- Building permit documents
- Operating and maintenance instructions
- Access to the BMS system to get the operating parameters of the HVAC systems

[1] Details of the Total Concept method can be found from: ”The Total Concept method. Guidebook for implementation and quality assurance”. 2014, www.totalconcept.info

- Annual energy statistics for district heating for the period of 2012, -13 and -14 (e.g. measured values and/or values corrected to normal year)
- Annual energy statistics for electricity for building operation for the period of 2012, -13 and -14.
- Annual energy statistics for electricity for the different tenants for the period of 2012, -13 and -14.
- Annual statistics for water use for the period of 2012, -13 and -14
- Report from building energy certification
- Interviews with the tenants, buildings´ technical manager and property manager

An in-depth energy audit has been carried out on site by Niels Radisch in the period of end 2014 and January 2015 and further work based on direct contact with Ballerup Kommune: Jan Kjærulff.

An energy balance of the building has been simulated with the help of a simulation tool Integrated Environmental Solutions (IES). The investment cost calculations are based on Total tool.

The report is divided into the following sections:

- Current situation of the building and its technical systems
- Energy and resource use
- Identified energy saving measures
- Action package based on Total Concept method
- Conclusions

3 Current situation with the building and its technical systems

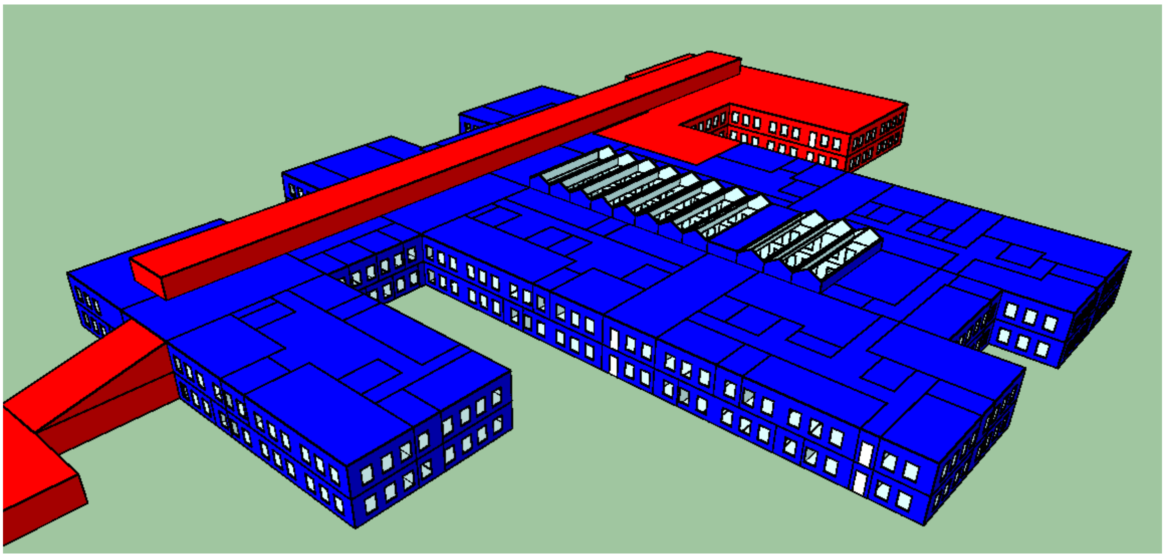
3.1 Building and its layout

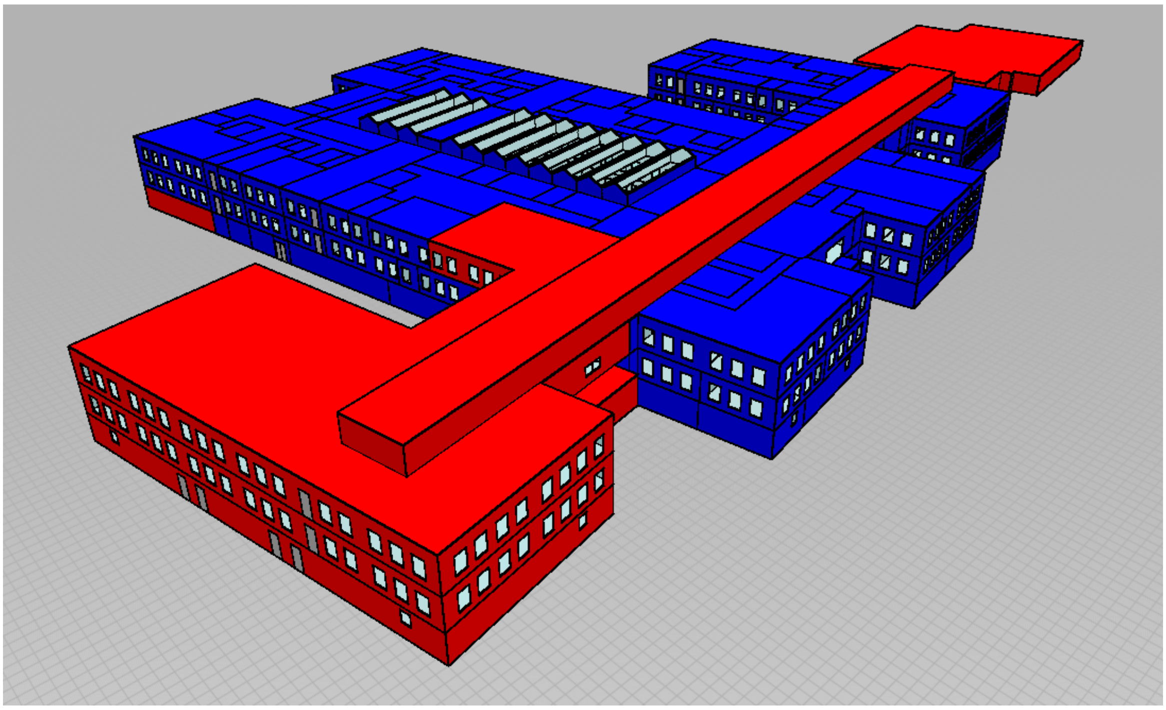
The building Ballerup Town Hall owned by Ballerup Kommune is located at Hold-an vej 7, 2750 Ballerup, Denmark. BBR area is 16,321 m². Simulated heated area is 16,414 (1% deviation)

The building is divided into 6 sections F1, F2, F3, M1, M2 and M3 on the ground floor. (only a small part of M3 is included in the simulation). 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 centre of the building there is an atrium.

The building was built in 1975, and was renovated in 2009 – 2010, where the inner courtyard was converted into a heated atrium.

Heating system is with radiators. Ventilation is with VAV with chilled inlet air. Additionally chilled beams are installed.





3.2 The use of the building

The building is used as a common office building consisting mainly of offices and meeting rooms. For the diverse room types the following internal loads is used for simulating:

Table 1: Internal loads

Room Category	Room type	Area (m^2)	Max no. of persons	People (m^2/pers)	Equipment (W/pers)	Equipment (W/m^2)	Lighting (W/m^2)
Office/ Meeting	Office	1200	150	8	100	12,5	2,1
	Large office	2986	430	7	100	14,0	2,1
	Meeting	1769	600	3	40	13,3	4,4
	Mayor meeting hall	143	50	3	40	13,3	5,2
Secondary functions	Atrium	625	-	-	-	-	1,8
	Basement archive+depot	3341	-	-	-	-	2,1
	Corridor	4884	-	-	-	-	2,1
	Gym	171	-	-	-	-	4,5
	IT	425	-	-	-	-	4,5
	Kitchen	48	-	-	-	-	3,46
	Sauna	21	-	-	-	-	4,5
	Secondary Rooms	681	-	-	-	-	2,1
	Shaft	167	-	-	-	-	0
	Stairs	299	-	-	-	-	2,1
	Tech.	59	-	-	-	-	4
	WC	273	-	-	-	-	2,6
Total		**17.092**					

Specific daily and weekly load profiles are given in the following table:

3.3 Indoor climate

According to NHR-report (Appendix 1.06) the following was observed on indoor climate:

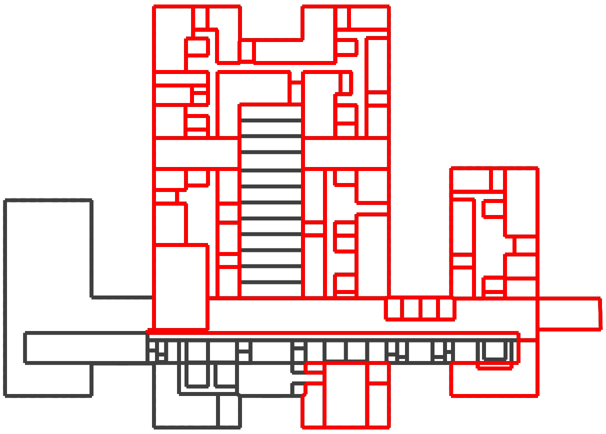
- The building seems to be have a rather high air- leakage. The cause may be from connections and joints in the modular facades. During winter there has been reported draft through the façades. The west-façade has draft issues from doors.
- There is to some extent reported discomfort due to the chilled beams.
- It was reported that during summer (2013) the rooms in general were too hot.

3.5 Building envelope

Picture taken from Google Maps on the 28th of April 2015.

Flat roof renovated has 400mm insulation while non-renovated flat roof has 200mm insulation. Renovated and non-renovated roof is estimated from pictures taken before and after renovation:


Picture to the right taken from KRAK.dk (date unknown) and picture to the left taken from Google Maps on the 28th of April 2015.



The red area is renovated roof, while the black area is non-renovated.

Element walls are around 250mm thick with 50mm insulation. Light outer wall for roof house is with 100mm insulation and steel walls. Element walls between heated room and outside is 250mm elements with 50mm insulation.
The simulations are done with an assessment of the structure. The wall is simulated with 50-50 of steel wall and sandwich element wall. This results in an average U-value of 0.35 W/m2K.
Light wall in canteen is constructed with 100mm insulation.

Windows/glass doors are 2-layer thermo windows. Non-glass doors are isolated.

Ground slab is constructed as concrete without any insulation.

Basement outer wall above and below ground is constructed with 300-350mm concrete without insulation.
Basement floor is non-isolated concrete slab.

In the simulation the following parameters are therefore used:

Facade, roof and floors:

- Façade, steel wall/sandwich element: U = 0.35 W/m2K
- External Basement wall: U = 0.66 W/m2K
- Basement floor: U = 0.16 W/m2K
- Floor slab: U = 0.27 W/m2K
- Flat Roof - renovated: U = 0.07 W/m2K
- Flat Roof – not renovated: U = 0.14 W/m2K

Windows and doors:

The thermo window is expected to have lost any kind of gass in the cavity (like argon). It is therefore estimated to have air in the cavity of 16mm.

Windows:

Uw = 2.93 W/m2K
gg = 0.71
LT= 0.83

Skylights:

Uw = 1,87 W/m2K
gg = 0.63
LT = 0.59

Doors:

- Glass doors: U = 2.93 W/m2K
- Isolated doors: U = 0.14 W/m2K

Solar shading:
Manually controlled outside roller blinds. Solar factor 0.4. According to NHR-report they are probably activated too late.

Infiltration
Infiltration is not known. Based on the buildings age and façade, infiltration is set to 0.85 l/(s·m² facade) or 0,29h^{-1} as average for whole building façade.

3.4 Technical systems

Technical systems are given in the table below.

Table 2: Ventilation, cooling and heating

Room Category	Room type	Ventilation/Cooling	Heating
Office/ Meeting	Office	VAV + chilled beams	Radiator
	Large office	VAV + chilled beams	Radiator
	Meeting	VAV	Radiator
	Mayor meeting hall	VAV	Radiator
Secondary functions	Atrium	Air supply	Heated Floor
	Basement archive+depot		Radiator
	Corridor	VAV + chilled beams	Radiator
	Gym	VAV	Radiator
	IT	VAV + chilled beams	Radiator
	Kitchen		Radiator
	Sauna		
	Secondary Rooms	VAV	None
	Shaft	None	None
	Stairs		Radiator
	Tech.		None
	WC	Exhaust	Radiator

For the sake of simulations, a simplification of the systems has been made:

System	Rooms
System 1 – VAV, Cooling and Heating	Large Offices Offices Corridors IT
System 2 – VAV and Heating	Meeting Room Mayor Meeting Hall Secondary Room Gym
	WC
System 3 – Heating	Atrium Basement Archive

	Basement Depot Kitchen Sauna Stairs Technical

3.4.1 Ventilation

The building is fully mechanically ventilated. In 2009-2011 the ventilation units and ducts were exchanged. The system is pressure controlled, with central cooling cooling coils. The units are BMS controlled and with heat recovery.
The building ventilation system consists of 12 Fläckt IV Flexomix VAV-systems with an average heat recovery of 80.8% and SEL 1.97 kJ/m³. See table below. Toilets are with separate exhaust ventilation.
The atrium is naturally ventilated with solar shading.
Part of the basement is naturally ventilated through leakages.

Nr	Betjener			Placering	Luftmængde	Fabrikant	Type	SEL (kJ/m3)	Temp. virk. (%)	Power (kW)		Luft mængde (l/s)	Bestykning	Årstal	Styring
										Heating	Cooling	IV produkt			
VE01	K+M	F1+M1	Stue+1.sal	Taghus	VAV	Fläckt	IV Flexomix	2,02	79,5	29	86,3	3639	VFL+KFL, VGV	2010	CTS
VE02	K+M	F2+M2	Stue+1.sal (midt)	Taghus	VAV	Fläckt	IV Flexomix	1,75	81,2	22	72,4	306	VFL+KFL, VGV	2010	CTS
VE03	K+M	F3+M3+M2(dele)	Stue+1.sal (midt)	Taghus	VAV	Fläckt	IV Flexomix	2,01	79,6	26,2	90,3	3611	VFL+KFL, VGV	2009	CTS
VE04	Møde	F2+M1	Stue (vest)	Taghus	VAV	Fläckt	IV Flexomix	1,85	80,3	18,1	55,5	2389	VFL+KFL, VGV	2010	CTS
VE05	Møde	F3	Stue+1.sal (vest)	Taghus	VAV	Fläckt	IV Flexomix	1,97	80,5	15,5	55,2	2139	VFL+KFL, VGV	2010	CTS
~~VE07~~	~~Helsehus~~		~~Stue+1.sal~~	~~Taghus~~	~~VAV~~	~~Fläckt~~	~~IV Flexomix~~					0	~~VFL+KFL, VGV~~	~~2010~~	~~CTS~~
VE10	Velfærd	F1	Kælder	Taghus	VAV	Fläckt	IV Flexomix	2,03	89,9	17,5	55,3	2250	VFL+KFL, VGV	2010	CTS
VE11	IT+Trykkeri	F2	Kælder	Taghus	CAV	Fläckt	IV Flexomix	1,82	81,6	5,9	19,8	833	VFL+KFL, VGV	2010	CTS
VE12	Gang mv	-	Kælder	Taghus	VAV	Fläckt	IV Flexomix	2,26	77,9	10,4	28,4	1194	VFL, VGV	2010	CTS
VE13	Byrådssal, køk mv	F2	1.sal (vest)	Taghus	VAV	Fläckt	IV Flexomix	1,96	80,5	16,1	52,2	1806	VFL+KFL, VGV	2010	CTS
VE25	K+M	T1 (F2+(M2 k) - Øst)	K+Stue+1.sal	Kælder	VAV	Fläckt	IV Flexomix	1,91	79,8	19,9	59	2528	VFL+KFL, VGV	2010	CTS
VE26	K+M	F3+(M2 st+1)-Øst	K+Stue+1.sal	Kælder	VAV	Fläckt	IV Flexomix	2,12	78,2	24,9	69,8	2917	VFL+KFL, VGV	2010	CTS
Avg. or SUM								**1,97**	**80,82**	**205,50**	**644,20**	**23611**			
VE_Atr: VE27 (AHU27)	Atrium	Atrium	Stue	Kælder	VAV	Fläckt	IV Flexomix	0.75 (0.86)	-	86.1 (86.1)	-	2222	VFL, kun indbl.	2011	CTS
VE_Køk	Køkken	F2 vest	1. sal	Teknikhus syd	VAV	Exhausto	VEX170 HRFC1W						VFL, VGV	2011	CTS
	Kælder	Øvrige rum naturligt ventilerede gennem utætheder (dvs. ingen ventilation)													

3.4.2 Heating

Utility is district heating. The main heating system consists of radiators with local manual thermostats. Pumps are of newer type Magna or UPE. In in the atrium a heated floor is installed. It is installed with a 2-string system for distribution. Supply temperature is controlled by outside temperature and wind.

For the simulation heating in the different rooms is estimated upon an effect pr. m² in one of the more critical rooms on each floor. The effect needed for heating is found by a heat loss calculation and it is assumed that the summation of the heat loss and heat gain from heating needs to be zero. Heat loss calculations, and thereby heating power for the floor, is done with the following rooms:

- Basement F2.00.10_B.Dep: 59 W/m²
- Ground Floor F3.01.58_L.Off: 10 W/m²
- 1st Floor F3.02.58_L.Off 40 W/m²

3.4.3 Cooling

The comfort cooling is done with chilled beams, type Lindab, controlled by BMS. Distribution of cold water is done with a 2-string system and 5 cooling mixing loops.

The cooling effect is contributed from 9 systems, placed on the roof. The average COP (EER) value is 3.44 and the total cooling effect is approximately 700 kW. The 9 systems are all from Uniflair. Four LRAC 180A, three ERAC 1222A and two ERAC 0721.

The two ERAC 0721 are placed in the basement for 40 kW cooling of server room.

3.4.4 Lighting

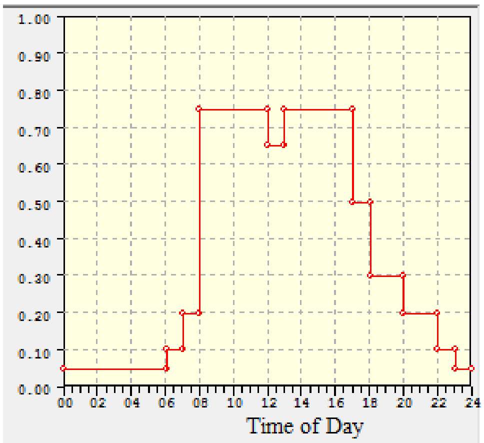
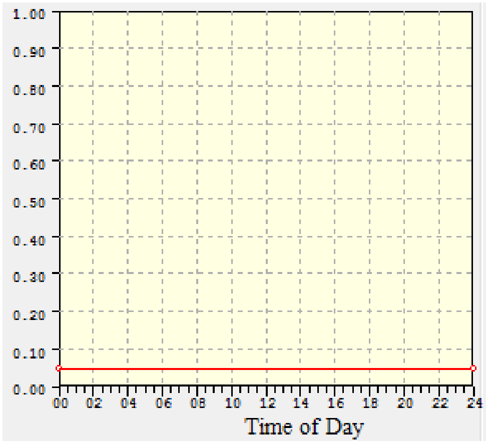
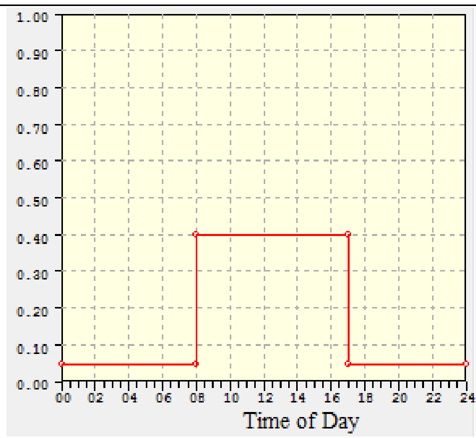
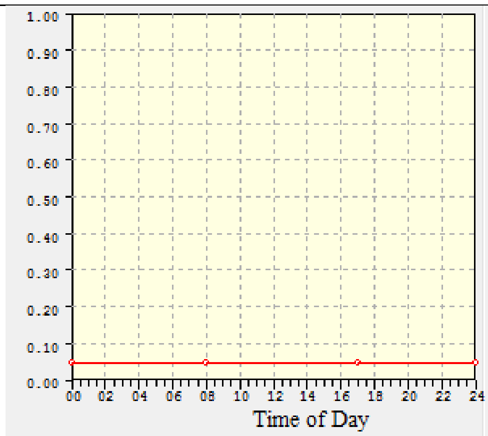
See Table 1 for lighting effect.

Lighting in offices, atrium and glazed corridors are with 28 W T5 tubes. In meeting rooms downlights integrated in ceiling with 28 W low energy bulbs.

Daylight control sensors are installed in Offices, Meeting Rooms, Corridors, Atrium, and renovated Basement. Mayor Meeting Hall and Basement is manually controlled, while lighting in WC's are installed with movement sensors.

3.4.5 Machines

Office equipment like computer, screen, extra lighting etc. is estimated to 100W/pers.

Rum	Weekdays (Monday – Friday)	Weekend
Offices		
Meeting		

3.4.6 Water supply and domestic hot water

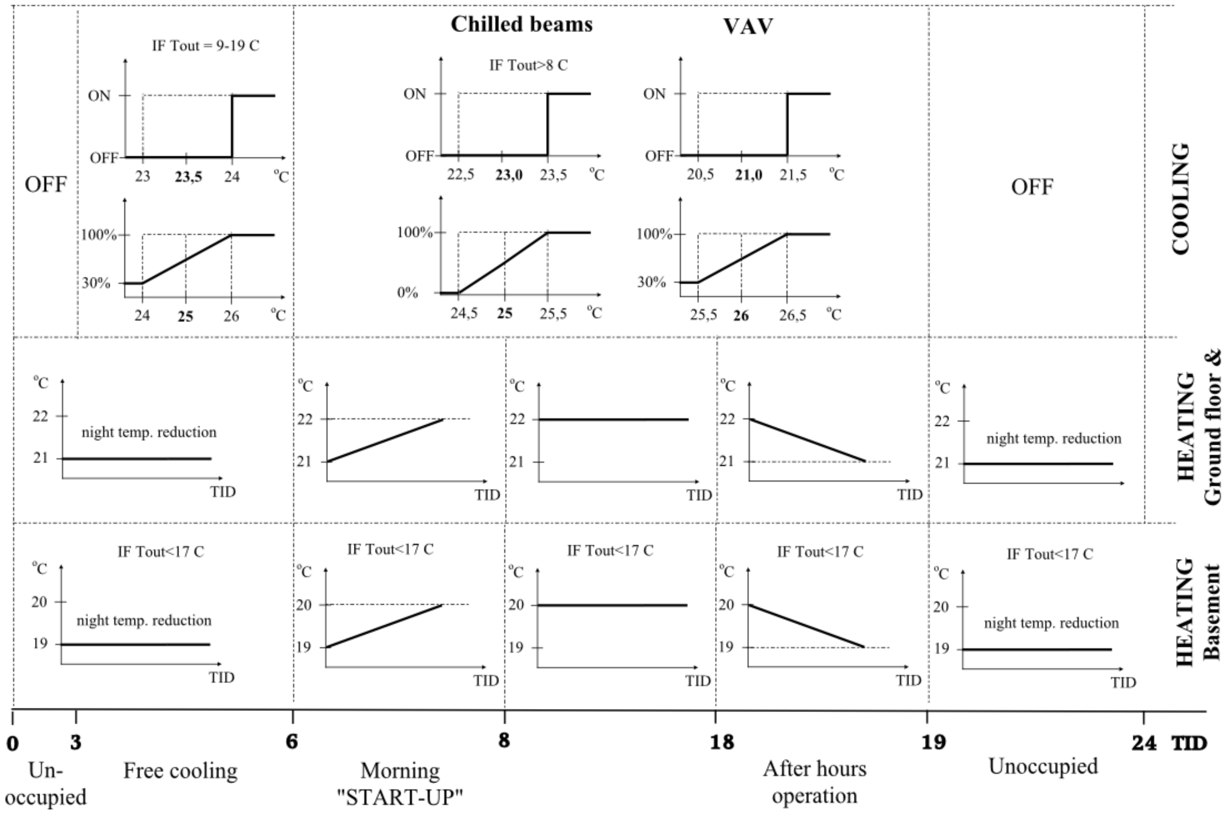
All piping for water supply and domestic hot water is done with 30mm insolation. There are installed three hot water tanks. One new preisolated hot water tank of 263 liter in tech. house South, One preisolated hot water tank of 208 liter from 200 in roof house and one new preisolated hot water tank of 1000 liter in basement.

3.4.7 Control and monitoring system(s) for technical installations

Control and monitoring systems are described in 3.4.1 – 3.4.4.

BMS is type Schneider. All radiator valves are with thermostatic valves. There is an overall system which controls ventilation and cooling. Heating is without BMS, but manually controlled according to season and weather.

On the basis of BMS pictures and dialogue with the owner the following set point strategy is used in the simulations:



Set points in the simulation model are represented by air temperature. The sensed (operative) temperature for Ballerup Rådhus is 0.5°C lower for winter and 0.5°C higher for summer.

Heating
The air temperature set point for radiators is 22°C (sensed temperature 21,5°C) during working hours and is gradually reduced during nighttime. The temperature of supply water is controlled by a thermometer placed outside the building. The heating system starts completely when outside temperature is over 17˚C.

Ventilation
The room temperature is controlled by chilled beams in offices and VAV in meeting rooms. The air flow has variable supply air temperature. Between 3 and 6am there is free

cooling activated if air temperature in the reference room (located at level 0) is over 24 ˚C and the outside temperature is in the interval of 9-19 ˚C.
There is no CO2 control in the room.

Supply air temperature varies with season and is set between 16 ˚C and 19 ˚C depending on outside temperature. For outside temperature below 5°C the inlet temperature is 19 ˚C and for outside temperatures over 21°C the temperature is 16˚C.

Domestic hot water
There is a night setback for domestic hot water temperature – from 55°C to 50°C.

4 Energy and resource use

4.1 Energy and resource use statistics

Measured energy usage from 2012 – 2014 is given in the table below

Ballerup Town Hall, measured annual energy usage

	Heat	Electricity (incl. server)	Server rooms
Year	MWh	kWh	kWh
2012	828	1,498,500	-
2013	823	1,478,600	13,141
2014	863	1,622,600	385,677
	kWh/m²	kWh/m²	-
2012	51	92	-
2013	51	91	-
2014	53	99	-

Total BBR area 16,321 m²

4.2 Energy end-users and baseline for energy performance improvements

In the following the different energy end-users of the building are shown with their approximate contribution to the total energy use of the building.

The simulated energy end use is given in following figures (in MWh and in kWh/m2):

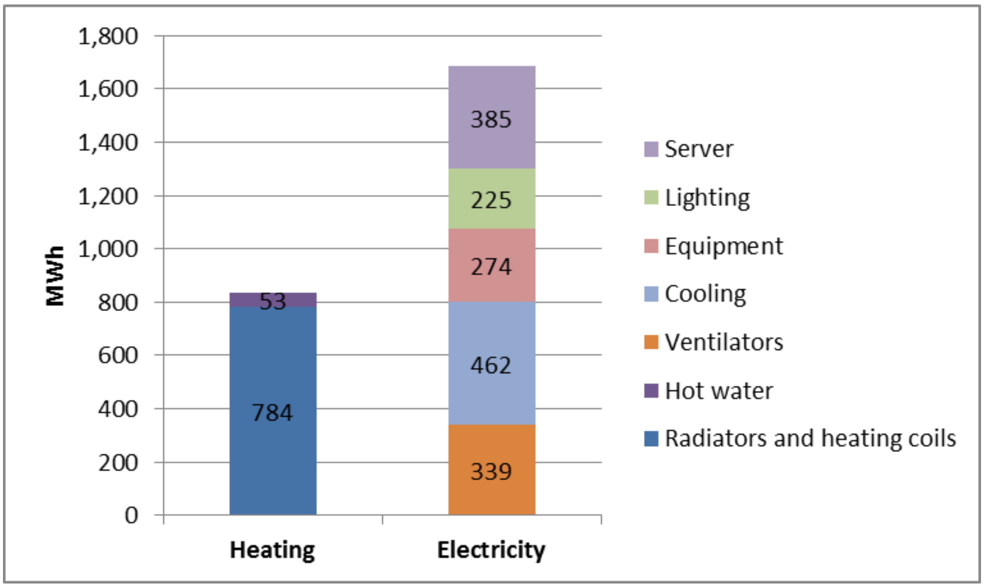


Figure 1. Energy end-use (MWh)

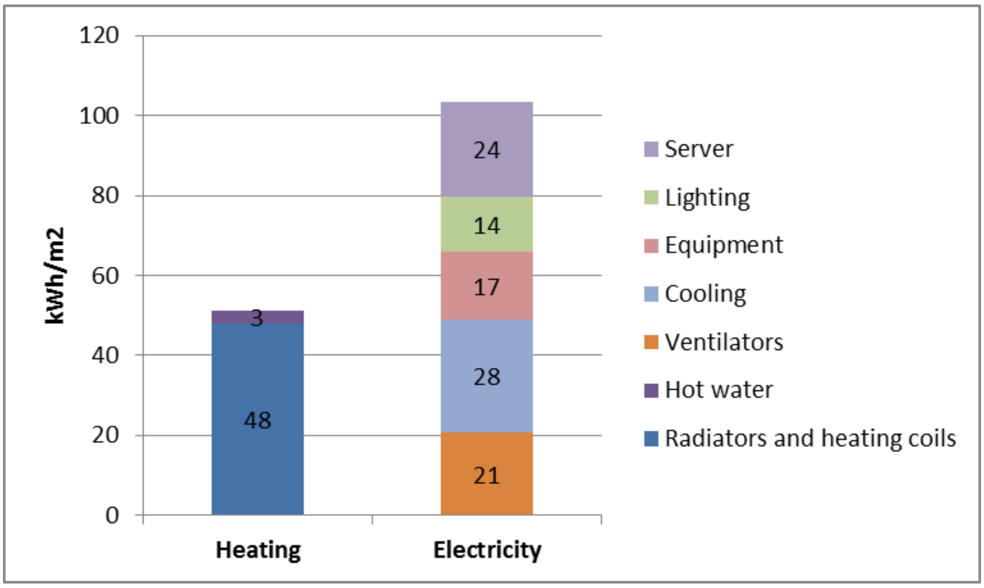


Figure 2 Energy end-use (kWh/m2)

Radiators and heating coils for ventilation make up the primary heating consumption.

The energy consumption for lighting, equipment and server room are **included** in the analysis and constitutes for the half of electricity consumption. Ventilation is approximately one fifth and cooling one third.

Based on information from energy account report there were following prices (exclusive of VAT) used:

- Heating: 0,55DKK/kWh (district heating)
- Electricity: 1,65DKK/kWh

As electricity is 2,5 times more expensive then heating, the correlation between energy consumption and energy cost is as following:

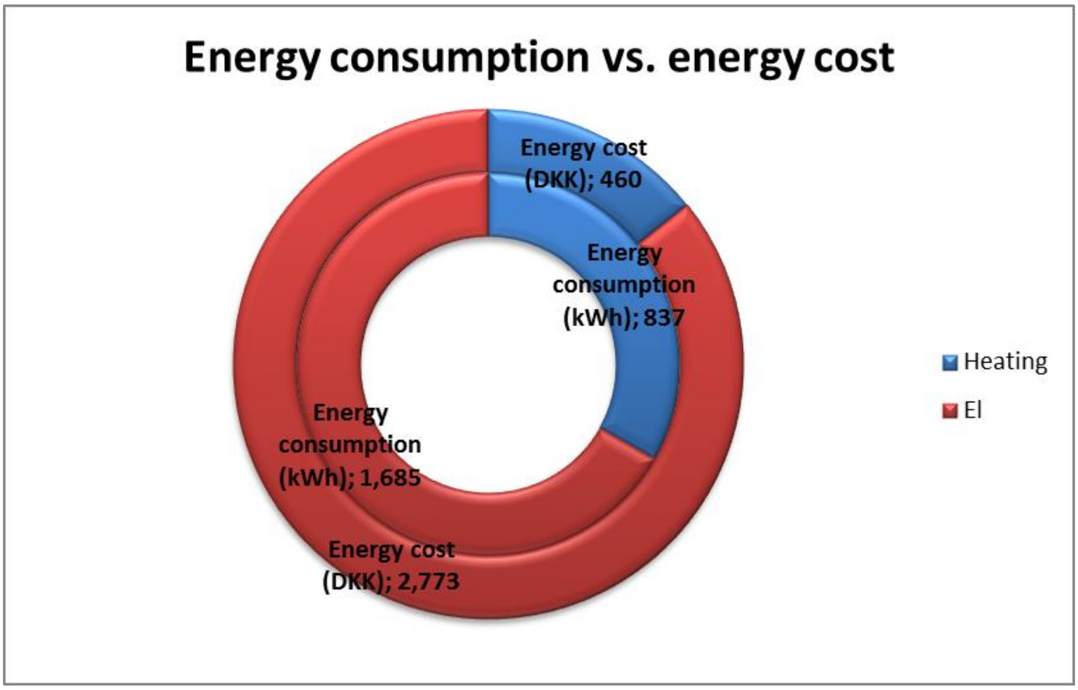


Figure 3 Comparison between energy consumption and energy cost (simulated scenario) – including tenants' energy consumption

Heating constitutes for 33% of energy consumption but only for 14% of energy cost. 67% of electricity consumption generates 86% of energy costs. Electricity consumption includes also tenancy energy consumption for lighting, equipment and server room.

Table 3 Energy consumption and cost – Case 0

	Energy consumption **MWh**	Cost **DKK**
Heating	837	460.000
Electricity	1685	2.773.000
Total	**2522**	**3.233.000**

5. Identified energy saving measures

The following measures were identified:

5.1 Exchanging windows
5.2 Optimization of BMS system, including heating, lighting, ventilation and solar shading
5.5 Photovoltaic

Following measures are not seen as potential energy saving measures

- Exchange of pumps – new pumps installed
- Ventilation units - new ventilation units installed
- Cooling system – chiller in a good condition and still with a satisfactory COP value
- Installed lighting effect is already rather low, and is not included as a potential energy saving measure.

5.1 Exchanging windows

Description of concept and technical assumptions

The concept assumes replacing all the windows. The existing external solar shading will not be replaced.

There is 810m2 of fenestration and 3200m2 of façade in the building.

The average U, LT and g-value for a new fenestration are as follows:

	Old windows	New windows
U-value (W/m2K)	2,93	0,87
g-value (-)	0,71	0,51
LT (light transmittance, %)	71	71
Solar shading factor	0,4	0,4

It is also assumed that the infiltration rate will drop from 0,85to 0,43 l/s per m2 of façade.

The cost estimation includes following elements:

Element	**Unit**	**Amount**	**Price per unit**	**Price**
Scaffolding	m2	3200	300	960.000
Removing the old windows, assembly of new windows and extra work (joint finish, lists, etc.)	pieces	380	2000	760.000
New windows	m2	810	1800	1.458.000
Sum				**3.178.000**
Building site	9%			285.000
Diverse	10%			320.000
Total				**3.783.000**

Results - energy

Result	**Value**	**Unit**	**Reduction**
Reduction, Electricity	-24.000	kWh/year	-1%
Reduction, Heating	356.000	kWh/year	42 %

Results - economy

Result	Value	Unit
Estimated implementation costs	3.783.000	DKK
Yearly expenditure cut	156.000	DKK/year

Additional comments

The value for electricity is negative because during some periods temperature increases above the room set point what activates ventilation and cooling more often.

Implementation issues:
This is a very costly investment. Moreover the concept needs to be prepared together with a plan for employees' relocation during construction work.

5.2 BMS optimization

Description of concept and technical assumptions

The existing BMS system is not optimized. The upgraded BMS system will provide the necessary and more accurate controls required for the refitted building.

The changes in BMS system implemented in simulations are as following:

- Supply temperature dependent not only on the outside temperature but also on solar radiation
- Efficient control of night cooling
- Optimized temperature control that responds to tenants' demand
- Avoiding heating and cooling at the same time (better strategy for set points)

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	120.900	kWh/year	7%
Reduction, Heating	67.000	kWh/year	8%

Results - economy

Result	Value	Unit
Estimated implementation costs	900.000	DKK
Yearly expenditure cut	236.000	DKK/year

Additional comments

The upgraded BMS system has to integrate heating and ventilation system (avoiding heating and cooling at the same time) .

Implementation issues:
Detailed description before implementation

5.3 Photovoltaic

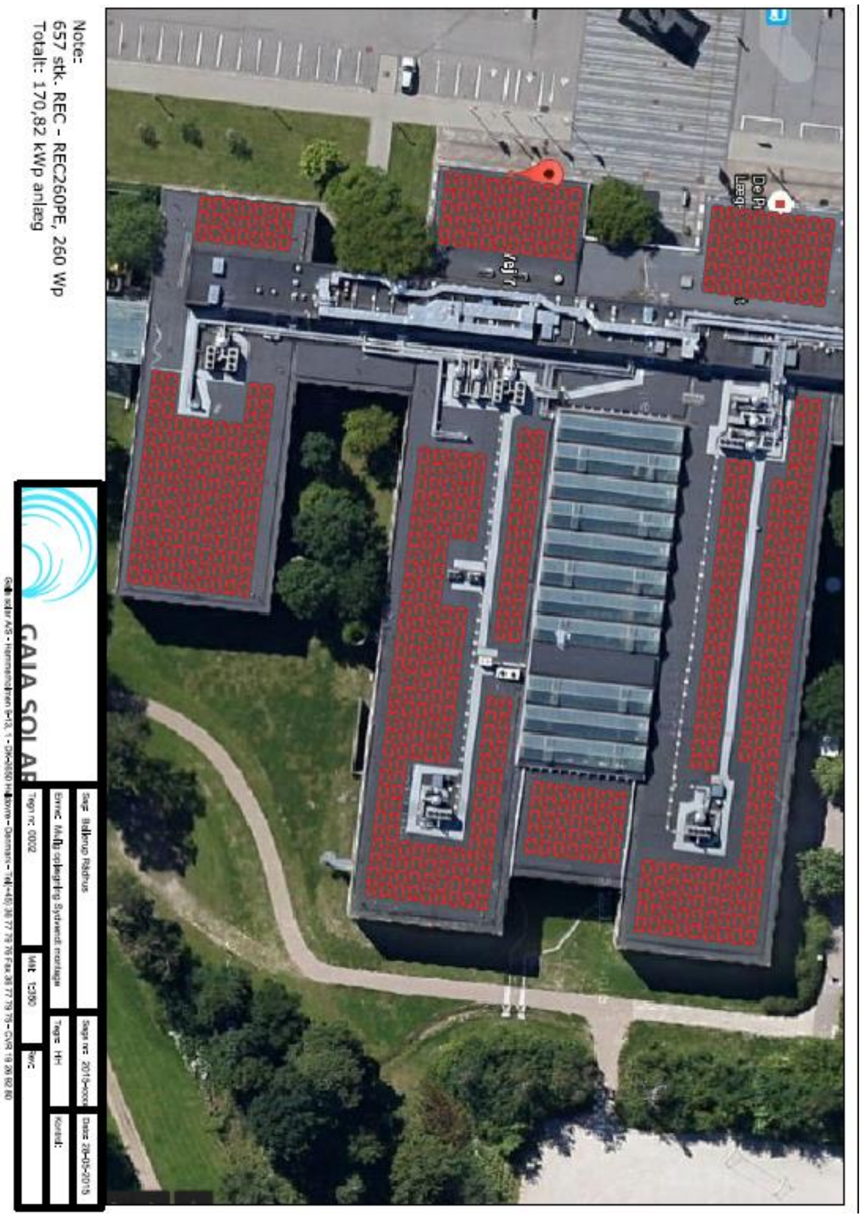
Description of concept and technical assumptions

Reducing the cost of electricity by producing part of the consumption with photovoltaics installed on the roof of the building.

Today there is no form of solar energy cells as part of the buildings system. For the sake of the concept, Gaia Solar has been introduced, and they have produced the following results, based on a rough estimate of the building (Figure 1), and by using data for their own systems for the simulations. The calculations have been done based on Gaia Solar's average data of 322 office/administrative buildings.

The roof as support for the photovoltaic system has not been studied to make sure that it will be able to take the deadload of the system.

Figure 1: Estimated roof area for photovoltaics



Technical assumptions and results

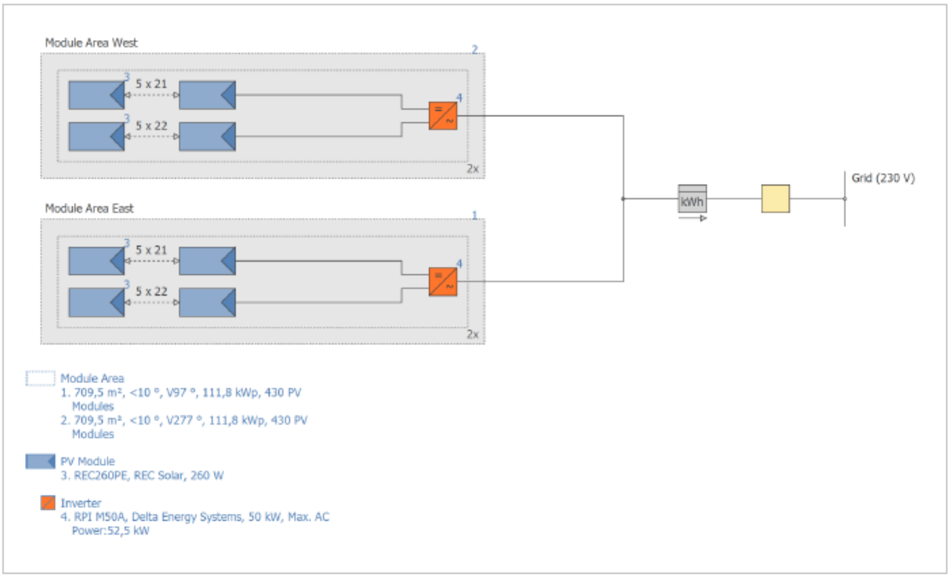


Figure 2: System specifics

Assumptions	Value	Unit
Generator surface	1,419	m²
Number of PV Modules	860	-
Number of Inverter	4	-
PV Generator Output	223.6	kWp
Performance Ratio (PR)	92.0	%

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	210.058	kWh/year	12 %
Reduction, Heating	0	kWh/year	0 %

Results - economy

Result	Value	Unit
Estimated implementation costs	2.124.000	DKK
Yearly expenditure cut	306.000	DKK/year (electricity)

Additional comments

The maintenance cost is assumed to be 40.000DKK/year and it is included in yearly expenditure cut.

Implementation issues:
Implementation depends on the roofs load bearing capacity. Review of tax regulations for photovoltaic.

6 Action package based on Total Concept method

There have been 3 energy measures analysed. The summary of the analysis can be found in the table below. It is important to underline that implementation of all energy measures will not give the saving that is a sum of all single energy savings. For example measures: replacing windows and upgrading BMS system influence each other and better strategies for BMS strategies will increase the saving from replacing the windows itself. That is why in the analysis we look at the measures as a package of solutions having impact on each other.

Case	Description	Reduction heating (kWh/year)	Reduction heating (DKK/year)	Reduction electricity (kWh/year)	Reduction electricity (DKK/year)	Implementation cost (DKK)
B1	Replacing windows	356000	195800	-24000	-39600	3783000
B2	Upgrading BMS system	67000	36850	120900	199485	900000
B3	PV panels			210058	306000	2124000
		423000	232650	306958	465885	8,122,900

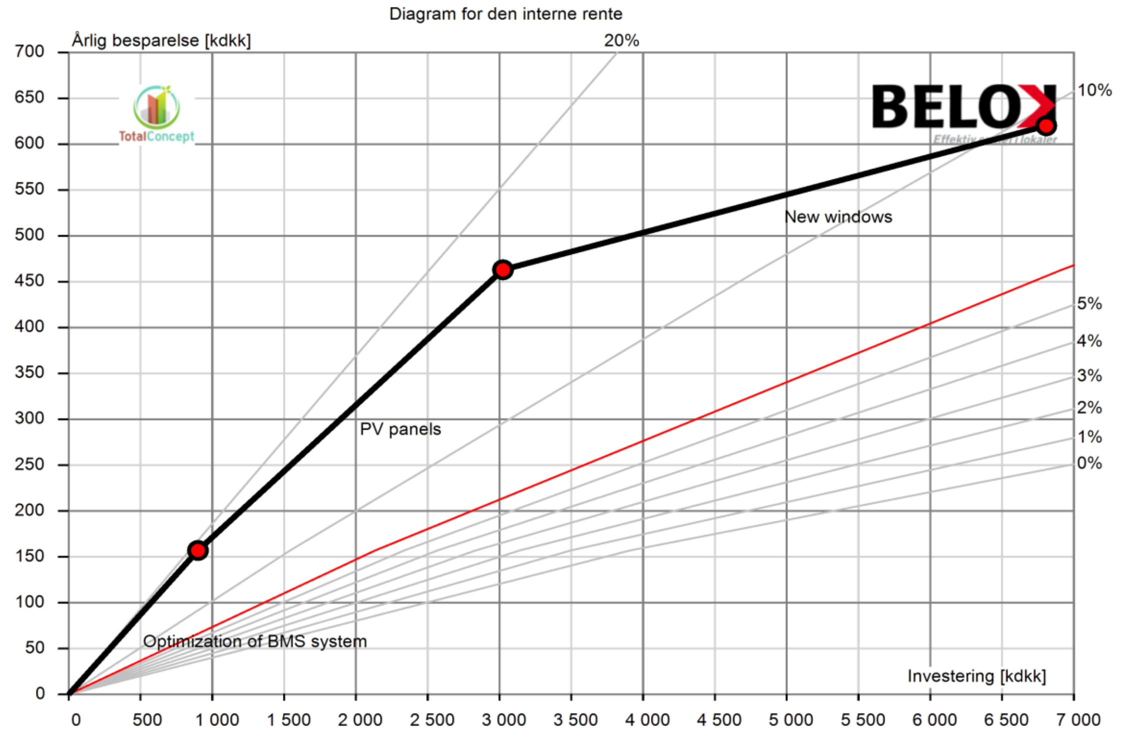
6.1 Input data for profitability calculations

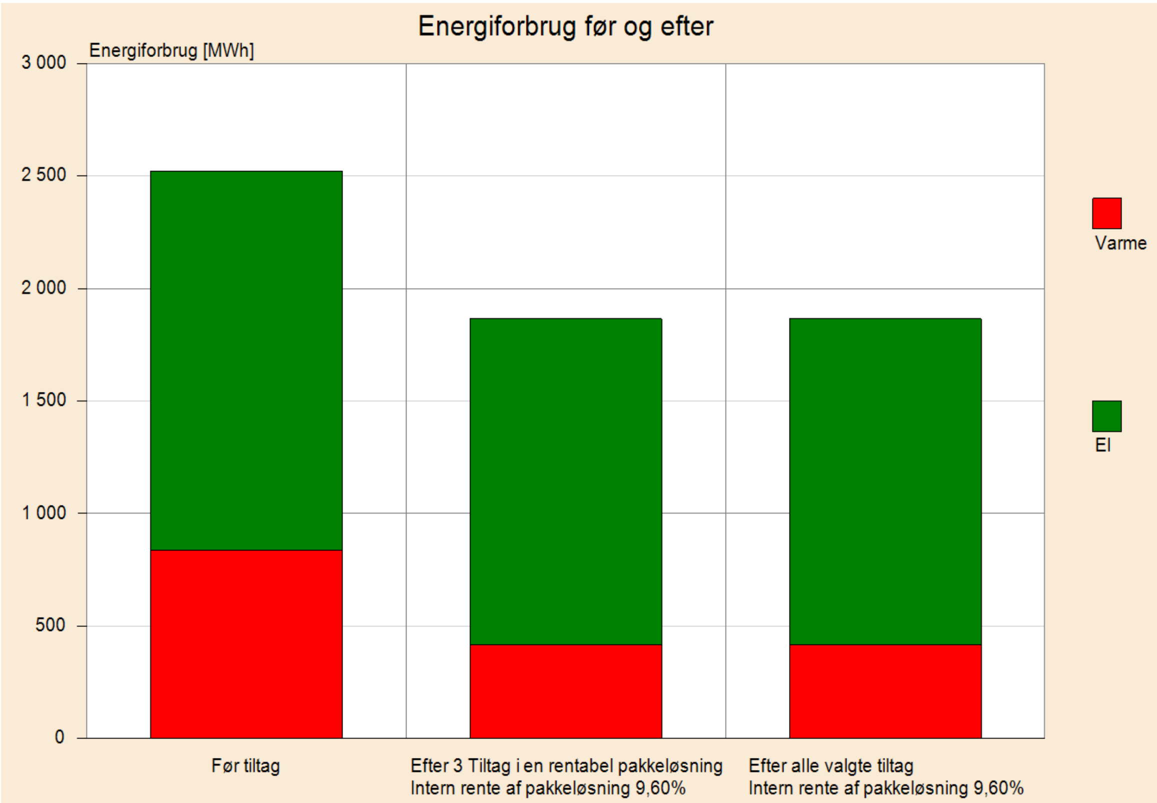
The following assumptions were used to perform profitability calculations:

- Prices: heat energy 0,55DKK/kWh; electricity 1,65DKK/kWh
- Calculation interest rate: 6%
- Relative energy price increase above inflation: 2%
- Lifetime of systems is specified in the table below

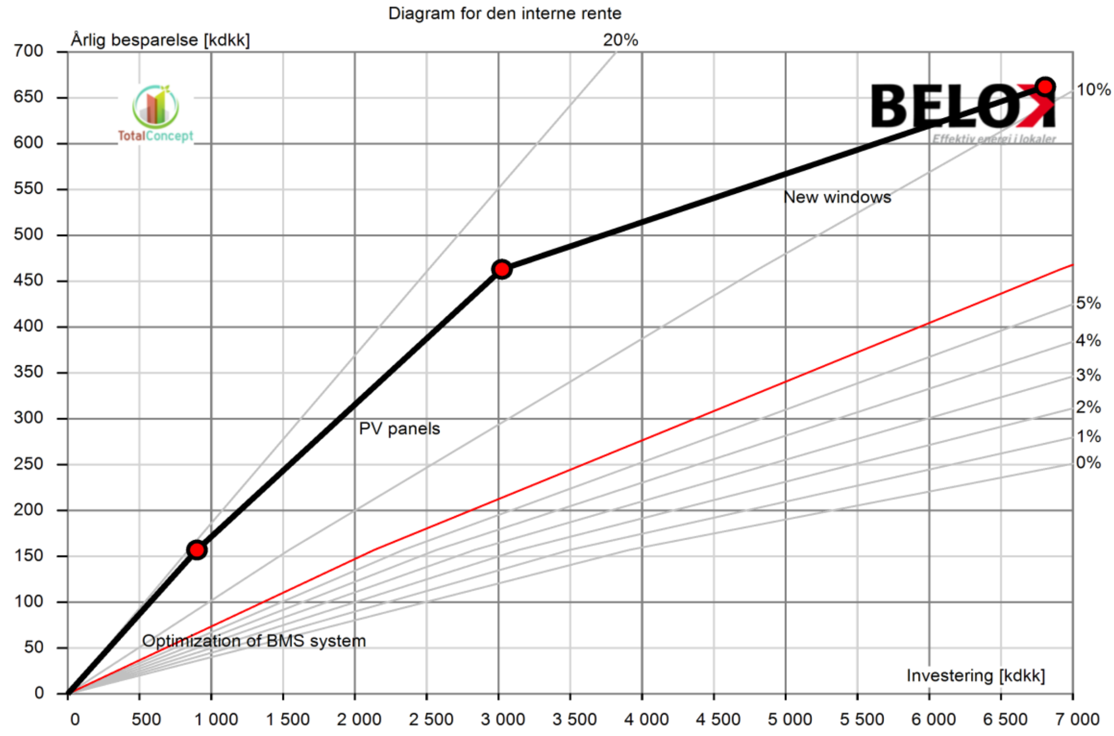
Case	Description	Lifetime
B1	Replacing windows	30
B2	Upgrading BMS system	20
B3	PV panels	25

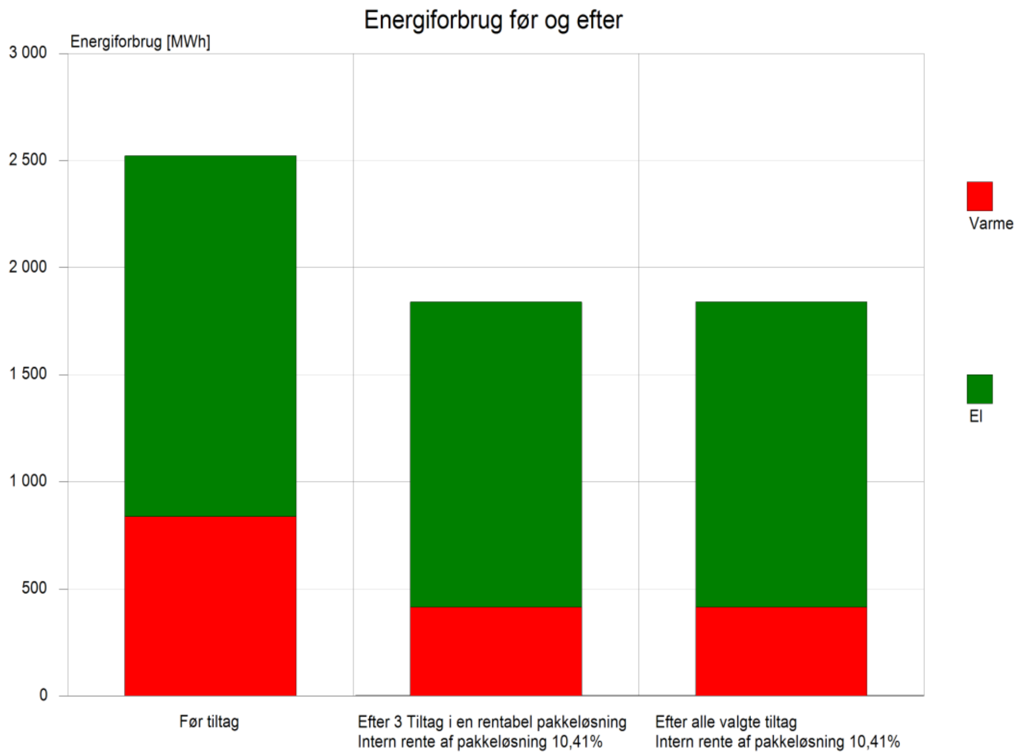
The primary action package summarizes all the single concepts and is as follows:

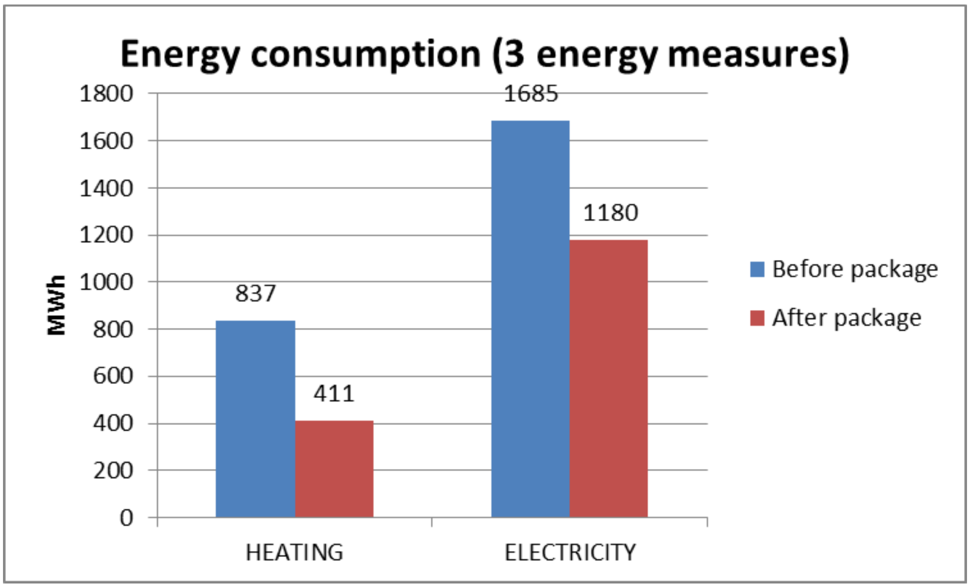




After forming a primary action package the simulations have to be iterated in order to take impact of energy measures on each other into account. Better set points strategy will avoid extra cooling in the building with new windows.
The impact of energy measures on each other is taken into account on the graph with final action package below:







The energy saving for the package that fulfills the owner internal rate of return is 50% for heating and 30% for electricity.

The annual cost saving is presented in the table below (The cost of electricity for tenants is also included in the table):

	Before package	After package	Saving (x1000DKK)
Heating (x1000DKK)	837	411	234
Electricity (x1000DKK)	1685	1180	833

7 Conclusions

The calculations show that all 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.

Appendix 1. Input data for energy simulations

Input data for energy simulations are the following:

App. 1.01 - Plan drawings
App. 1.02 - Ventilation systems
App. 1.03 – Ventilation rates and cooling
App. 1.04 – EMO report
App. 1.05 - BMS measurement data 2012-2014
App. 1.06 – NHR energy optimization report
App. 1.07 – U-values

Appendix 2. Input data for energy saving measures

Input data for energy simulations are the following:
App. 2.01 Photovoltaic