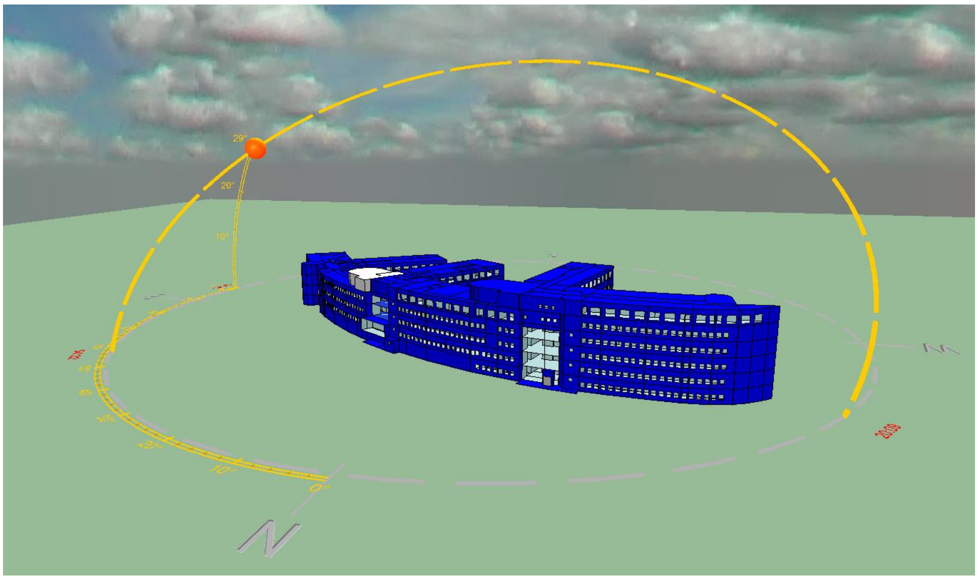
Lyngby Port

Energy efficiency improvements according to Total Concept method



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1 Background

The office building Lyngby Port, with several tenants, is being prepared for a new tenant in larger parts of the building. It is expected that there will be a general change from cell offices to more open office areas, supporting a higher number of employees.

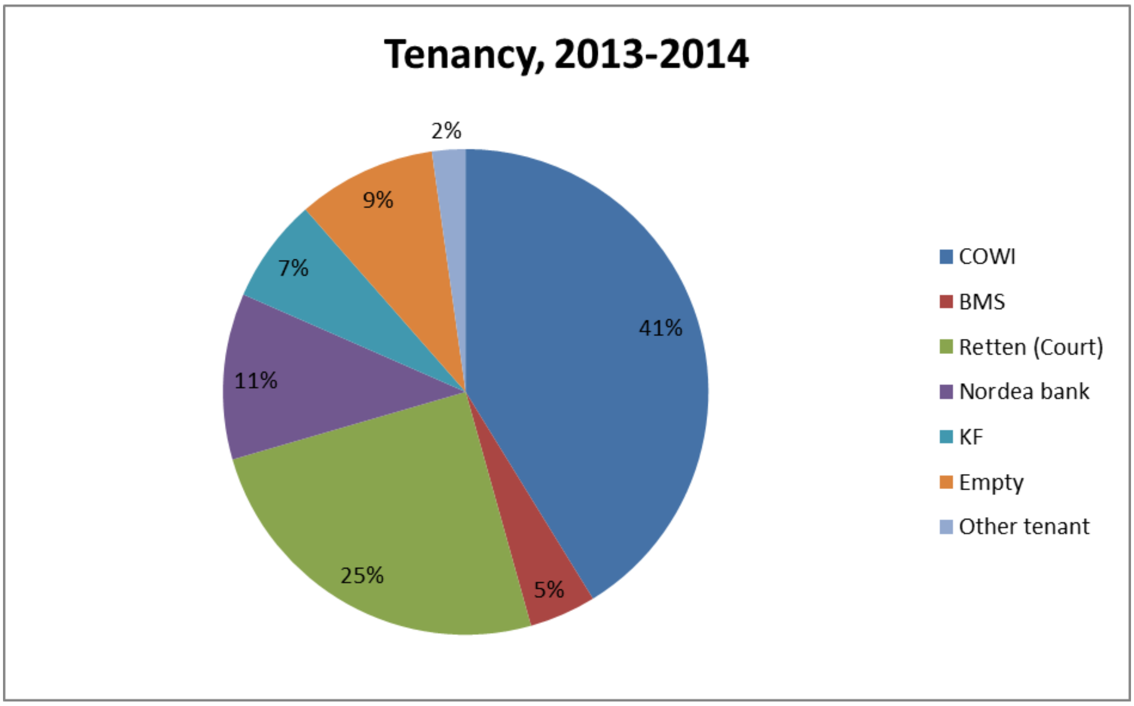


Figure 1 Tenancy in the analysed period 2013-2014

With a coming renovation it is attractive to look at potential energy saving measures which can be implemented in connection with this, thereby obtaining a better energy-attractiveness of the building.

The owner of the property is Nordea Ejendomme.

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 Lyngby Port 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.

[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

- 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 Nordea Ejendomme and 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
- Monthly energy statistics for district heating for the period 2013 and 2014 (e.g. measured values and/or values corrected to normal year)
- Monthly energy statistics for electricity for building operation for the period 2013 and 2014
- Monthly energy statistics for electricity for the different tenants for the period 2013 and 2014
- Annual statistics for water use for the period 2013 and 2014
- Report from building energy certification
- Interviews with the tenants, buildings´ technical manager and property manager

An energy audit has been carried out on site by Pawel Krawczyk in the period January 8th 2015 and April 15th 2015

An energy balance of the building has been simulated with the help of the simulation tool IES-VE. The investment cost calculations are based on Pawel Krawczyk.

The report is divided into the following sections:

- Current situation of the building and its technical systems
  Summary of the current situation of the building, building's use, indoor climate and technical systems

- Energy and resource use
  Overview of the current energy use of the building and buildings energy balance calculated with the simulation program. Establishing the baseline.

- Identified energy saving measures
  Overview of the identified energy saving measures and their estimated energy and cost savings.

- Action package based on Total Concept method
  Results of the profitability calculations: details of the action package fulfilling the profitability demands of the property owner/client, total investment costs and calculated total energy and cost savings after implementing the action package.

- Conclusions
  The conclusions from the project, carrying out Step 1 of the Total Concept method

3 Current situation with the building and its technical systems

3.1 Building and its layout

The building Lyngby Port owned by Nordea Ejendomme is located in Lyngby, Lyngby Hovedgade 94-98, Denmark, near to Lyngby Station.

The building is built in 1992 and divided into 3 building segments; A, B and C at Lyngby Hovedgade 94, 96 and 98. In 2014 Building A was rented by COWI, B by Lyngby Retten and Nordea Bank and C by TRYG Forsikring. The building is curved, giving several orientations for the office spaces.

Lyngby Port has 7 floors including basement. Segment A has 7 floors, B has 6 floors and C has 5 floors. In the basement an unheated parking area is located.
From the center main building three "fingers" stretches out and contains most of the office area. Fingers do not have heated basement. Main "body" or "bow" of the building contains main part of technical rooms and restrooms.

Figure 2 Lyngby Port - northern façade

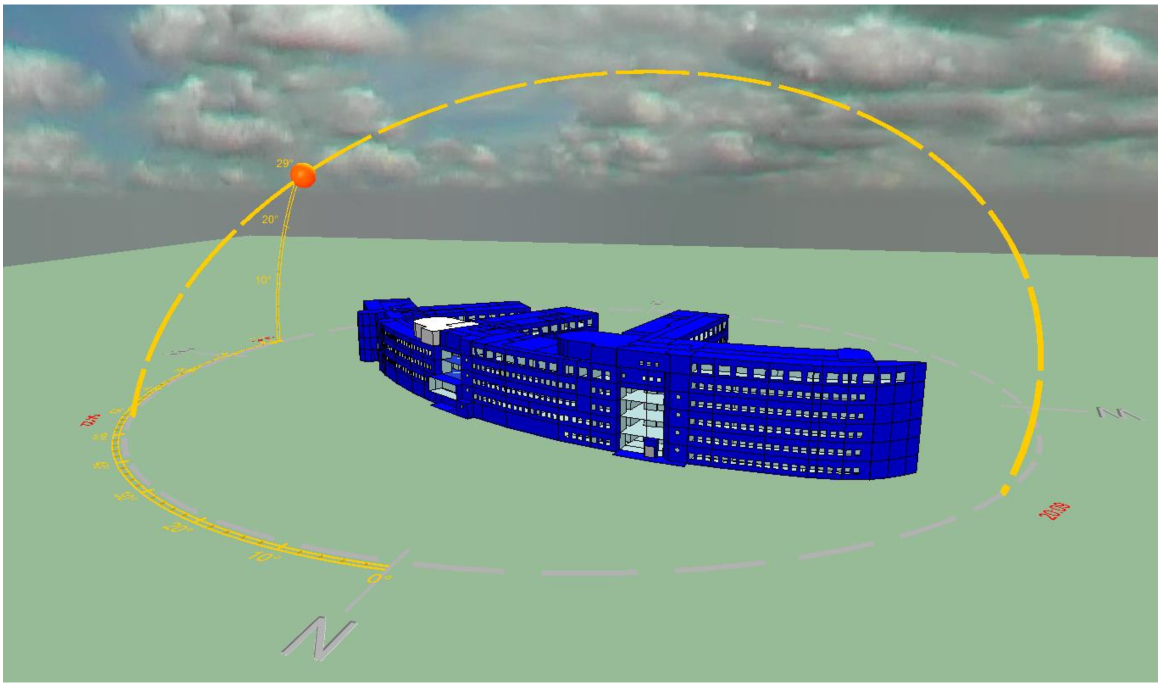


Figure 3 Lyngby Port - northern façade, 3D model

Figure 4 Lyngby Port – southern façade

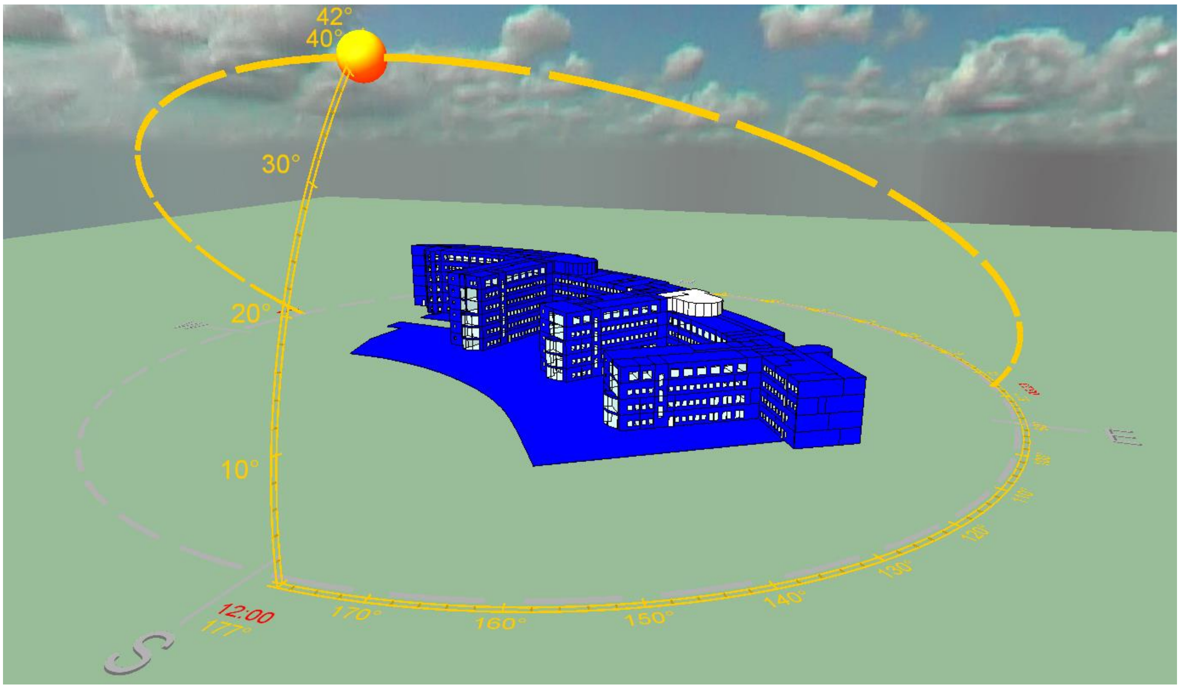


Figure 5 Lyngby Port – southern façade, 3D model

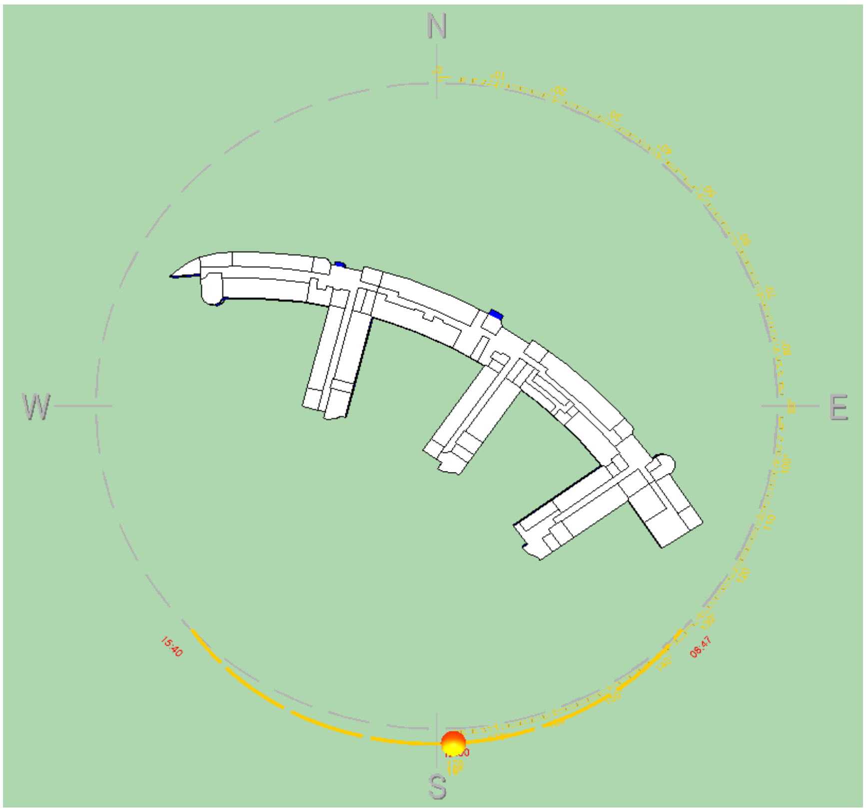


Figure 6 Lyngby Port – plan, 3D model

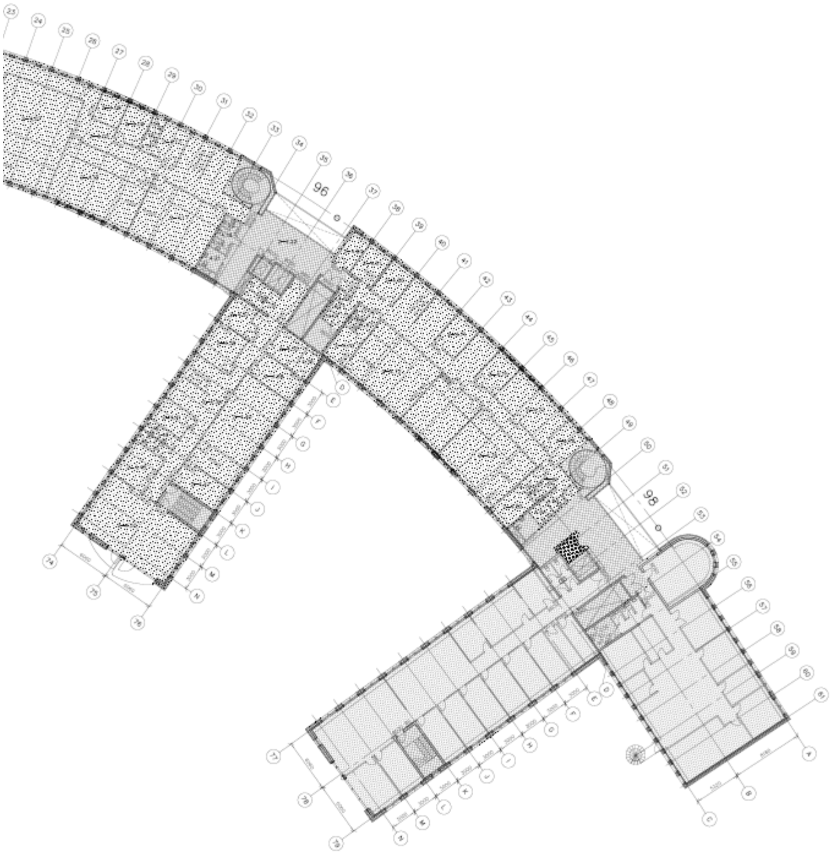


Figure 7. Part of 2nd floor plan.

The heated area is 20,630 m², with 15,714 m² mechanically ventilated area, and the rest is not mechanically ventilated. Unheated parking basement is additional 6,350 m² including technical areas.

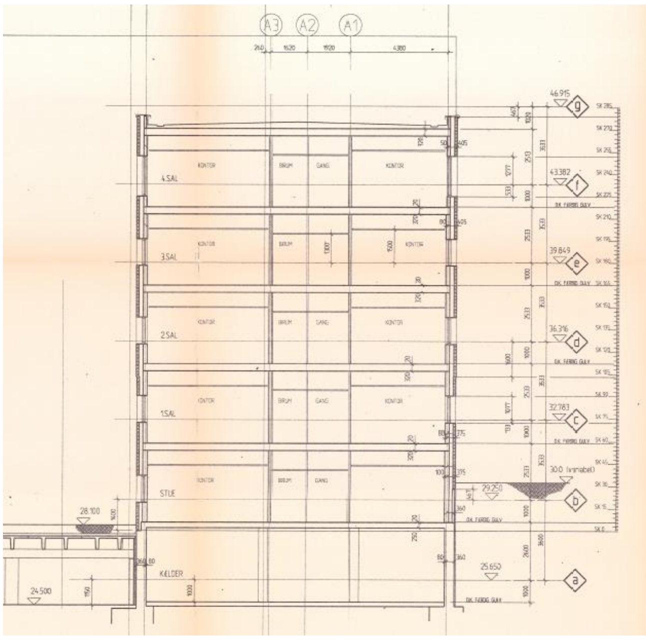


Figure 8. Section of building

3.2 The use of the building

Part A, B and C are rented out as office space to different companies. The whole of 1st floor of building B is for Nordea Bank. Working hours are mainly from 8.00 till 17.00 during weekdays. There is also a parking area in the basement level. The overall usage of the building has been the same since construction.

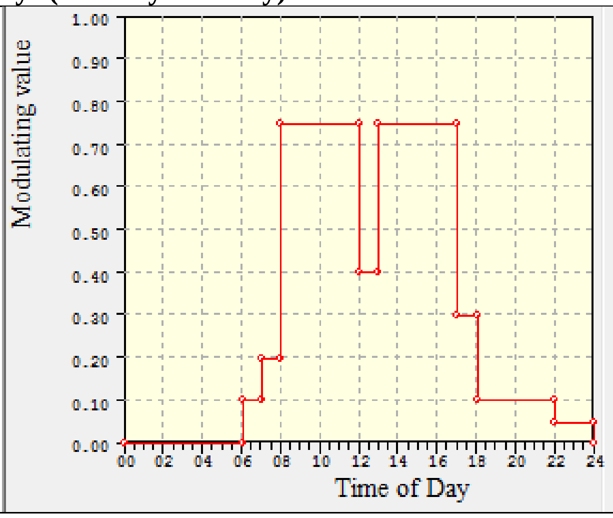
Internal loads are given in the following table:

Tabel 1 Internal loads

Room Category	Room type	Area (m^2)	No. of persons	People (m^2/pers)	Equipment (W/pers)	Equipment (W/m^2)	Lighting (W/m^2)
Office/Meeting	ROOM A	4515	400	11.3	100 W/pers.	8,9	6
	ROOM B	4792	300	20.3	100 W/pers.	4,6	6
	ROOM B – Bank	1266	300	20.3	150 W/pers.	9,3	6
	ROOM C	2994	75	39.9	100 W/pers.	2,5	6
Secondary functions	Tech.	1482	-	-	-	-	4.5
	WC	894	-	-	-	-	7.0
	Corridor	3645	-	-	-	-	4.0
	Stairs	917	-	-	-	-	7.0
	Parking	6612	-	-	-	-	3.0

Occupancy factor for persons and equipment used for simulation purposes is generally 75% at peak load. Specific daily and weekly load profiles are given in the following table:

Tabel 2 Occupancies used in model

Load/days	Weekdays (Monday – Friday)	Weekend
People		Off

All “lunch rooms” are simulated as office/meeting room. Court rooms located on 3rd and 4th floor are simulated with same people load and daily profile as offices.

3.3 Indoor climate

Nordea Ejendomme has informed that the overall indoor climate is with acceptable air quality, lighting and noise reduction, typical for buildings from that time. During summer period temperature in the offices is often too high.
The simulations show that 6% of all rooms can experience high temperatures during summer. All the rooms are situated in the “Finger” part of the building.

It is concluded that the installed diffusers do not work as designed – supply temperatures under 19˚C causes draught and therefore limits the cooling capacity of the system, which would be increased with lower supply temperatures. The diffusers are mounted incorrectly in the suspended ceiling – the cold air falls down and causes drought among employees.

There has been no earlier assessment of the indoor climate. Indoor climate for the new renovation is specified as class B (operative temperature, draught, air quality) or better according to EN15251.

3.5 Building envelope

The building envelope consists of flat roof isolated with roughly 300mm mineral wool all over. Balcony is isolated with 200mm mineral wool.

Most off outer walls are made as masonry with 45mm spacing. Outside is covered with bricks, inside with aggregated concrete and 190mm mineral wool as isolation between. Basement walls towards earth are made with 40 mm concrete and 100 polystyrene plate on the inside of the wall. Basement wall towards non heated area is built the same, but with mineral wool as isolating material instead.

Windows used are 2- and 3-layer thermo windows. The windows are simulated with only air and not argon in the cavity, as it is estimated that most of this gas has evaporated during the last 20 years, which gives a minor increase in the U-value. Most windows are mounted with inner sun screening.
Basement flooring is constructed in concrete. 200 mm expanded clay aggregate towards the dirt.

In the simulation the following parameters are therefore used:
Facade, roof and floors:

- Facade: U = 0.22 W/m2K
- External Basement wall: U = 0.41 W/m2K
- Basement floor: U = 0.45 W/m2K
- Floor slab: U = 0.27 W/m2K
- Flat Roof: U = 0,16 W/m2K
- Balcony Roof: U = 0.21W/m2K

Windows and doors:
Windows:
Uw = 2.54 W/m2K
gg = 0.7
LT= 0.71
Doors: Uw = 2.2 W/m2K

Solar shading: Inner sun screening built-in between 2-layer thermo window and outer 1 layer glass. Solar factor 0.4. Manually controlled.
There is no solar shading on north side of the building – towards highway.

Infiltration
Infiltration is set to 0.25 l/(s·m² facade) for whole building façade.

3.4 Technical systems

The technical system is in good condition, but has mostly not been upgraded since construction in 1992. Further description of the specific systems is found further down.

The technical details and input data used for energy simulations are specified in Appendix 1.

Tabel 3 Ventilation and heating

Room Category	Room type	Ventilation/cooling	Heating
Office/Meeting	ROOM A	VAV	Radiator
	ROOM B	VAV	Radiator
	ROOM B – Bank	VAV	Radiator
	ROOM C	VAV	Radiator
Extra	Tech.	None	-
	WC	Exhaust	Radiator
	Corridor	None	Radiator
	Stairs	None	Radiator
	Parking	Parking ventilation	None

3.4.1 Ventilation

The buildings ventilation system is divided into 6 VAV- systems with heat recovery (71-74%) and 6 exhaust systems with no heat recovery. The 6 exhaust systems; 1 for cooling technical room; 2 for kitchens; 1 for labs and printer rooms; 1 for fume cupboard. All systems are approximately 23 years old and in good condition. It is though evaluated that efficiency of fans and heat recovery has dropped by approximately 10%.

The air distribution works with a variable flow rate CTS-system. Constant air pressure in air ducts. Ducts are approximately same age and condition as ventilation system.

There is exhaust ventilation in parking basement.

Exhaust ventilation is less than 5% of the total ventilation of the building, and is therefore not included in the model.

3.4.2 Heating

The main heating system consists of radiators in all heated rooms.

For heating two boilers from DANSTOKER are installed. They are of the type VBN 1250 and 800. Gas-heaters for the two kettles are respectively: Weishaupt Monarch G8/1-D and G7/1-D. (APPENDIX 1.10). It is evaluated that efficiency of the boilers has dropped by approximately 10%.

Heat distribution piping is done with a two-string supply system, going from basement to roof. Technical rooms are placed in the unheated parking basement, so part of the distribution is through basement. Mixing plants are placed in technical rooms in basement and in roof houses A and B.

Basement under the building (storage, bath, etc.) is treated as heated area.
Circulation pipes in heated area are isolated with 30mm, and 60mm in unheated area. Circulation pipes cover the building basement to 3rd floor with two times 135m along the arc and two times 35m in each finger. On 4th floor 2 times 90m in arc and two times 35m in finger A and B. On 5th floor two times 45m in arc and two times 35m in fanger A. In each center area between arc and finger, are placed risers with the length of 3.5m pr. story.
Heating is simulated in detail in office space (ApacheHVAC) and less detailed (Apache) in other rooms.

EMO-repport states that domestic cold water use is 1800 m³ pr. year. It is assumed that 30 % of this corresponding to 540 m³ pr. year is domestic hot water.

3.4.3 Cooling

The cooling system consists of 2 compressor-/water cooling-systems with 6 cooling units with an average COP=2.5 and is in very poor condition. Chillers are used for distribution. There have been no changes since construction.

Cooling central is placed in basement parking area. Mixing plants are placed in basement C and roof houses A and B. The building is cooled through the ventilation air.

The cooling system consists of following elements:

- 2 water-cooled chillers, type Trane Scroll CCUE207:
  - cooling capacity – 2x182kW;
  - compressor – 2x43kW;
  - flow: 8,8ls; Tin=11˚C and Tout=6˚C;
  - COP=4.2;
  - refrigerant: R22
- 4 air-cooled condensers, type TTC SMR 144-700;
  - ventilator effect: 4x1.3kW;
  - nominal capacity: 4x58kW=232kW
- 5 ice tanks, type Calmar 1190; storage capacity: 670kWh (latent – 570kWh, sensible – 100kWh)

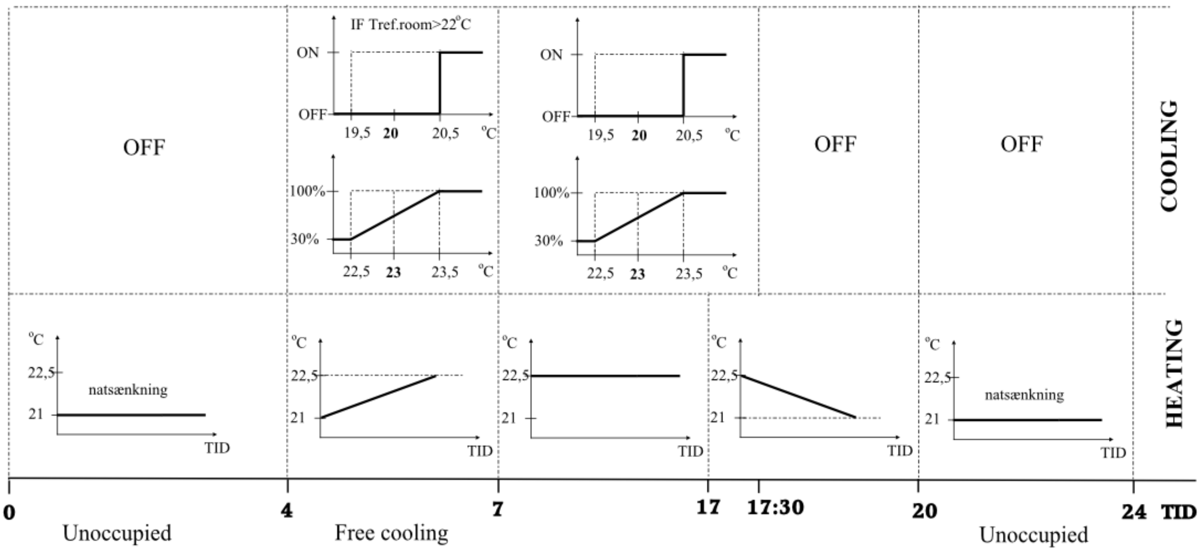
It is assumed that pumps and control devices reduce COP by 10%. The system is in a bad condition and it is therefore assumed 15% extra deterioration of COP factor. The system was established in 1992 but because of incorrect usage of the system the guarantee expired already in 1994.
The cooling capacity of the system is **364**kW and the calculated COP is **3.36**. The simulated COP = 2.5.

Cooling machine is available for cooling of ventilation air between 7 and 17 on weekdays.

3.4.4 Set points

Following set points are given during office hours and after:

Tabel 4 Set points for ventilation



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

Heating

The air temperature set point for radiators is 22,5°C (sensed temperature 22°C) during working hours and is gradually reduced during nighttime. The temperature of supply water is controlled by a thermometer placed outside the building.

Ventilation

The room temperature is controlled by variable air flow as well as by supply air temperature. The ventilation diffusers can control ventilation flow in a very limited deadband – at 22°C is being supplied 30% of the max airflow while already at 23°C the max airflow.

Between 4 and 7 in the night there is free cooling activated if air temperature in the reference room (located at level 00, Finger C) is over 22 ˚C.

Supply air temperature varies with season and is set between 19 ˚C and 22 ˚C depending on outside temperature. For outside temperature below 5°C the inlet temperature is 22 ˚C and for outside temperatures over 21°C the temperature is 19˚C.

3.4.5 Lighting

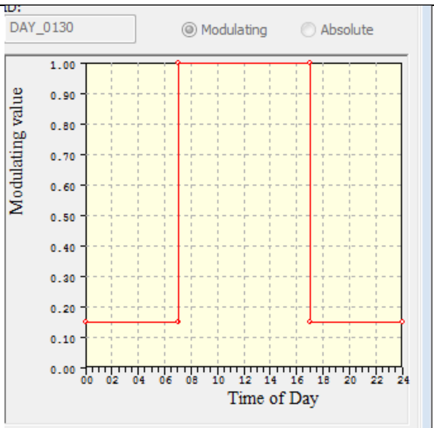
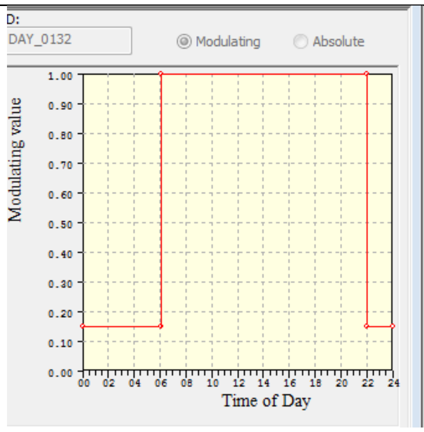
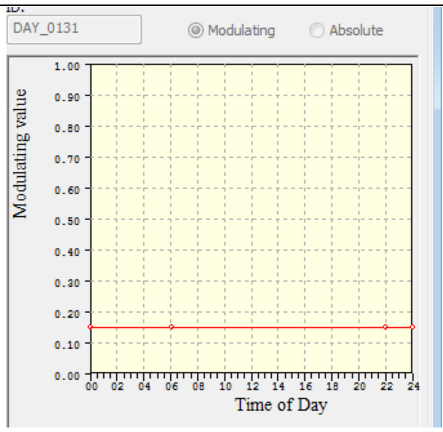
The lighting systems in offices correspond to 6 W/m² office space. There is no movement or daylight control in offices, kitchens, technical rooms or bathrooms. Movement control for lighting can be found in corridors and staircases.

Tabel 5 Occupancies used in model

Room Category	Room type	People (m²/pers.)	Equipment	Lighting (W/m²)
Office/Meeting	ROOM A	11.3	100 W/pers.	6
	ROOM B	20.3	100 W/pers.	6
	ROOM B – Bank	20.3	150 W/pers.	6
	ROOM C	39.9	100 W/pers.	6
Extra	Tech.	0	-	4.5
	WC	0	0	7.0
	Corridor	0	0	4.0
	Stairs	0	0	7.0
	Parking	0	0	3.0

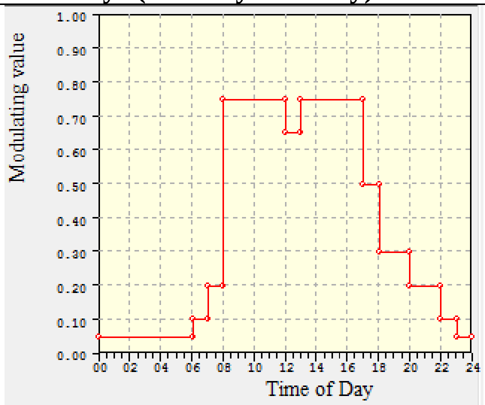
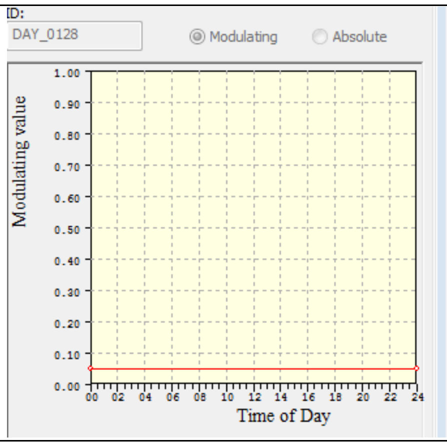
Daily and weekly profiles are given below.

Tabel 6 Daily and weekly profiles for lighting

Rum	**Weekdays (Monday – Friday)**	**Weekend**
Office	Manual regulation of daylight. In model simulated so there has to be a lux level in the darker end of the room corresponding to more than 2%, before the light is turned off.	**Off**
Secondary rooms	 **Tech, WC, Corr, Stairs – 7-17**	**Off**
Parking	 **Parking – 6-22**	 **Parking – weekend**

3.4.6 Equipment

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

Rum	Weekdays (Monday – Friday)	Weekend
Equipment		

There is no server room or kitchen in the building. Additional equipment, like coffee machines, refrigerator etc. is limited, and therefore omitted in the simulations.

There are no direct measurements of energy usage from elevators. It is estimated that an older hydraulic elevator will have an energy usage of 7,000 kWh per year. As the elevators will not be renovated, this is not investigated further.

3.4.7 Water supply and domestic hot water

Main cold water supply is from basement, and supplied to technical rooms in cores A, B and C. Heating of cold water is primarily in 6 decentral electrical water heaters. Central hot water production is to finger C.

3.4.8 Control and monitoring system(s) for technical installations

Control and monitoring systems are described in 3.4.1 – 3.4.4.

Nordea Ejendomme informs that BMS though does not work correctly and needs an upgrade in connection with the renovation.
Because of a very limited temperature deadband for ventilation system and draught problems there is a high risk for simultaneous heating and cooling throughout the year.

4 Energy and resource use

Heat, power and water demand for the building has been given for the years 2013 and 2014. From 2014 sections A and C of the building are near vacant.

In the future planned building, the person load will be higher, which without other measures will increase the energy consumption of the building.

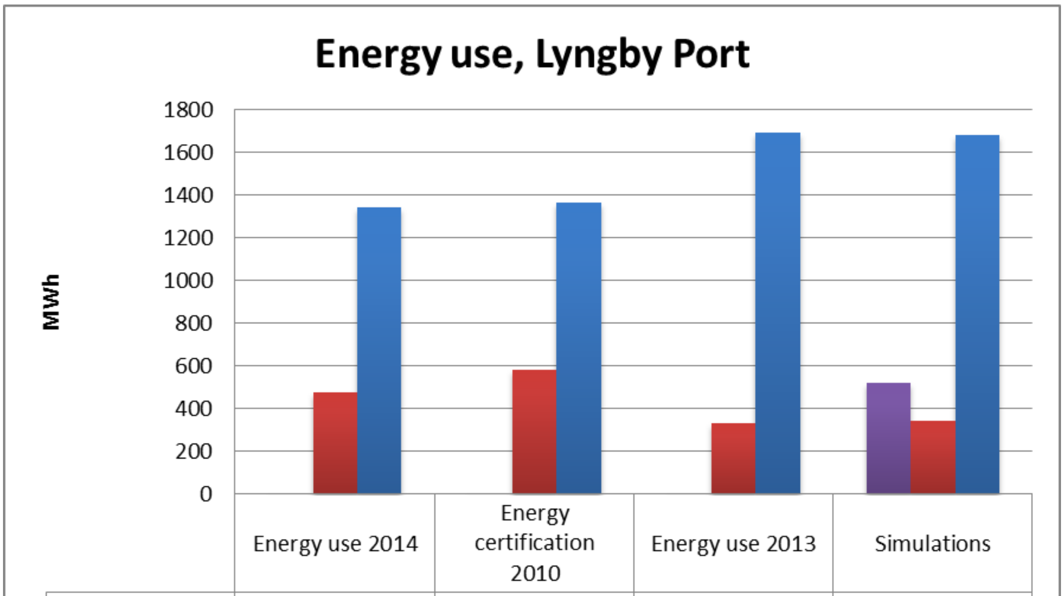
4.1 Energy and resource use statistics

The energy statistics come from following sources:

- Energy certification 2010 (Appendix 1.12)
- BMS measurement data 2013 (Appendix 1.13)
- Energy account report 2014 (Appendix 1.14)

The data is compared with results of the simulations. The results are divided into: gas consumption (heating, hot water, weather porches, heating coils), electricity consumption for ventilation and cooling and electricity consumption for equipment and lighting (small power). Small power is evaluation based on lighting and equipment profiles as the tenant energy consumptions are not available.
The data from 2013 is corrected to a reference normal year used in simulations.

The compiled total energy consumption is the following:



	Energy use 2014	Energy certification 2010	Energy use 2013	Simulations
El "small power"	0	0	0	522
El (common, incl. ventilation and cooling)	478	582	337	343
Gas	1345	1368	1692	1683

Figure 9. Annual energy consumption, Lyngby Port, based on energy measurements from 2014, Energy certificate, and energy measurements 2013. The data is incomplete.

The simulated results and corrected data from 2013 show deviation of 2%., and therefore in correspondence with the measured data. The measurement for “small power” – energy of tenants was not available.
 The results of the simulated model are assumed to be Case 0 – existing building, which is described further in 4.3.

4.2 Energy end-users

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):

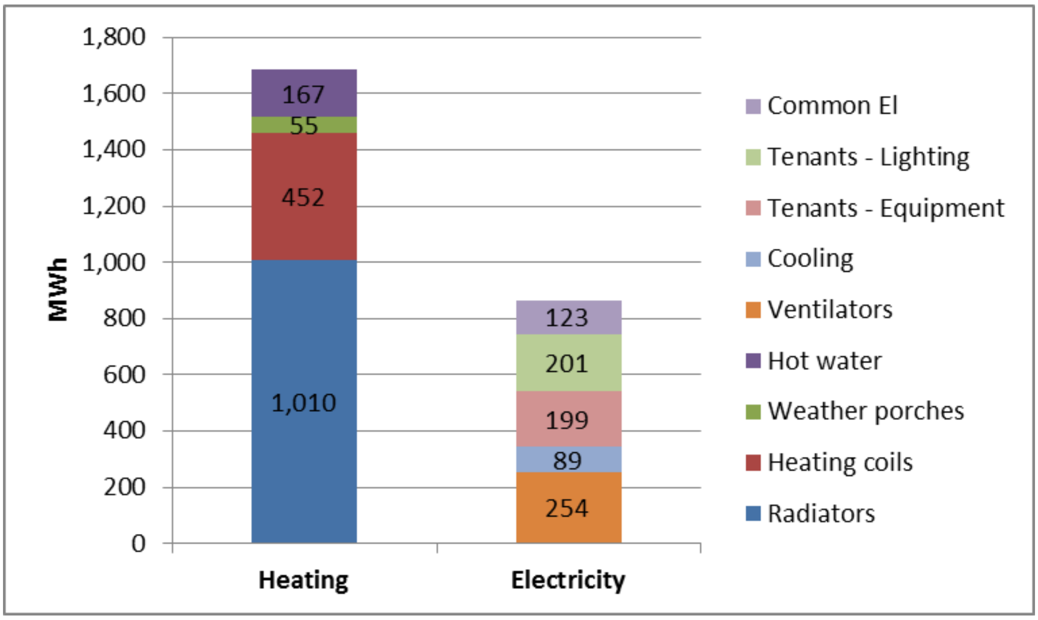


Figure 10. Energy end-use (MWh)

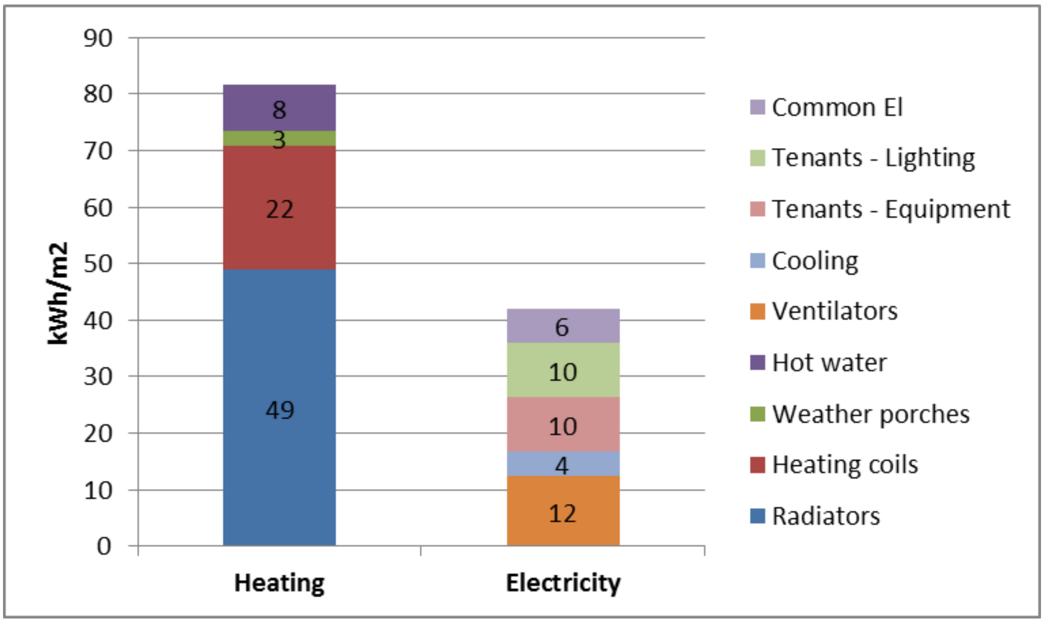


Figure 11 Energy end-use (kWh/m2)

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

The estimation of tenants lighting and equipment is **included** in the analysis and constitutes for the half of electricity consumption. Ventilation is approximately one fourth, cooling one tenth, and finally electricity in the common areas about one seventh of the electrical consumption.

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

- Heating: 0,65DKK/kWh (natural gas)
- 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:

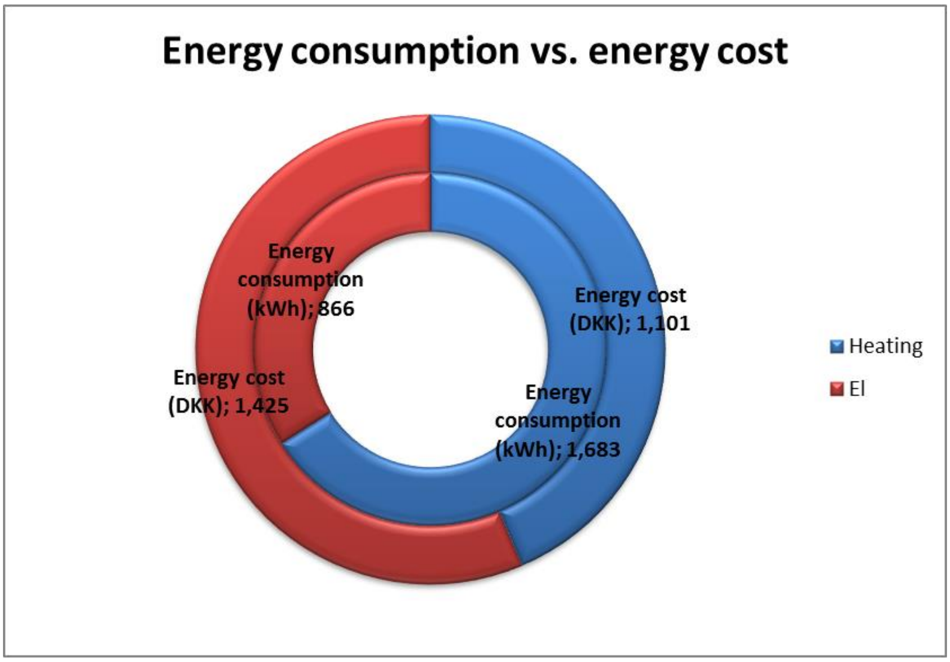


Figure 12 Comparison between energy consumption and energy cost (simulated scenario) – including tenants' energy consumption

Heating constitutes for 66% of energy consumption but only for 44% of energy cost. 34% of electricity consumption generates 56% of energy costs. Electricity consumption includes also estimated tenancy energy consumption for lighting and equipment.

Table 1 Energy consumption and cost – Case 0

	Energy consumption **MWh**	Cost **DKK**
Heating	1683	1.100.000
Electricity	866	1.425.000
Total	**2549**	**2.525.000**

4.3 Baseline for energy performance improvements

Case 0 – Existing Building

As shown in Figure 9 the simulated results and corrected data from 2013 show deviation of only 2%. This is within the estimated uncertainty limit of 20%, and therefore in correspondence with the measured data.

The model was therefore seen to be sufficiently calibrated to be a used for estimating energy performance improvements.

B0 - Baseline for energy performance improvements

The Case 0 - calibrated model showed correspondence between measurements and simulation model. However the assumptions do not reflect future use, with a higher person load in section A and C of the building. This is based on 20% more people in the A section of the building. The B section is adapted with same load per square meter.

The baseline model B0 is therefore carried out with following person loads:

Tabel 7 Internal loads for Baseline building B0. The red marks are changed assumptions.

Room Category	Room type	Area (m^2)	No. of persons	People (m^2/pers)	Equipment (W/pers)	Equipment (W/m^2)	Lighting (W/m^2)
Office/Meeting	ROOM A	4515	480	9.4	100 W/pers.	10.6	6
	ROOM B	4792	300	20.3	100 W/pers.	4,6	6
	ROOM B – Bank	1266	300	20.3	150 W/pers.	9,3	6
	ROOM C	2994	320	9.4	100 W/pers.	10.6	6
Secondary functions	Tech.	1482	-	-	-	-	4.5
	WC	894	-	-	-	-	7.0
	Corridor	3644	-	-	-	-	4.0
	Stairs	917	-	-	-	-	7.0
	Parking	6612	-	-	-	-	3.0

The result of the higher person loads is that several rooms will have higher operative temperatures than existing fit-out. It is therefore necessary to lower ventilation inlet temperature from 19˚C to designed 17˚C. This change increases energy consumption in comparison to case 0. The results for the Baseline B0 are presented below.

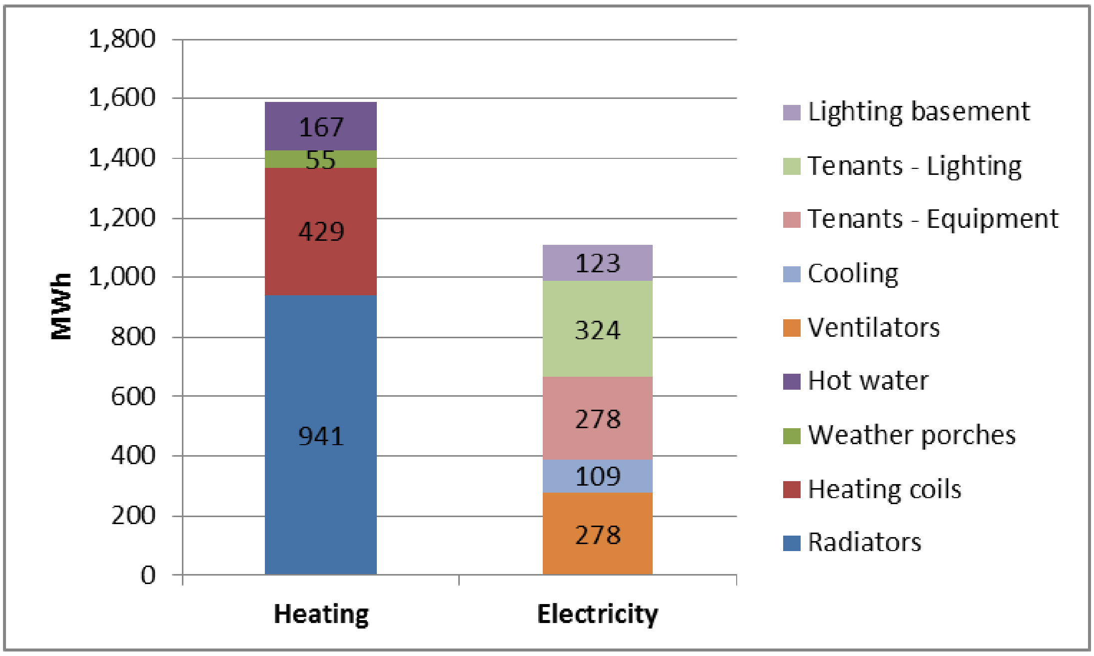


Figure 13. Energy end-use (MWh)

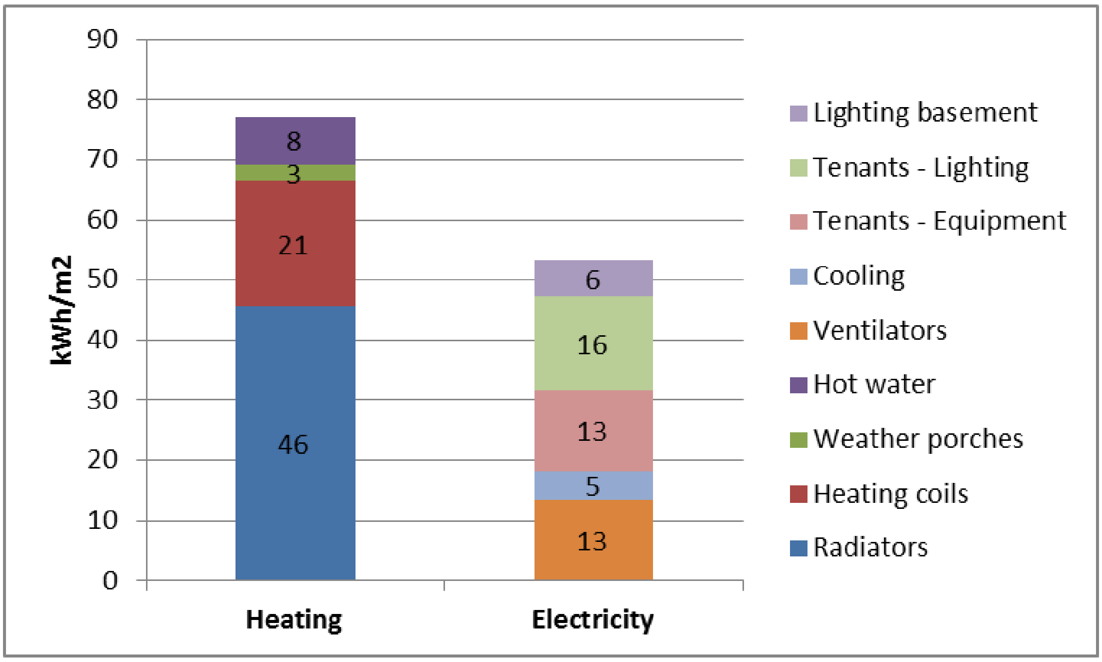


Figure 14 Energy end-use (kWh/m2)

The higher occupancy load reduces heating consumption but in the same time increases consumption of electricity. This change results also in more warm days during summer periods. The simulations show an increase in percentage of rooms with high temperatures from 6% for a case 0 to 9% for baseline B0. There are 10 rooms identified, where room temperature is over 26˚C for more than 100h and 17rooms, where temperature is higher than 27˚C for more than 25hours. The number of hours with high temperatures can be lowered by more efficient regulation (set points, deadbands, etc.)

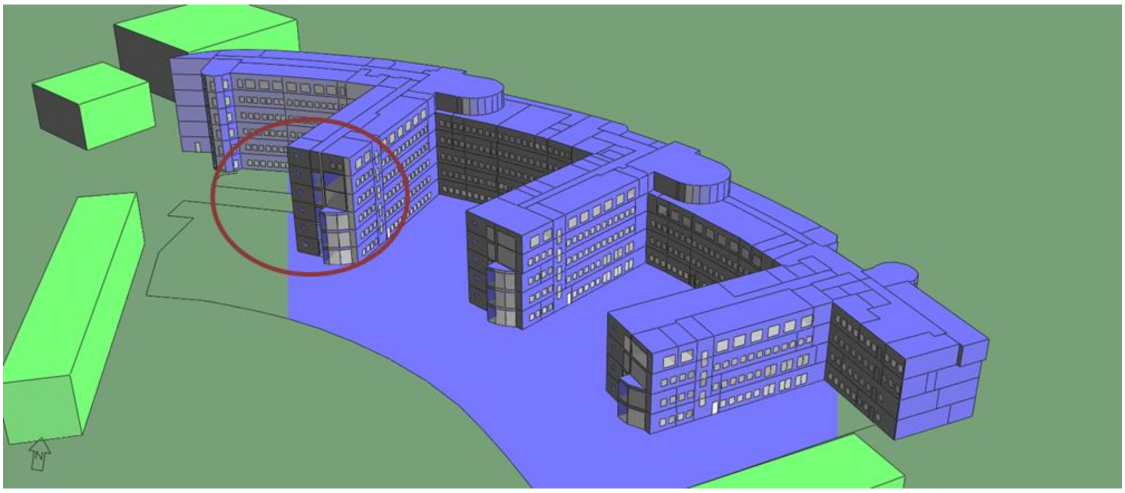


Figure 15 Rooms with high temperatures in the summer period

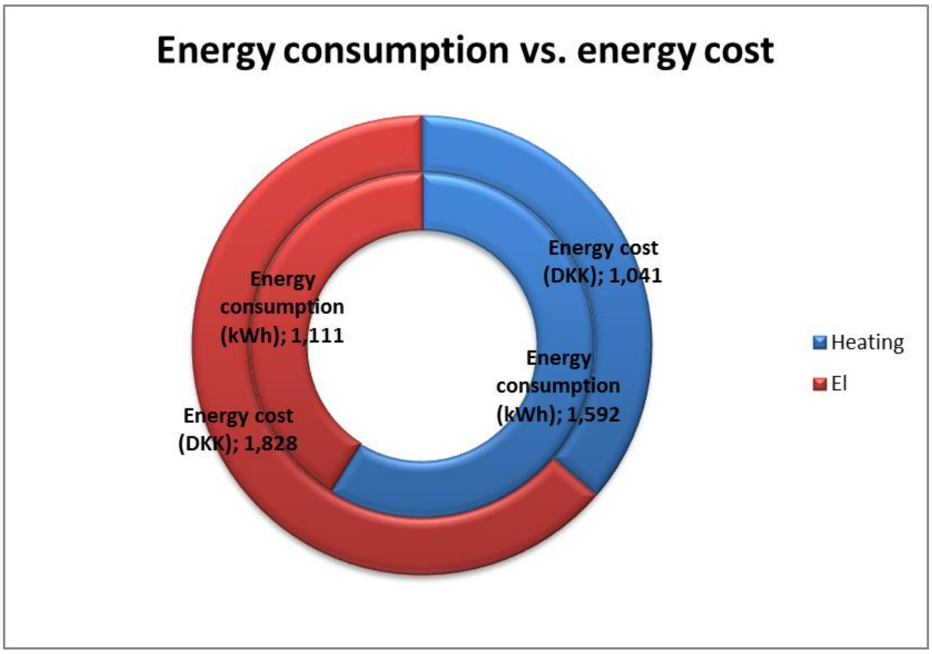


Figure 16 Comparison between energy consumption and energy cost – including tenants' energy consumption

Heating constitutes for 59% of energy consumption but only for 37% of energy cost. 41% of electricity consumption generates 63% of energy costs. Electricity consumption includes also estimated tenancy energy consumption for lighting and equipment.

Table 2 Energy consumption and cost – Baseline B0

	Energy consumption **MWh**	Cost **DKK**
Heating	1592	1.041.000
Electricity	1111	1.828.000
Total	**2549**	**2.870.000**

5. Identified energy saving measures

The following measures were identified:

B1) Conversion of natural gas boilers to district heating
B2) Replacing existing cooling machine
B3) Isolating cooling pipes in the shafts
B4) Replacing fans in ventilation units.
B5) Optimization of BMS system, including heating, lighting, ventilation and solar shading.
B6) Lighting sensors in toilets, corridors and technical rooms.
B7) Photovoltaic
B8) Replacing existing windows and solar shading

Following measures are not seen as potential energy saving measures

- Exchange of pumps as described in earlier energy certificate was performed last year, and therefore not a potential energy saving measure.
- Installed lighting effect is already rather low, and is not included as a potential energy saving measure.

Prices for the given measures are general estimates, and are not detailed

5.1 Measure B1 - Conversion of natural gas boilers to district heating

Description of concept and technical assumptions

The existing 2 gas boilers will be replaced by district heating. The district heating system will be used for both delivering heating and domestic hot water to the building.

It is assumed that efficiency of the system will increase from 84% to 95%. The price for the heating will drop by 14% from 0,65DKK/kWh to 0,57DKK/kWh[2]
Lifetime of the installation is set as 30 years.

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	0	kWh/year	0 %
Reduction, Heating	187.000	kWh/year	12 %

Results - economy

Result	Value	Unit
Estimated implementation costs	150.000	DKK
Yearly expenditure cut	234.000	DKK/year

Additional comments

The efficiency of the system can be even higher than assumed 95%, if the heat exchangers and connecting pipes will be well insulated.
It is recommended to insulate heat exchangers with minimum of 50mm PUR insulation. It is assumed that it is included in the price of 150.000DKK.
It has been communicated that the excavation starts in 2015 and the system should be established primo 2016.

Implementation issues:
-

[2] 2015-priser for fjernvarme fra Vestforbrænding

5.2 Measure B2 - Replacement of existing cooling machine

Description of concept and technical assumptions

Replacing old R-22 cooling systems with 1 new HFO chiller. The new 2-compressors chiller will have a capacity of 600kW and EER 4,03 with temperature set 13/8˚C.
It is assumed that supply temperature increase from 8 to 10˚C when outside air temperature drops below 15 ˚C.
Lifetime of the installation is set as 20 years.

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	58.000	kWh/year	5 %
Reduction, Heating	0	kWh/year	0 %

Results - economy

Result	Value	Unit
Estimated implementation costs	2.215.900	DKK
Yearly expenditure cut	96.000	DKK/year (electricity)
	20.000	DKK/year (maintenance of compressor)
	10.000	DKK/year (leakage reduction)

Additional comments

The maintenance costs is anticipated to be lower comparing to the old system. It is therefore assumed that the maintenance cost will drop by 20.000DKK annually. Moreover the refrigerant leakage is also assumed to decrease from 10% to 5%.
Additionally existing HFC R-22will be replaced with more environmentally friendly HFO.

<u>Implementation issues:</u>
-

5.3 Measure B3 – Insulating ventilation ducts in the shafts

Description of concept and technical assumptions

At the moment the ventilation ducts placed in the shafts are not insulated. The table below shows estimation of temperature increase in the ventilation ducts before and after insulation:

Building	Length of supply ducts in the shaft (m)	Temperature increase without insulation	Temperature increase with 30mm insulation
A	2 ducts x 20m = 40m	0,9˚C	0,1˚C
B	2 ducts x 16m = 32m	1,0˚C	0,1˚C
C	2 ducts x 14m = 28m	0,9˚C	0,1˚C

It is assumed that the average air velocity in ducts is 3m/s and surrounding temperature in shaft 25˚C.

Results - energy

Result	**Value**	**Unit**	**Reduction**
Reduction, Electricity	16.000	kWh/year	1,5 %
Reduction, Heating	0	kWh/year	0 %

Results - economy

Result	Value	Unit
Estimated implementation costs	107.000	DKK
Yearly expenditure cut	26.400	DKK/year

Additional comments

The reduction in electricity is calculated for the new cooling system with a nominal EER 4,03kW/kW.

Implementation issues:
Investigation for sufficient space in shafts and possible requirements for platforms

5.4 Measure B4 - Replacement of fans in ventilation units.

Description of concept and technical assumptions

The existing ventilation units are equipped in old-type centrifugal ventilators. New ventilators are more efficient and have higher rpm value what allows to reduce motor effect for the same air flow.
It is assumed that the direct driven ventilators will help to reduce pressure by 250Pa because of removing high velocity in outler (comparing to centrifugal ventilators).

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	164.400	kWh/year	15%
Reduction, Heating	-45.300	kWh/year	-3 %

Results - economy

Result	Value	Unit
Estimated implementation costs	550.000	DKK
Yearly expenditure cut	242.000	DKK/year

Additional comments

Before replacing ventilators it is recommended to measure external pressure in the ventilation system at the maximum air flow.
The negative value for heating comes from lower power of ventilators – it means that the motor airstream heat pickup is lower for new, smaller ventilators and the difference has to be delivered by radiators or heating coils. The prices for heating are calculated as 0,65DKK/kWh.

Implementation issues:
Detailed review of all ventilators to be performed

5.5 Measure B5 - Optimization of BMS system, including heating, lighting, ventilation and solar shading.

Description of concept and technical assumptions

The existing BMS system is old and outdated, and difficult to maintain. It is not feasible to reuse existing cables. Additionally these will not fit in the planned change from single offices to open plan offices.

Therefore, optimization of BMS system will mean total replacement to a complete new system. Estimated cost of changing this system, while only upgrading rooms in block A is:

New central BMS panel and controls:	kr. 250,000
BMS for existing ventilation units:	kr. 250,000
Office rooms (5 setpoints per room, 58 open offices)	kr. 1,500,000
Secondary rooms	kr. 250,000
Total	**kr. 2,250,000.**

The new 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
- Higher deadband for ventilation flows in the rooms
- Avoiding heating and cooling at the same time (better strategy for set points)

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	137.900	kWh/year	12%
Reduction, Heating	183.000	kWh/year	11%

Results - economy

Result	Value	Unit
Estimated implementation costs	2.250.000	DKK
Yearly expenditure cut	346.500	DKK/year

Additional comments

The new BMS system has to integrate heating and ventilation system (avoiding heating and cooling at the same time) . The prices for heating are calculated as 0,65DKK/kWh.

Implementation issues:
Detailed project before implementation

5.6 Measure B6 - Lighting sensors in toilets, corridors and technical rooms.

Description of concept and technical assumptions

There are 47 toilet cores, where the lighting system can be controlled by PIR sensors. At the moment the lights are controlled manually. There will be installed 1 PIR sensor per 1 toilet core. It is assumed that the change will decrease energy consumption in toilets by 10%[3] and will not affect the heating consumption.

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	3.000	kWh/year	0,5%
Reduction, Heating	0	kWh/year	0 %

Results - economy

Result	Value	Unit
Estimated implementation costs	70.500	DKK
Yearly expenditure cut	4.950	DKK/year

Additional comments

-

Implementation issues:
-

[3] ASHRAE 90.1 2007 Lighting system – Space by Space method

5.7 Measure B7 – 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 17), 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.

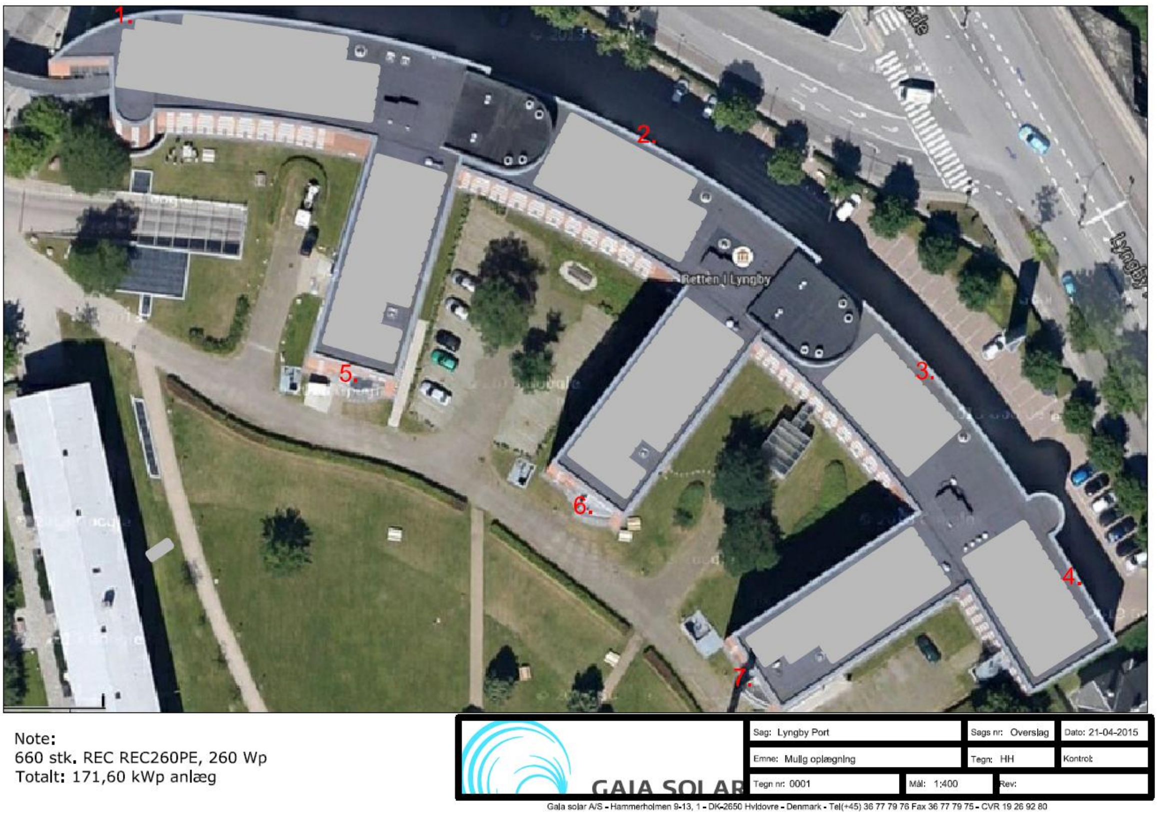


Figure 17 Estimated roof area for photovoltaics

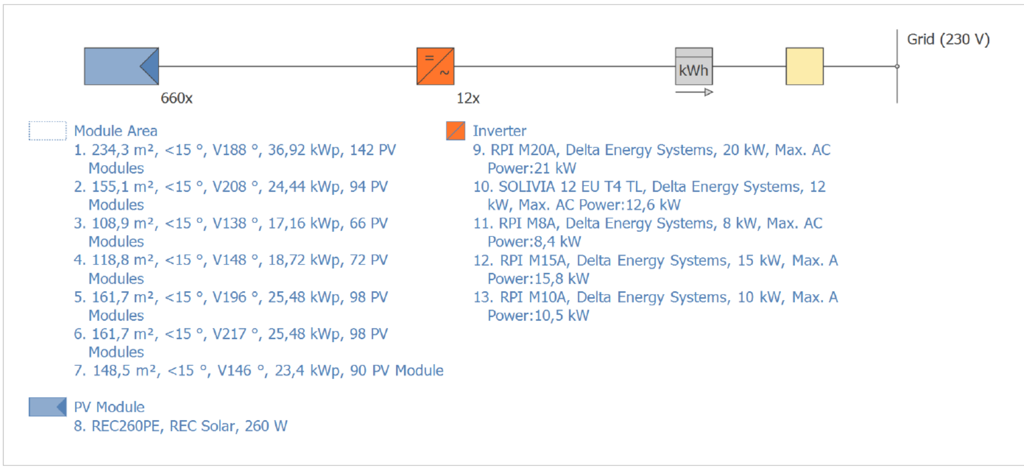


Figure 18 Parameters of the system

Assumptions	Value	Unit
Generator surface	1089	m²
Number of PV Modules	660	-
Number of Inverter	12	-
PV Generator Output	171.6	kWp
Performance Ratio (PR)	91.6	%

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	165.800	kWh/year	15 %
Reduction, Heating	0	kWh/year	0 %

Results - economy

Result	Value	Unit
Estimated implementation costs	1.750.000	DKK
Yearly expenditure cut	253.000	DKK/year (electricity)

Additional comments

The maintenance cost is assumed to be 20.000DKK/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.

5.7 Measure B8 – Replacing existing windows and solar shading

Description of concept and technical assumptions

The concept assumes replacing all the windows. The existing solar shading consists of built-in venetian blinds so replacing the windows needs to be considered together with replacing the solar shading on the southern façade.

There is 2040m2 of fenestration and 10.500m2 of façade in the building.

Table 3 Overview over fenestration in Lyngby Port

Height x Width	1.0x1.2		0.8x0.8		r=0.5 (circular)		1.8x2.2		Full facade	
Facade area	Count	Area [m²]	Count	Area [m²]	Count	Area [m²]	Count	Area [m²]	Count	Area [m²]
Total	887	1064	7	4	25	20	27	107	300	386

Height x Width	1.8x1.0		1.8x2.0		0.6x1.0		2.6x1.0		**Total**	
Facade area	Count	Area [m²]	Count	Area [m²]	Count	Area [m²]	Count	Area [m²]	Count	Area [m²]
Total	87	157	73	263	8	5	12	31	**1426**	**2037**

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

	Old windows	New windows
U-value (W/m2K)	2,54	0,87
g-value (-)	0,7	0,51
LT (light transmittance, %)	71	71
Solar shading factor	0,4	0,2

It is also assumed that the infiltration rate will drop from 0,25to 0,2 l/s per m2 of façade.

The cost estimation includes following elements:

Element	**Unit**	**Amount**	**Price per unit**	**Price**
Scaffolding	m2	10500	300	3,150,000
Removing the old windows, assembly of new windows and extra work (joint finish, lists, etc.)	pieces	1426	2000	2,852,000
New windows	m2	2040	1800	3,672,000
External blinds	m2	1178	2000	2,356,000
Sum				**12,030,000**
Building site	9%			1,082,700
Diverse	10%			1,203,000
Total				**14,315,700**

Results - energy

Result	Value	Unit	Reduction
Reduction, Electricity	-48.700	kWh/year	-4%
Reduction, Heating	431.100	kWh/year	27 %

Results - economy

Result	Value	Unit
Estimated implementation costs	14.316.000	DKK
Yearly expenditure cut	200.000	DKK/year

Additional comments

The price of the solution with build in solar shading is very similar to the solution with external blinds. The maintenance cost is also assumed to be the same.
The value for electricity is negative because during some periods temperature increases above the room set point what activates ventilation and cooling more often.
The expenditure cut for heating is calculated with the price 0,65DKK/kWh.

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.

6 Action package based on Total Concept method

There have been 8 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 conversion to district heating influence each other and better heating system efficiency will decrease 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	Conversion of natural gas boilers to district heating	187000	234000			150000
B2	Replacement of existing cooling machine			58000	126000	2215900
B3	Insulating ventilation ducts in the shafts			16000	26400	107000
B4	Replacement of fans in ventilation units	-45300	-29445	164400	271260	550000
B5	Optimization of BMS system, including heating, lighting, ventilation and solar shading	183000	119000	137900	227500	2250000
B6	Lighting sensors in toilets, corridors and technical rooms			3000	4950	70500
B7	PV panels			165800	253000	1750000
B8	Replacing existing windows and solar shading	431100	280000	-48700	-80300	14315000
		755800	603555	496400	828810	21408400

6.1 Input data for profitability calculations

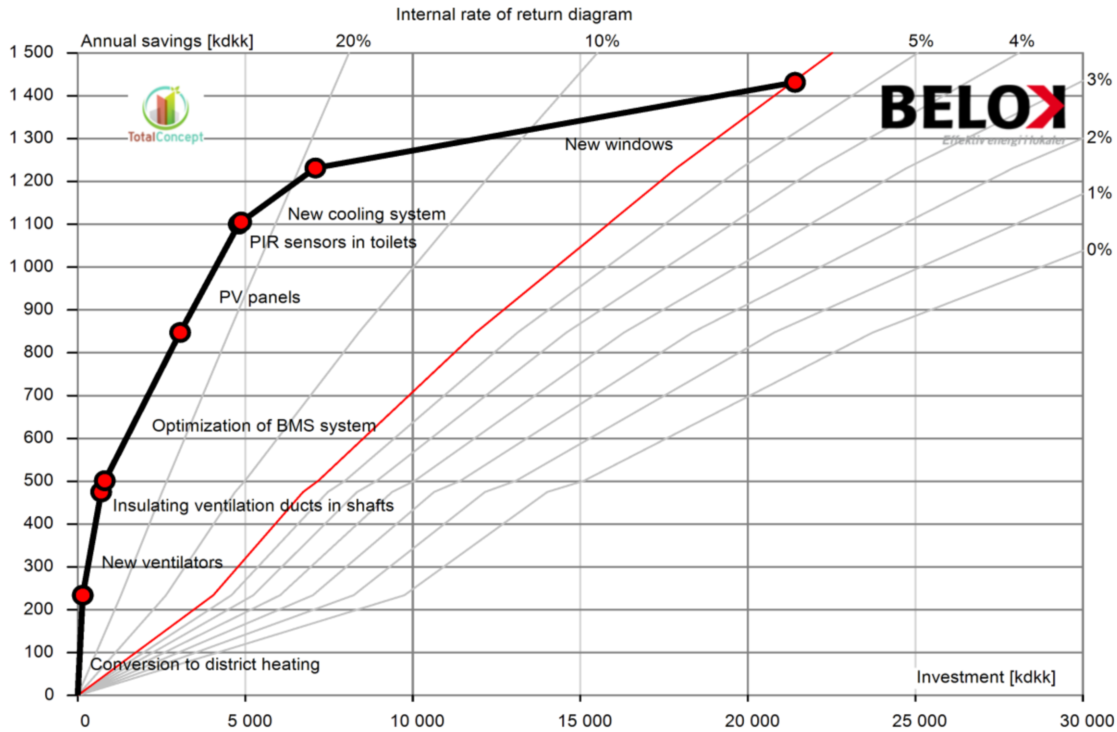
The following assumptions were used to perform profitability calculations:

- Prices: heat energy 0,65DKK/kWh (after conversion 0,57DKK/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	Conversion of natural gas boilers to district heating	30
B2	Replacement of existing cooling machine	20
B3	Insulating ventilation ducts in the shafts	30
B4	Replacement of fans in ventilation units	15
B5	Optimization of BMS system, including heating, lighting, ventilation and solar shading	20
B6	Lighting sensors in toilets, corridors and technical rooms	20
B7	PV panels	25
B8	Replacing existing windows and solar shading	30

6.2 Results

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



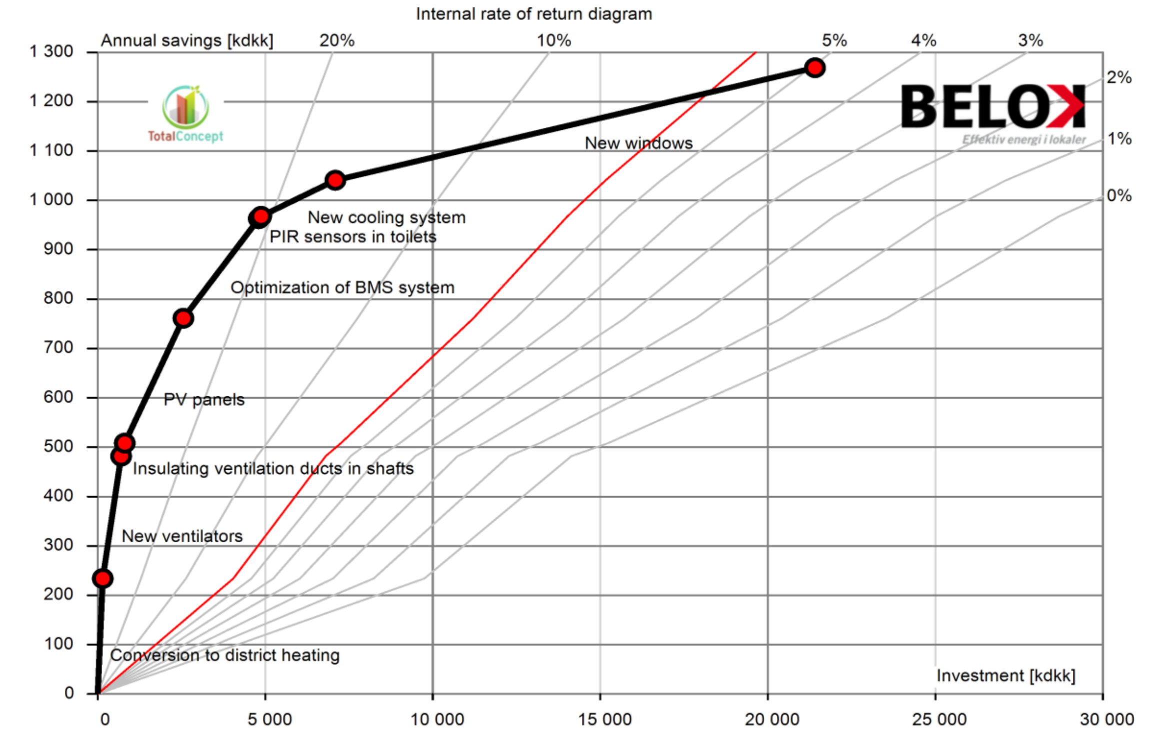
N..	Name	Economic calculat.. period [year]	Invest.. [kdkk]	Internal rate of return [%]	Heat energy saving [MWh]	Heat energy cost saving [kdkk]	Electricity saving [MWh]	Electricity cost saving [kdkk]	Total cost saving [kdkk]	Profit [-]	Sum of internal rate [%]	LCC [kdkk]
2	Conversion to district ...	30	150	158,00	390	234	0	0	234	26,98	158,00	-3050,32
5	New ventilators	15	550	45,62	-50	-30	301,11	271	241	4,87	69,87	-2462,12
8	Insulating ventilation ...	30	107	26,63	0	0	16	26,4	26,4	4,27	64,10	-241,66
6	Optimization of BMS ...	20	2250	16,31	198,33	119	252,22	227	346	2,09	29,41	-1852,14
1	PV panels	25	1750	15,89	0	0	153,33	253	253	2,26	24,48	-1410,06
3	PIR sensors in toilets	20	70	5,66	0	0	3,03	5	5	0,97	24,24	21,72
4	New cooling system	25	2216	4,91	0	0	140	126	126	0,89	18,65	889,92
7	New windows	30	14315	-2,89	466,66	280	-88,88	-80	200	0,24	5,96	13532,46

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. While conversion to district heating and insulating ventilation ducts in shafts are measures not affecting each other, new ventilators will have a lower saving impact after implementation of district heating than implementing new ventilators as a single measure. The replacement of ventilators affects not only the electricity consumption but also heating energy consumption – the heating consumption will increase (see description for a single measure) but it will be heating consumption with already increased efficiency (district heating).

The single energy measure: “new ventilators” is compared to the baseline with old heating system. The goal of iterations is to take new heating system into account as it will be a part of the action package.

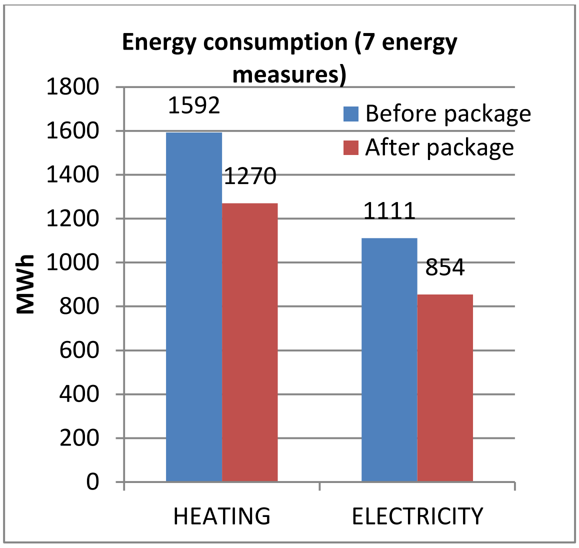
The same is relevant for other potential energy measures – the energy saving of more profitable measures limit the saving potential of the next measure.

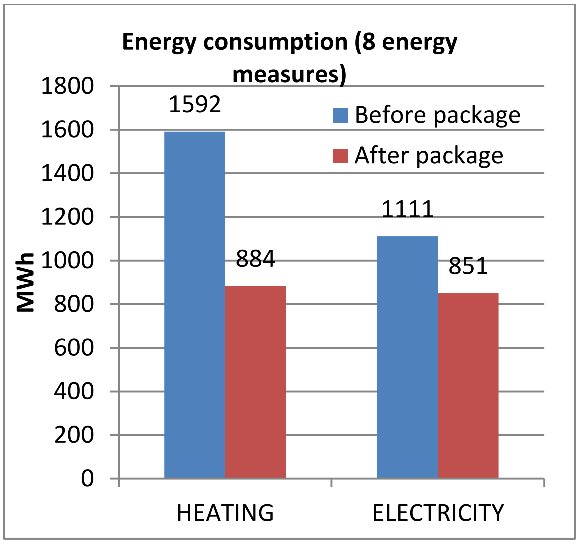
The impact of energy measures on each other is taken into account on the graph with final action package below:



E..	N..	Name	Economic calculat.. period [year]	Invest.. [kdkk]	Internal rate of return [%]	Heat energy saving [MWh]	Heat energy cost saving [kdkk]	Electricity saving [MWh]	Electricity cost saving [kdkk]	Total cost saving [kdkk]	Profit [-]	Sum of internal rate [%]	LCC [kdkk]
☑	2	Conversion to district ...	30	150	158,00	390	234	0	0	234	26,98	158,00	-3050,32
☑	5	New ventilators	15	550	46,92	-38,33	-23	301,11	271	248	5,01	70,84	-2558,47
☑	8	Insulating ventilation ...	30	107	26,63	0	0	16	26,4	26,4	4,27	64,98	-241,66
☑	1	PV panels	25	1750	15,89	0	0	281,11	253	253	2,26	31,56	-1410,06
☑	6	Optimization of BMS ...	20	2250	8,33	161,66	97	116,11	104,5	201,5	1,22	21,45	136,87
☑	3	PIR sensors in toilets	20	70	5,66	0	0	3,03	5	5	0,97	21,26	21,72
☑	4	New cooling system	25	2216	0,55	0	0	81,11	73	73	0,51	15,67	1619,46
☑	7	New windows	30	14315	-2,22	370	222	6,66	6	228	0,28	4,94	13147,05

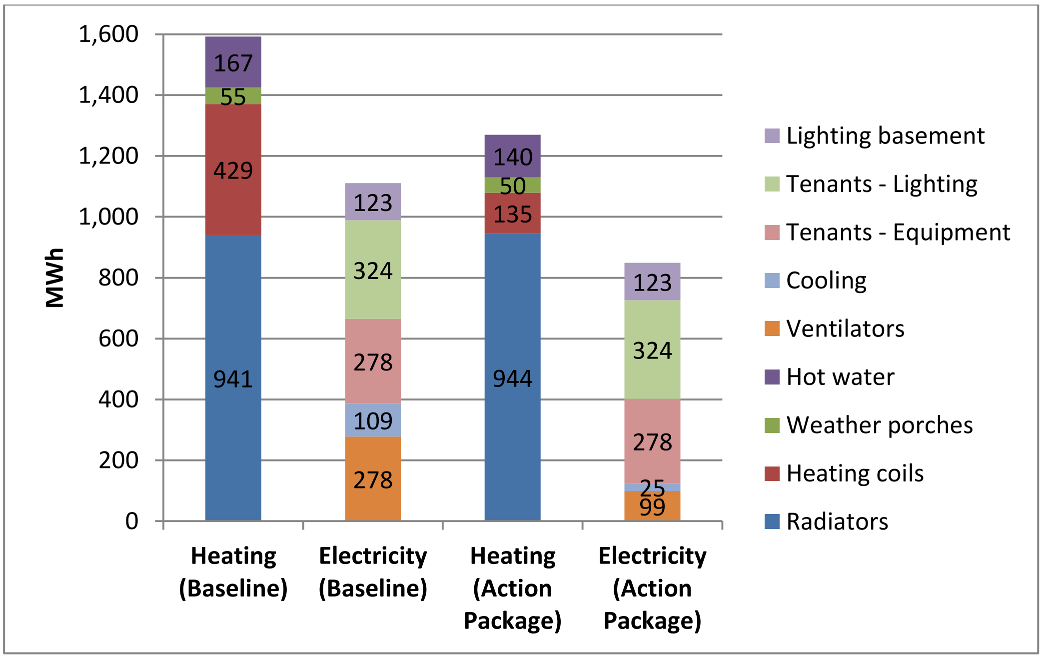
As shown on the graph, 1 energy measure (new windows) is situated below 6% threshold for internal rate. It is a consequence of reduced saving potential of some measures while combined in the package. The optimized BMS system results in a big energy saving for cooling. That is why the replacement of cooling system does not result in such a high saving as for a single measure.
The graphs below show 2 action packages: with 7 energy measures that fulfill the owner internal rate of return and with all 8 potential energy measures.





The energy saving for the package that fulfills the owner internal rate of return is 20% for heating and 23% for electricity. For the package with 8 measures it is respectively 44 and 23%.

The detailed results of the final action package are presented in the table below:



The graph also shows that reduction for the common electricity is around 50%. The electricity for tenant's energy consumption is a fixed value.

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)	1041	738	304
Electricity (x1000DKK)	1828	1405	423

7 Conclusions

The calculations show that only 1 energy measure is not profitable – new windows, while first 7 energy measures have a total internal rate of return of nearly 16%. Especially 2 first measures, conversion to district heating and new ventilators, have a huge impact on energy cost in the building. The reduction in heating price by 14% is a significant factor in the calculations.

The replacement of BMS system has also 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.

Appendix 1. Input data for energy simulations

Input data for energy simulations are the following:

App. 1.01 - Plan drawings; Nordea Ejendomme
App. 1.02 - Ventilation systems
App. 1.03 - daylight simulations
App. 1.04 - Areas with window types
App. 1.05 - Flow rates
App. 1.06 - Heating power
App. 1.07 - Heating pipe system diagram
App. 1.08 - Heating pipe system
App. 1.09 - Boilers
App. 1.10 - 09.02.2015 dividing building into sections
App.1.11-EM_2833_Lyngby Hovedgade 94
App.1.12 BMS measurement data-Målinger 2013 PALK_02
App.1.13 Energy account report-Lyngbyport Aflæsningsskemaer Jan-feb…

Appendix 2. Input data for energy saving measures

Input data for energy simulations are the following:

App. 2.01 Prices for district heating
App. 2.02 New cooling system
App. 2.03 New fans in ventilation units
App. 2.04 Photovoltaic
App. 2.05 New windows