***Programme of actions towards Factor 4 in existing social housings in Europe***

**Deliverable 7**

# Potential energy savings for some representative buildings by using only the ecological objective of a LCEC analysis

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**Part 1 – The Danish analysis**

**www.suden.org/Factor4**

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# 1. REMINDER ON THE FACTOR 4 PROJECT

The Factor 4 project follows the Sustainable Development World Strategy worked out in Johannesburg in 2002 and aims at working out:

- an operational tool (the Factor 4 model) for a long term management of the building stock of a social owner in the one hand,
- and recommendations for all the actors concerned.

The Factor 4 objective is to work out a Factor 4 approach with a decision aid tool for helping social owners and their partners to build up sustainable strategies for energy retrofitting of social housing.

Factor 4 deals with existing social housing buildings, which will still be there in 2030-2050, and which will improve their energy efficiency by a minimum of 30 % in a short term and more in a long term, using renewable energy in order to participate to the reduction of greenhouse effect gas (GEG) emission by a factor 4 before 2050.

## *1.1. EXPECTED AND/OR ACHIEVED RESULTS*

The key products, with their use and impacts, generated by - or expected from - our project are

- A Factor model for social owners with specific adapted versions for at least 4 countries (Denmark, France, Germany and Italy), easy to use and directly usable by social owners themselves for the optimization of the retrofitting works.

As the Factor 4 model allows working out various scenarii, it will help to get an idea of what would be the best strategy for the building stock or for some specific buildings.

This Factor 4 model will also be an economic tool to be used with the Energy Performance Building diagnosis (which is only a technical diagnosis according to the European Directive).

In regeneration projects at the neighbourhood scale such as URBACT or in national programmes (ANRU in France, NRU in UK, Contratti di quartieri in Italy…), the Factor 4 model will also be a decision aid tool for selecting the buildings to be demolished or to be partly (or softly) renovated. This decision aid tool will be used by social owners themselves but also by their financial partners or by local authorities as regards buildings from various social owners.

At the building scale the Factor 4 model will complete the technical diagnosis with economical data.

At least, this Factor 4 model should also be a way towards the integration of energy in the (strategic) management plan of social owners' building stocks.

- Recommendations for social owners, local authorities, public administration and banks as regards energy savings in social housing towards a factor 4.

- Demonstration case studies in order to be as operational as possible. Tests will be carried out on the building stock of the Factor 4 partners showing how the SEC model can be used and which results can be expected.

# 2. Summary

This report describes three case studies of social housing in Denmark. The three housing stocks are managed by the housing association KAB and are selected from a typology study and it represents the social housing stock in the best way. The first case study is a housing stock from 1950 in a three floor level and basement with double brick wall which was a common construction method at that time. The second case study is a newer settlement constructed in 1980 heated by district heating. The third case study is heated by natural gas. All three case studies are located in the suburb of Copenhagen and the categories represent 30 % of the total social housing stock managed by KAB.

The calculation of the three cases shows that it is possible to reduce the heat consumption for space heating and domestic hot water by 70 – 80 % by implementing different energy savings technologies. It is assessed that it is possible to reduce the electricity consumption by 20 – 30 % which means that a smaller percentage of the electricity consumption depends on individual behaviour, and common initiatives can not reduce this individual electricity demand. Only a smaller water savings can be achieved. The total reduction of $CO_2$ is calculated to be 40 – 50 % which is lower than the objective of the factor 4 project. The suggested energy savings technologies are all well known technologies. All the suggested measures have been demonstrated and is confirmed to be practical applicable.

The $CO_2$ emission from district heating production has been decreasing up till now. The reduction is caused by using more renewable energy source in the district heating network like waste energy, and bio mass. If this development continues the total $CO_2$ reduction from the social housing stock in Denmark can be as high as 75 % and the objective of the Factor 4 project is fulfilled. The savings consist of 40-50 % from building improvements and the 25 % from supply system.

The energy improvements of the buildings require an extra investment of approximately 10.000 Euro per dwelling and a cost benefit analysis shows that it is not profitable for the tenants since the simple pay back time is 40- 50 years. Only an increase in energy costs of 3 % per year will make the investment profitable.

# 3. The Danish Typology

The Danish methodology application is developed based on the social housing schemes managed by KAB and reported in the KAB Statistics 2005. The statistics include 24000 dwellings in 143 estates with a total of 1,700,000 m2 treated floor area. The smallest estate includes 6 dwellings and the biggest 1,645 dwellings.

Six main criteria have been selected for the Danish social housing stock analysis: Climatic, Type of construction, Construction date, Type of energy resource, Type of distribution, Building Energy Management System (BEMS)

*Climatic area*

The climate in Denmark do not differ very much from one area to another. Only small variations have been monitored and it has no significant influence on the energy consumption for heating. It is common practice to use the Danish TRY weather data for energy calculations of buildings.

*Type of construction*

Four types of building constructions have been selected for the Danish building stock: houses in one floor level, houses in two floor level and building block with more than two floor levels. Since the KAB Statistic include information on group of houses some estates consists of a combination of

different type of houses called mixed housing. Building block represents 64 % of the whole social building stock.

*Date of construction*

The construction date follows the updating of the Danish building regulation and consists of four periods:

BR00: before 1980

BR82: from 1980 to 1995

BR95: from 1995 to 2006

BR06: after 2006

In the new building regulation BR06 two low energy standards are defined "class 1 & class 2" which are expected to be the requirements in the building regulation in the near future (year 2010 and 2015 respectively). 74 % of the social houses are constructed before 1983.

The energy performance of most of the old buildings (category BR00) has been improved. All buildings in the KAB Statistics have windows with two layers of glass which was not available when the buildinsg were constructed. Insulation has been added to the external cavity walls and the heat distribution systems have been insulated and thermostatic valves are installed on all radiators.

*Heat supply*

All the estates in the statistics are heat supplied in tree different ways: by district heating, natural gas and by local combined heat and power generation (CHP). The heat consumption in houses heated by natural gas is monitored by the gas input and the losses in the burner are included in the data. 83 % of the housing stock is heated by district heating.

*Distribution*

The internal distribution of the heat in the houses follows one of the following principles: Single pipe system, Double pipe system, and Combined.

It is expected that the principles of distribution is important for the consumption of space heating as the single pipe systems are old systems without sufficient controlling potential (flow and temperature).

*BEMS*

To improve the heating system a building energy management system (BEMS) has been installed in many estates. BEMS is installed in the major part (69 %) of the estates managed by KAB.

Individual energy meters have been installed in all buildings and it has had a great impact on the tenants' energy behaviour as the energy consumption goes down by approximately 25 % when the meters are installed.

The use of condensing gas boilers has also had an important effect on the energy consumption but this information is not included in the KAB Statistics.

E.g. energy meters and condensing gas boilers were installed in a housing scheme in year 2003 and the yearly energy consumption dropped from 150 kWh/m2 to 105 kWh/m2 or 30%.

The tenants' energy behaviour and the energy management of the heating installation are two important issues which have a significant impact on the energy consumption of the estates. This information is not included in the KAB Statistics and they are not included in the Danish typology.

| Supply | Distribution | BEMS | Climatic data | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Single houses | | | Terrace houses | | | Building block | | | Mixed housing | | |
| | | | BR00 | BR01 | BR02 | BR00 | BR01 | BR02 | BR00 | BR01 | BR02 | BR00 | BR01 | BR02 |
| District heating | Single pipe | no | | | | | | | 64 | | | | | |
| | | yes | | | | | | | 241 | | | 102 | | |
| | Double pipe | no | 22 | | | 31 | | | 54 | 11 | 3 | | 20 | |
| | | yes | | | | | 8 | | 204 | 15 | 40 | 35 | | |
| | Combined | no | | | | | | | | | | | 10 | |
| | | yes | | | | | | | | 6 | 24 | | 84 | 4 |
| Natural gas | Single pipe | no | | | | | | | | | | | | |
| | | yes | | | | | | | | | | | | |
| | Double pipe | no | | | | | | | 34 | 2 | 2 | | | |
| | | yes | | | | | 11 | | | | | | 7 | |
| | Combined | no | | | | | | | | 1 | | | 1.1 | |
| | | yes | | | | | | | | | | | 10.2 | |
| CHP | Single pipe | no | | | | | | | 7 | | | 31 | | |
| | | yes | | | | | | | | | | | | |
| | Double pipe | no | 25 | | 57 | | | | | | 1 | | | |
| | | yes | | | | | | | | | | | | |
| | Combined | no | | | | | | | | | 3 | | | 2 |
| | | yes | | | | | | | | | | | 7 | |

**Figure 1 : Danish typology of the social housing stock.**

# 4. KILDEVÆNGET

## *4.1. Project description*

Name and location of the project: Kildevænget, Gladsaxe.

Kildevænget is a social housing stock with 450 housing units in a three floor level and basement. The total rented floor area is 35,136 m2 and the average size of the apartments is 78 m2. The whole settlement is heat supplied by district heating from a combined heat and power plant. The district heating is lead into the building blocks through a central boiler room and is distributed to five sub-boiler rooms. The domestic hot water is produced in each sub-boiler room from where the space heating and domestic hot water are distributed to the apartments through an internal district heating network with separate pipes for space heating and domestic hot water. The total consumption of district heating is monitored in the central boiler room and covers the total space heating and domestic hot water demand including losses from the internal district heating network.

Since the construction date several improvements have been introduced:

1985: The heat supply changed from oil to district heating.

1986: New windows with 2-layer glass with integrated air inlet dampers.

2003: New 4000 litre domestic hot water storage in each sub-boiler room.

2005: New internal district heating network.

2006: Automatic light control on the stair cases and in the basement.

2006: The pump in the internal distribution network is replaced by new automatically controlled pumps.

**Figure 2 : Photo of Kildevænget, south west facade.**

**Figure 3 : Kildevænget, north east facade.**

**Figure 4 : 3 kW pump for space heating distribution**

**Figure 5 : 4000 litre domestic hot water storage.**

**Figure 6 : Common laundry facilities in the basement.**

## *4.2. Building typology data*

Kildevænget represents the category in the Danish typology with the largest treated floor area:

| | |
|---|---|
| Climatic data: | Copenhagen |
| Type of building: | Building block |
| Year of construction: | 1958 (no energy requirement, BR0) |
| Heating supply: | District heating (CHP) |
| Distribution: | Single pipe system |
| BEMS: | yes |

## 4.3. Monitored heat consumption

The consumption of district heating, electricity and water for the whole settlement have been monitored during the last five years. The district heating is the total district heating that enters the central boiler room divided by the total heated floor area. The consumption of electricity is the common use excluding individual electricity usages in the apartments. The common electricity covers the pumps, lighting in staircases and basements, outdoor lighting, laundries and lightings in rooms for common activities. The monitored data are shown in Table 1.

**Table 1 : Monitored consumptions per treated floor area in Kildevænget.**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Gen |
|---|---|---|---|---|---|---|---|
| Heat | 144 | 132 | 129 | 131 | 135 | 135 | 134 |
| Water | 0.81 | 0.78 | 0.77 | 0.76 | 0.70 | | 0.76 |
| Elektricitet | 8.0 | 8.1 | 8.2 | 7.8 | 6.0 | | 7.6 |

The monitored data are adjusted compared with a normal climatic year and it is possible to compare the data year by year. The average energy consumption during the last five years is 134 kWh/m2 and it is 9 % above the average of the category which is 123 kWh/m2. In general the heat consumption in Kildevænget is too high mainly because the flow temperature of the internal distribution network is high and consequently the heat losses from the piping to the ground are too high. Also the tenants' energy behaviour is assessed to be bad. There are no explanations of the variations between years.

The energy manager has proposed an extension of the district heating heat exchanger to improve the operation in order to achieve lower heat losses from theinternal district heating network. Today the whole settlement receives a penalty from the district heating supply company as a result of too high return temperature. Also an awareness campaign for the tenants has been proposed to improve the operation of the radiators in the apartments. It is estimated that a 2 % energy saving can be achieved by better operation of the radiators and it is equivalent to 30.000 DKK per year (4000 Euro).

Automatic light control in stair cases has been installed in one block and an electricity saving of 70 % has been identified. It is recommended by the energy manager to install the automatic light control in the remaining stair cases.

## 4.4. Calculation of energy consumption

The energy needs for space heating and domestic hot water including losses in the internal district heating network are calculated by ASCOT and Be06 and the results are:

| | |
|---|---|
| Be06 | 158 kWh/m2 |
| ASCOT | 121 kWh/m2 |
| Målinger 2005 | 135 kWh/m2 |

*Assumptions*

The area of the building elements have been measured on the original drawings.

The input data to the ASCOT software are shown in Table 2.

**Table 2 : Input data to the ASCOT tool**

| **Project ID** | **Kildevænget** |
|---|---|
| Year of construction | 1958 |
| Size of the buiding project (treated floor area) | 1760 m² |
| Number of dwellings | 24 |
| Number of floor levels | 3 |
| Building category | Building block with flats |
| Central- or individual heating | Central heating system |
| Internal distribution | Insufficient insulation |
| Energy resource (Fuel type) | District heating |
| Efficiency of the heat production | 88% |
| Reference, electricity | 31 kWh/m² |
| Reference, water inclusive hot water | 0.70 m³/m² |
| Reference consumption hot water | 30% |
| **Weather data** | |
| Station | DK, Copenhagen |
| **Building characteristics** | |
| Wall, U-Value | 0.45 W/m²K |
| Roof, U-Value | 0.39 W/m²K |
| Floor, U-Value | 0.54 W/m²K |
| Window, U-Value [W/m2K] | 2.40 W/m²K |
| **Data for new heating system** | |
| Central- or individual heating | Central heating system |
| Heating supply system | District heating |
| Efficiency of the heat production | 95% |
| **Economic data** | |
| Investment of reference project | 0.00 DKK/m2 |
| Set aside (maintenance) | 2.5% % |
| Expected economic lifetime | 30.00 years |
| Discount rate | 5.0% |
| Tax of interest | 0.0% |
| Inflation of energy | 2.5% |
| Inflation of maintenance | 2.0% |

The whole settlement includes 16 building blocks, and block No. 15 is used for the Be06 calculations. The block consists of 24 dwellings in three floor levels with a total treated floor area of 1760 m2. The building block is calculated with unheated stair cases and basement.

The external wall is cavity brick wall with insulation between the outside. The flowing U-values have been used:

| | |
|---|---|
| External wall, 140 mm cavity wall with 10 % massive wall. | 0,45 W/m2K |
| Partition wall to staicases. | 1,75 W/m2K |
| Basement wall below ground level | 0,54 W/m2K |
| Basement wall above ground level | 0,54 W/m2K |
| Floor slap between ground floor and basement | 1,14 W/m2K |
| Floor in basement | 0,56 W/m2K |
| Roof/sealing | 0,39 W/m2K |
| Windows, 2 layer of glasses | 2,40 W/m2K |

The total window area is 18 % of the treated floor area.

The dwellings are ventilated by natural ventilation with extract air from kitchen and toilets.

## 4.5. Energy Scenario

The housing scheme is well preserved with regular maintenance and with some energy savings improvements. The energy consumption is high compared to the energy standard in new houses and the energy performance must be improved considerably if the houses should be attractive also in year 2050. It is assessed that comprehensive energy savings initiatives must be implemented if the housing scheme is still well preserved in year 2050. The following text describes how 60 % energy savings can be achieved by implementing different energy savings measures. 100 mm external wall insulation is proposed which in reality will be difficult since the present architectural design has great value and must be protected in the future. It is necessary to develop techniques which can improve the external wall without changing the architectural design of the building. The fresh air and good indoor air quality must be established by installing mechanical ventilation with heat recovery. This kind of installation needs space but different demonstration projects have shown attractive solutions in the existing housing stock. Utilisation of solar energy is proposed as supplementary energy supply system for heating domestic hot water. The system is a centralised system with two sq. solar collectors per dwelling and the existing distribution network for hot water. The present heat loss from distribution is high and in the future these losses will represent a bigger contribution of the total heat demand in the future when net space heating demand is reduced. Therefore it is necessary to improve the distribution network, and research is necessary to achieve a full energy efficient supply system for housing.

The energy consumption is calculated by the software Be06 when implementing different energy saving technologies and the results are shown in Figure 7. The proposed energy improvements give a total energy saving of 65 %.

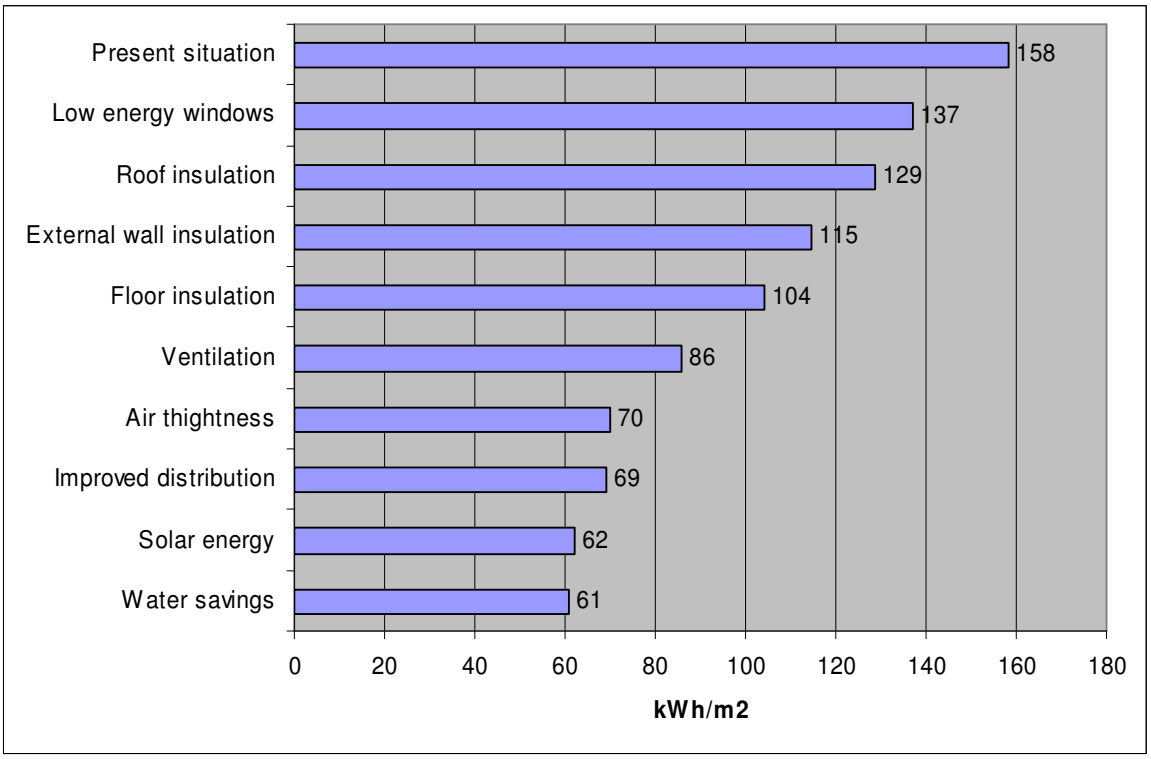


**Figure 7 : Energy savings obtained by installing different energy savings techmologies.**

In addition to the energy savings for space heating the water savings also gives a lower heat demand for producing domestic hot water.

- Installation of new low energy windows reduce the energy consumption for space heating from 158 kWh/m2 to 137 kWh/m2.
- Extra insulation on the roof reduces the heat consumption to 129 kWh/m2.
- Wall and floor insulation reduces the heat consumption to 115 kWh/m2.
- Mechanical ventilation with heat recovery reduces the heat consumption to 86 kWh/m2 assuming counter flow heat exchanger and low energy DC-fans.
- Improved air tightness to passive house level (0.6 l/sm2 with an air pressure on 50 Pa) reduces the yearly heat consumption to 70 kWh/m2.
- Improved insulation of district heating distribution network reduces the energy consumption to 69 kWh/m2.
- Solar heating system for heating domestic hot water reduces the heat demand to 62 kWh/m2. The solar heating system is a central system with a collector area of 2 sq. per dwelling.
- Finally water savings reduces the heat consumption to 60 kWh/m2.

- Roof insulation: By adding 200 mm insulation in the roof attic the energy for heating is reduced by 8 %. The roof attic is empty and it will be easy to add a new layer of insulation.

Low e-windows: Installing new windows in the building reduces the needs for heating. The U-value of the existing windows is 3.1W/m2K, and the value of the new low e-windows is 1.2 W/m2. 29 % savings are achieved compared to the base case.

Façade insulation: 150 mm external insulation of the entire façade will reduce the energy for space heating. An external insulation will effectively reduce the transmission losses including minimising the heat losses through cold bridges. The external insulation is a dramatically change of the building but it is necessary if the target of 75 % reduction in CO2 emission has to be achieved.

Floor slap insulation. The floor slap between ground floor and basement is insulated by 100 mm Rockwool. The basement is unheated and the insulation will reduce the transmission losses from the apartments to the basement.

Mechanical ventilation. By installing mechanical ventilation with heat recovery (MVHR) the ventilation losses are reduced. It is assumed high temperature effectiveness (85 %) with energy efficient distribution ducts and fans. To achieve the estimated saving it is anticipated that the building is very airtight obtained during installation of new windows and the external insulation of the building envelope.

DHW circuit for SH. All the technologies mentioned above reduce the need for space heating, and the main consumer is now the domestic hot water production and distribution. The space heating supply system is proposed to be changed by removing the whole internal distribution network, including the radiators in the apartments, and utilise the domestic hot water circuit for space heating, and install a heating coil in the air inlet ducts of the mechanical ventilation system. That will reduce the distribution losses considerably.

DHW circuit: Improvement of the distribution network for domestic hot water. The total energy consumption is now reduced by 76 % compared to the base case.

Solar heating: Finally solar heating for domestic hot water is proposed as a central system using the domestic hot water storage tanks in the five sub-boiler room as solar storage tanks. The DHW circuit will distribute the solar energy for domestic hot water and space heating as well. 1 m2 solar collector per apartment is proposed which means five systems with 90 m2 solar collector each. The base energy consumption for heating is now reduced by 90 %.

The energy savings obtained by introducing the energy savings measures mentioned above are also calculated by the Ascot tool and the results are shown in Figure 8 together with the Be06 results. It seems that the estimated savings calculated by the two tools corresponds quit well.

The different energy savings technologies are not identical defined in the two tools as the tenants' behaviour is not included in the Be06 programme, and losses from production and distribution are not defined in the same manner. In spite of these differences the results from the two calculation tools are close to each other.

## 4.6. Economic viability

The cost benefit analysis is calculated by use of the calculation tool ASCOT and the results are given in Table 3.

**Table 3 : Key figures of the cost benefit analysis – Kildevænget.**

| | | per sqm. | per dwell | per block | per settlement |
|---|---|---|---|---|---|
| Present heat consumption | kWh | 121 | 8873 | 212960 | 3993000 |
| Reduced heat consumption | kWh | 25.2 | 1848 | 44352 | 831600 |
| Present CO2 emission | ton | 0.034 | 2.53 | 60.7 | 1137.7125 |
| Reduced CO2 emission | ton | 0.013 | 0.96 | 22.9 | 430.2375 |
| Present running costs | kr. | 18 | 1,339 | 32,126 | 602,358 |
| Reduced running costs | kr. | 14 | 1,013 | 24,320 | 456,000 |
| Extra investment costs | kr. | 191 | 13,994 | 335,867 | 6,297,501 |

The yearly heat demand is reduced from 121 to 25 kWh/m2 corresponding to an 80 % saving. To achieve the high rate of saving it requires an investment in low energy technologies of 14.000 Euro per dwellings or 6.3 million for the whole settlement.

The running costs are reduced from 1.340 to 1.000 Euro per dwelling corresponding to 20 %. The saving in percent is relatively low as the energy savings technologies require extra maintenance costs. That means the economic viability is not attractive for the tenants as the simple pay back time is calculated to 43 years. Even with an increase in the energy costs the investment is not a profitable investment for the tenants.

The following energy costs have been used in the economic costs calculations:

| | | |
|---|---|---|
| District heating | 54 | Euro per MWh |
| Electricity | 276 | Euro per MWh |
| Water | 5.0 | Euro per m3 |

The objective of the Factor 4 project is to reduce the CO2 emission caused by the energy use in the building. This means heating, electricity and water. The Ascot programme is used to calculate the CO2 emission and the list of improvements shown in Table 4 are proposed in Kildevænget to be able to achieve the Factor 4 objective.

By introducing all the technologies mentioned in the list the CO2 emission will be reduced by 63 %, and the Factor 4 objective of 75 % will not be reached. The CO2 emission from heating is reduced by 85 % and the electricity by only 50 % which results in a total reduction of 63 %. It is assessed that it will be difficult to achieve further savings on site, but the CO2 emission from public electricity supply will contribute to further CO2 reduction as renewable sources like wind power and waste energy are expected to be more common as the energy resources in the future, and it will bring the total savings above the target of 75 %.

**Table 4 : Proposed energy savings of the case study – Kildevænget.**

| | | Technologies | Already implemented | Possible implementation | Implementation needed Factor 4 |
|---|---|---|---|---|---|
| **Heating** | | | | | |
| H | 1 | Passive solar heat design | | | |
| H | 2 | Controlled mechanical ventilation | | | x |
| H | 3 | Airtightness | | | x |
| H | 4 | Energy savings through water savings | | | x |
| H | 5 | Energy savings through tenants behaiviour | | | x |
| H | 6 | Windows | | | x |
| H | 7 | Individual meters | x | | |
| H | 8 | Cold bridges reduction | | | x |
| H | 9 | Additional thermal insulation of walls | | | x |
| H | 10 | Additional thermal insulation of roof | | | x |
| H | 11 | Additional thermal insulation of floor | | | x |
| H | 12 | Pipe insulation | | | x |
| H | 13 | Balance between distribution | | | |
| H | 14 | Cooling | | | |
| H | 15 | Building energy management system | | x | |
| H | 16 | Heat pumps | | | |
| H | 17 | Thermostatic valves | x | | |
| H | 18 | New heating system including CHP | | x | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| **Water** | | | | | |
| W | 1 | Individuel meters | x | | |
| W | 2 | Solar thermal collectors for domestic hot water | | | x |
| W | 3 | Hot water distribution | | | x |
| W | 4 | New hot water tank with semi-istantaneous system | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| **Electricity** | | | | | |
| E | 1 | Energy efficient lighting | | | x |
| E | 2 | Electricity savings through ventilation | | | x |
| E | 3 | Electricity savings through tenants behaivour | | | x |
| E | 4 | Hard white goods - Grade A or better | | x | |
| E | 5 | Roofed clothes drying yards | | | x |
| E | 6 | Daylight optimisation | | | |
| E | 7 | PV panels | | x | |
| E | 8 | Regulation of circulation pumps of individual biolers | x | | |
| E | 9 | Closing audiovisual and electric equipment | | | |
| E | 10 | Collective laundry | x | | |

# 5. Bøgehegnet

## 5.1. Description

The buildings in Bøgehegnet are constructed in 1985 and the site is located south of Copenhagen in the municipality of Greve. The settlement consists of 298 dwellings with a total treated floor area of 24,165 m2 with an average of 81 m2 per dwellings. The settlement is constructed as a mixed housing in a 2 – 4 floor level.

The houses are heat supplied with district heating supplied to a common heating plant. The domestic hot water is produced in the heating plant and distributed to the dwellings by an internal distribution network partly in the ground and partly in the basement.

The houses are ventilated by mechanical ventilation system.

**Figure 8 : Photo of the social housing stock – Bøgehegnet.**

## 5.2. Building typology data

The typology is defined as:

| | |
|---|---|
| Climatic data: | Copenhagen |
| Type of building: | Mixed housing |
| Year of construction: | 1985 (no energy requirement, BR01) |
| Heating supply: | District heating |
| Distribution: | Single pipe system |
| BEMS: | yes |

## 5.3. Monitored heat consumption

The total yearly demand of heat, water and electricity are monitored and are shown in Table 5.

**Table 5 : Monitored consumptions per treated floor area, Bøgehegnet.**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Average |
|---|---|---|---|---|---|---|---|
| Heat | 107 | 100 | 104 | 105 | 109 | 105 | 105 |
| Water | 1.06 | 1.04 | 1.10 | 1.10 | 1.09 | | 1.08 |
| Electricity | 7.3 | 7.2 | 7.1 | 6.1 | 6.1 | | 6.8 |

The monitored heat consumption is normalised to the standard year. Heat and water consumption is total demand of the whole settlement. The electricity covers the common consumption inclusive of lighting in common inside area and outside area, and the electricity consumption in the common laundry facilities.

The monitored data are below average of compatible social housing schemes.

## 5.4. Calculated energy consumption

The energy consumption is calculated for one building block in a 2½ floor level with total of 12 dwellings. There are three stair cases with one apartment in one floor level and two apartment in a two floor level on first floor.

The energy needs for space heating and domestic hot water, including losses in the internal district heating network, are calculated by ASCOT and Be06 and the results are:

| | |
|---|---|
| Be06 | 135 kWh/m2 |
| ASCOT | 107 kWh/m2 |
| Målinger 2005 | 105 kWh/m2 |

There is a good correspondance between monitored and calculated heat demand when using ASCOT, but the Be06 results is different from the monitored value.

**Assumptions:**

*Ascot*

The area of the building elements has been measured on the original drawings. The input data to the ASCOT software are shown in Table 6.

**Table 6 : Input data to the ASCOT tool.**

| | |
|---|---|
| **Projekt ID** | **Bøgehegnet** |
| Byggeår | 1985 |
| Bygningsareal | 951 m² |
| Antal boliger | 12 |
| Antal etager | 3 |
| Bygningskattegori | Etageboliger |
| Central- eller individuel opvarmning | Central opvarmning |
| Internt varmefordelingsnet | Mangelfuld isolering |
| Varmeforsyningsanlæg | Fjernvarme |
| Virkningsgraden af internt varmeanlæg | 88% |
| Elforbrug | 31 kWh/m² |
| Vandforbrug | 1.10 m³/m² |
| Varmtvandsforbrug | 30% |
| **Vejrdata** | |
| Vejrstation | DK, Copenhagen |
| **Building characteristics** | |
| Vægge (U-værdi) | 0.34 W/m²K |
| Loft (U-værdi) | 0.21 W/m²K |
| Terrændæk (U-værdi) | 0.23 W/m²K |
| Gennemsnitlig U-værdi for vinduer | 2.40 W/m²K |
| **Data for nyt varmeanlæg** | |
| Internt varmefordelingsnet | Central opvarmning |
| Varmeforsyningsanlæg | Fjernvarme |
| Virkningsgrad af internt varmeanlæg | 95% |
| **Økonomiske data** | |
| Investering i referenceprojekt | 0.00 DKK/m2 |
| Drifts og vedligehold | 2.5% % |
| Levetid | 30.00 years |
| Effektive årlige rente | 5.0% |
| Skat af renteindtægter | 0.0% |
| Prisstigningstakt på energi | 2.5% |
| Prisstigningstakt på vedligehold | 2.0% |

*Be06*

One building block in a 2½ floor level without basement is calculated. The following heat loss coefficient has been used:

| | | |
|---|---|---|
| External concrete wall | | 0.41 W/m2K |
| External light wall | 0.35 W/m2K | |
| External heavy wall | 0,29 W/m2K | |
| Floor | | 0.23 W/m2K |
| Roof | | 0.21 W/m2K |
| Windows, 2-layer | 2.40 W/m2K | |

## 5.5. Energy Senario

The whole settlement is constructed in 1985 following the energy requirement from 1982 (BR82). Different façade constructions have been used with possible energy improvement by installing extra insulation. The mechanical exhausted air ventilation system can be improved by installing inlet ducts with heat recovery.

There are good possibilities to installed solar energy. The solar energy can be installed as a centralised system connected to the internal distribution network.

The savings obtained by implement different energy savings technologies are shown in Figure 9.

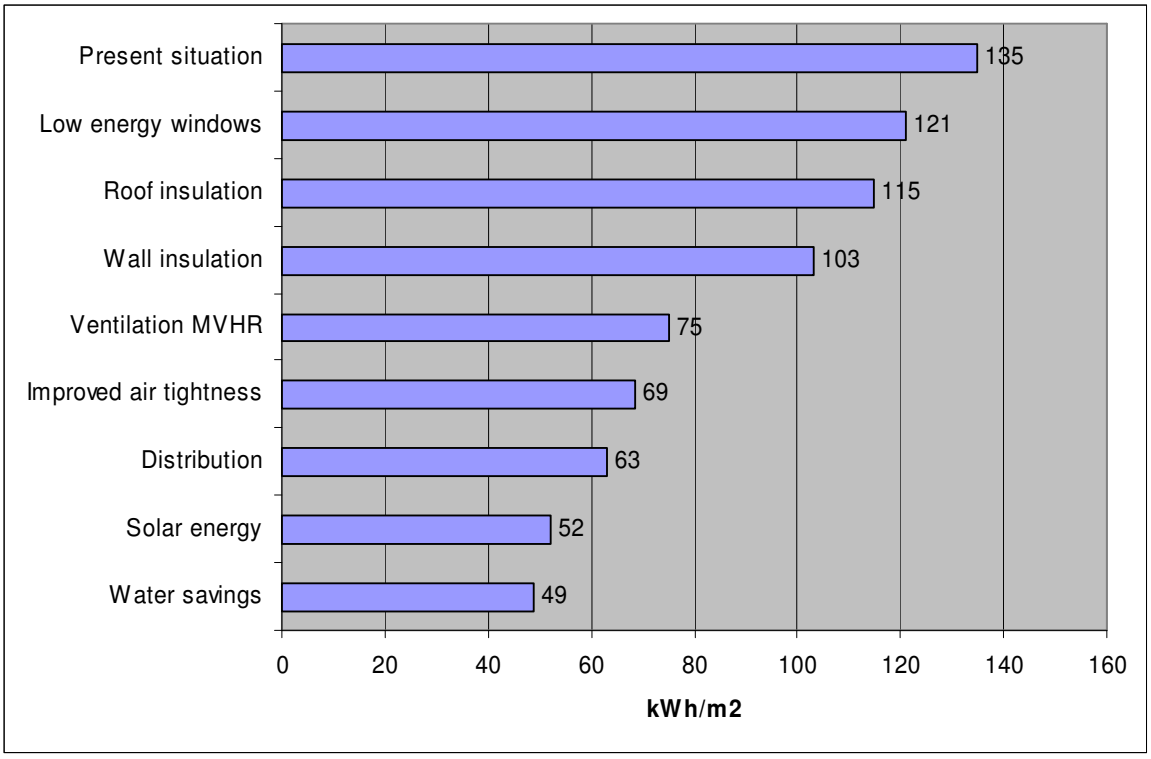


**Figure 9 : Calculated energy consumption for space heating by installing different energy savings technologies.**

- Installation of new low energy windows reduce the energy consumption for space heating from 135 kWh/m2 to 121 kWh/m2.
- Extra insulation of the roof reduces the heat consumption to 115 kWh/m2.
- Wall and floor insulation reduces the heat consumption to 103 kWh/m2.
- Mechanical ventilation with heat recovery reduces the heat consumption to 75 kWh/m2 assuming counter flow heat exchanger and low energy DC-fans.
- Improved air tightness to passive house level (0.6 l/sm2 with an air pressure on 50 Pa) reduces the yearly heat consumption to 69 kWh/m2.
- Improved insulation of district heating distribution network reduces the energy consumption to 63 kWh/m2.

- Solar heating system for heating domestic hot water reduces the heat demand to 52 kWh/m2. The solar heating system is a central system with a collector area of 2 sq. per dwelling.
- Finally water savings reduces the heat consumption to 49 kWh/m2.

## 5.6. Economic Viability

The cost benefits analysis of the energy improvements are calculated with ASCOT and the results are shown Table 7.

**Table 7 : Key figures from the cost benefit analysis, Bøgehegnet.**

| | | per sqm. | per dwell | per block | per settlement |
|---|---|---|---|---|---|
| Present heat consumption | kWh | 107 | 8456 | 101,472 | 2,578,406 |
| Reduced heat consumption | kWh | 30 | 2338 | 28,055 | 712,868 |
| Present CO2 emission | ton | 0.033 | 3 | 31 | 787 |
| Reduced CO2 emission | ton | 0.014 | 1 | 13 | 336 |
| Present running costs | Euro | 19 | 1,531 | 18,377 | 466,966 |
| Reduced running costs | Euro | 16 | 1,255 | 15,065 | 382,812 |
| Extra investment costs | Euro | 179 | 14,173 | 170,070 | 4,321,507 |

The calculated yearly heat demand is reduced from 107 to 30 kWh/m2 according to 72 %. The lower energy consumption for heating and electricity reduced the CO2 emission by 1.2 ton per dwelling corresponding to 47 %. This reduction requires an investment in extra energy saving measures of 4.3 million Euros for the whole settlement.

The total expenditure for energy and water will be reduced from 1.531 Euro to 1.255 Euro per year or 14 %. The running costs are only reduced by 14 % and do not correspond to the high energy savings, as the maintenance costs for the new energy savings technologies demand extra maintenance costs. This means that simple pay back time is 51 years which is not economic attractive for the tenants. Even if the supply costs are increased this will not change the fact that energy improvements are a good investment.

**Table 8 : Proposed energy savings technologies in Bøgehegnet.**

| | | Technologies | Already implemented | Possible implementation | Implementation needed Factor 4 |
|---|---|---|---|---|---|
| **Heating** | | | | | |
| H | 1 | Passive solar heat design | | | |
| H | 2 | Controlled mechanical ventilation | | | x |
| H | 3 | Airtightness | | | x |
| H | 4 | Energy savings through water savings | | | x |
| H | 5 | Energy savings through tenants behaiviour | | | x |
| H | 6 | Windows | | | x |
| H | 7 | Individual meters | x | | |
| H | 8 | Cold bridges reduction | | | x |
| H | 9 | Additional thermal insulation of walls | | | x |
| H | 10 | Additional thermal insulation of roof | | | x |
| H | 11 | Additional thermal insulation of floor | | | x |
| H | 12 | Pipe insulation | | | x |
| H | 13 | Balance between distribution | | | |
| H | 14 | Cooling | | | |
| H | 15 | Building energy management system | x | | |
| H | 16 | Heat pumps | | | |
| H | 17 | Thermostatic valves | x | | |
| H | 18 | New heating system including CHP | | | |
| | | | | | |
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| | | | | | |
| **Water** | | | | | |
| W | 1 | Individuel meters | x | | |
| W | 2 | Solar thermal collectors for domestic hot water | | | x |
| W | 3 | Hot water distribution | | | |
| W | 4 | New hot water tank with semi-istantaneous system | | | |
| | | | | | |
| | | | | | |
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| | | | | | |
| **Electricity** | | | | | |
| E | 1 | Energy efficient lighting | | | x |
| H | 2 | Electricity savings through ventilation | | | x |
| H | 3 | Electricity savings through tenants behaivour | | | x |
| H | 4 | Hard white goods - Grade A or better | | x | |
| H | 5 | Roofed clothes drying yards | | | x |
| H | 6 | Daylight optimisation | | | |
| H | 7 | PV panels | | x | |
| H | 8 | Regulation of circulation pumps of individual biolers | | | x |
| H | 9 | Closing audiovisual and electric equipment | | x | |
| H | 10 | Collective laundry | x | | |

# 6. Egebjergvang

## 6.1. Description

The social housing stock was build in 1985 in Ballerup, a suburb to Copenhagen, and consists of 146 dwellings with a total treated floor area of 10,248 sq. The houses are built as mixed housing one, two or three floor levels. The three floor level building blocks are with basement.

The houses are heat supplied from a central heating plant with natural gas. The domestic hot water is produced in the heating plant and is distributed to the dwellings by an internal distribution network. The space heating is distributed in a separate network. The maximum heating power of the gas furnace is 900 kW, and the volume of the hot water storage tank is 3500 litres and supply the whole settlement with hot water.

I 2004 the central heating plant was renovated with a new gas furnace and new high energy efficient pumps. At the same time individual heat meters were installed in all the dwellings.

**Figure 10 : Photo of the Egebjergvang social housing stock.**

## 6.2. Building Typology Data

Egebjergvang represents the category in the Danish typology with the largest treated floor area:

| | |
|---|---|
| Climatic data: | Copenhagen |
| Type of building: | Mixed housing |
| Year of construction: | 1985 |
| Heating supply: | Natural gas, central heating |

| | |
|---|---|
| Distribution: | Combined pipe system |
| BEMS: | yes |

## 6.3. Monitored heat consumption

The total yearly demand of heat, water and electricity are monitored and are shown in Table 9.

**Table 9 : Monitored consumption.**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Average |
|---|---|---|---|---|---|---|---|
| Heat | 154 | 150 | 154 | 145 | 118 | 105 | 124 |
| Water | 0.98 | 0.97 | 0.98 | 0.93 | 0.88 | | 1.37 |
| Electricity | 13.4 | 13.3 | 13.5 | 13.3 | 12.3 | | 9.42 |

The monitored heat consumption is normalised to the standard year. Heat and water consumption is the total demand of the whole settlement. The electricity covers the common consumption inclusive of lighting in common inside and outside areas, and the electricity consumption in the common laundry facilities.

Compared with building of same typology the monitored heat and water consumption is low, but the electricity is higher. Especially the water consumption is much lower than the average. The heat consumption was from 2003 to 2005 reduced by 35 % and corresponds to the energy improvements which have been implemented in the heating plant and also by installing individual meters.

The electricity consumption is high and one reason is that the lighting in the base is always turned on. The electricity consumption is reduced from 2003 to 2004 properly caused by installing new high efficient pump in the central heating plant.

## 6.4. Calculated energy consumption

The energy consumption is calculated for one building block in a 2 floor level with a total of 6 dwellings, and a total treated floor area of 532 m2 with an average of 89 m2. The considered block is assumed to be representative for the whole settlement and the calculated key figures can be used for the whole settlement.

The energy need for space heating and domestic hot water, including losses in the internal district heating network, are calculated by ASCOT and Be06 and the results are:

| | |
|---|---|
| Be06 | 117 kWh/m2 |
| ASCOT | 97.5 kWh/m2 |
| Monitoring 2005 | 105 kWh/m2 |

There is a good correspondance between monitored and calculated heat demand when using ASCOT but the Be06 results is different from the monitored value.

*Assumptions*

*Ascot*

The area of the building elements has been measured on the original drawings. The input data to the ASCOT software are shown in Table 10.

**Table 10 : Input data for the ASCOT calculations.**

| | | |
|---|---|---|
| **Project ID** | **Egebjergvang** | |
| Year of construction | 1985 | |
| Size of the buiding project (treated floor area) | 532 | m² |
| Number of dwellings | 6 | |
| Number of floor levels | 2 | |
| Building category | Building block with flats | |
| Central- or individual heating | Central heating system | |
| Internal distribution | Medium insulation | |
| Energy resource (Fuel type) | District heating | |
| Efficiency of the heat production | 90% | |
| Reference, electricity | 31 | kWh/m² |
| Reference, water inclusive hot water | 0.88 | m³/m² |
| Reference consumption hot water | 30% | |
| **Weather data** | | |
| Station | DK, Copenhagen | |
| **Building characteristics** | | |
| Wall, U-Value | 0.25 | W/m²K |
| Roof, U-Value | 0.35 | W/m²K |
| Floor, U-Value | 0.32 | W/m²K |
| Window, U-Value [W/m2K] | 2.80 | W/m²K |
| **Data for new heating system** | | |
| Central- or individual heating | Central heating system | |
| Heating supply system | N-gas | |
| Efficiency of the heat production | 90% | |
| **Economic data** | | |
| Investment of reference project | 0.00 | DKK/m2 |
| Set aside (maintenance) | 2.5% | % |
| Expected economic lifetime | 30.00 | years |
| Discount rate | 5.0% | |
| Tax of interest | 0.0% | |
| Inflation of energy | 2.5% | |
| Inflation of maintenance | 2.0% | |

*Be06*

The Egebjergvang consist of light and heavy external walls, and since the energy consumption depends of the thermal mass of the building construction this has been taken into account regarding the calculation model. 40 % of the external wall is light construction. The heat loss coefficient of the light external wall is 0.264 W/m2K and for the heavy construction 0.247 W/m2K.

The cold bridges are calculated by using the following figures:

Around windows: 160 m med 0,06 W/mK.

The foundations: 68 m med 0,18 W/mK.

The total area of the windows and doors is 57 m2 and correspond to 11 % of the treated floor area, which means that the window area is small compared to the norms of 22 %, and consequently reduces the utilisation of the passive solar energy. The windows have two layers of glass with an estimated heat loss coefficient of 2.8 W/m2K and a g-value of 0.75.

There is mechanical exhausted ventilation from kitchen and bath room. Constant air flow at 20 l/sm2 from kitchen and 15 l/sm2 from bath room with a total of 210 l/s according to 39 l/sm2. The electricity consumption for the exhausted air fans is 1.8 kJ/m3.

The heat for space heating and the domestic hot water is produced in the central heating plant and distributed to the dwellings in two separate distribution network. The distribution network is a combined system with flow temperature of 70/40 oC with a total length of 70 m, and a heat loss coefficient of 0.2 W/m. The circulation pump is automatically controlled with a nominal power of 120 W. The length of the distribution network for domestic hot water is 60 m with a heat loss coefficient of 0.2 W/mK, and a pump power of 30 W.

The total hot water consumption is 250 l/m2 heated, and a hot water storage tank of 131 litres.

The figures above correspond to the considered building block with six dwellings.

## 6.5. Energy senario

The estimated energy savings obtained by the implementation of different energy saving technologies are shown in Figure 11. The total savings are 74 %, and the reduced energy demand correspond to the low energy houses class 1 requirements in the Danish building regulation.

The present yearly energy consumption for space heating and domestic hot water is calculated to 117 kWh/m2, and it is above the monitored consumption in 2005 whish was 105 kWh/m2.

- New windows with a heat loss coefficient of 1.2 W/m2K will reduce the heat consumption to 101 kWh/m2. The new windows have a net solar energy utilisation factor of 0.65.
- The present insulation thickness in the roof is only 100 m which is a poor insultation compared to standard today. Additional 200 mm insulation will bring the heat demand down to 85.7 kWh/m2.
- The wall and the floor are insulated with additional 100 mm insulation material and the heat demand is reduced to 74 kWh/m2.
- Mechanical ventilation with heat recovery reduces the heat demands to 59 kWh/m2. It is assumed that the temperature efficiency of the heat recovery unit is 85 %.

- Air tightness of the building will reduce the heat consumption to 46.7 kWh/m2. It is assumed that the air tightness is improved from 2.5 to 0.6 l/sm2 with 50 Pa depressurised test of the building.
- The internal distribution network is improved by extra insulation.
- A solar heating system is proposed for heating domestic hot water, and the energy consumption is now 34.2 kWh/m2

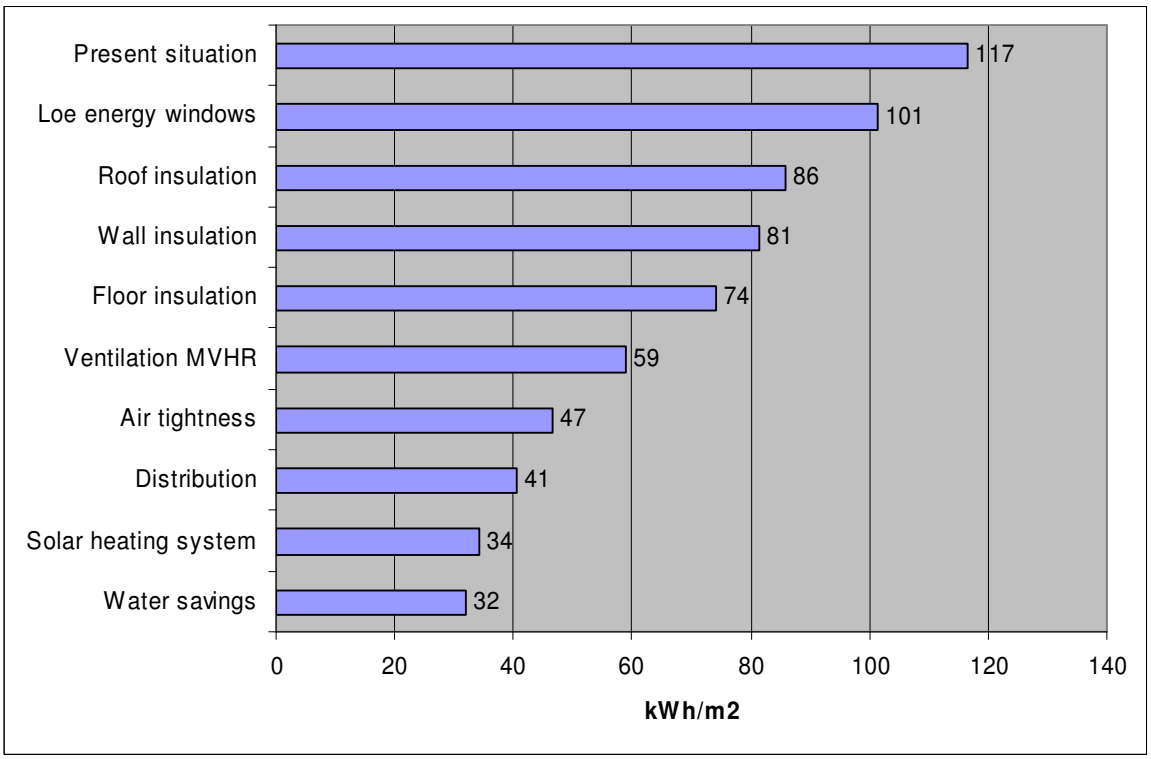


**Figure 11 : Energy savings obtained by installing different energy savings technologies.**

## 6.6. Economic Viability

By using the Be06 software the above mentioned energy saving technologies will reduce the total heat consumption by 74 %, and the ASCOT software calculated the same percentage of savings. The key figures from the ASCOT calculation are shown in Table 11.

**Table 11 : Key figures of the cost benefit analysis, Egebjergvang.**

| | | per sqm | per dwellig | per block | Whole settlem |
|---|---|---|---|---|---|
| Present heat demand | kWh | 98 | 8645 | 51870 | 999180 |
| Reduced heat demand | kWh | 26 | 2270 | 13619 | 262349 |
| Present CO2 emission | ton | 0.029 | 2.5 | 15.2 | 293 |
| Reduced CO2 emission | ton | 0.012 | 1.1 | 6.5 | 125 |
| Present running costs | kr. | 21 | 1,852 | 11,110 | 214,009 |
| Reduced running costs | kr. | 15 | 1,318 | 7,910 | 152,375 |
| Extra investment | kr. | 187 | 16,566 | 99,395 | 1,914,668 |

By improving all the buildings in Egebjergvang with the improvements described above the energy consumption will be reduce from 1,000,000 kWh to 300,000 kWh. The CO2 emission go down from 1.3 ton to 0.7 ton per dwelling corresponding to 42 %. The extra investment costs are approximately 2 million Euros with a simple pay back time of 37 years.

**Table 12 : Proposed energy savings of the case study, Egebjergvang.**

| | | Technologies | Already imple-mented | Possible implemen-tation | Implemen-tation needed Factor 4 |
|---|---|---|---|---|---|
| **Heating** | | | | | |
| H | 1 | Passive solar heat design | | | |
| H | 2 | Controlled mechanical ventilation | | | x |
| H | 3 | Airtightness | | | x |
| H | 4 | Energy savings through water savings | | | x |
| H | 5 | Energy savings through tenants behaiviour | | | x |
| H | 6 | Windows | | | x |
| H | 7 | Individual meters | x | | |
| H | 8 | Cold bridges reduction | | | x |
| H | 9 | Additional thermal insulation of walls | | | x |
| H | 10 | Additional thermal insulation of roof | | | x |
| H | 11 | Additional thermal insulation of floor | | | x |
| H | 12 | Pipe insulation | | | x |
| H | 13 | Balance between distribution | | | |
| H | 14 | Cooling | | | |
| H | 15 | Building energy management system | x | | |
| H | 16 | Heat pumps | | | |
| H | 17 | Thermostatic valves | x | | |
| H | 18 | New heating system including CHP | x | | |
| | | | | | |
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| | | | | | |
| **Water** | | | | | |
| W | 1 | Individuel meters | | | x |
| W | 2 | Solar thermal collectors for domestic hot water | | | x |
| W | 3 | Hot water distribution | | | x |
| W | 4 | New hot water tank with semi-istantaneous system | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| **Electricity** | | | | | |
| E | 1 | Energy efficient lighting | | | x |
| H | 2 | Electricity savings through ventilation | | | x |
| H | 3 | Electricity savings through tenants behaivour | | | x |
| H | 4 | Hard white goods - Grade A or better | | x | |
| H | 5 | Roofed clothes drying yards | | | x |
| H | 6 | Daylight optimisation | | | |
| H | 7 | PV panels | | x | |
| H | 8 | Regulation of circulation pumps of individual biolers | x | | |
| H | 9 | Closing audiovisual and electric equipment | | x | |
| H | 10 | Collective laundry | x | | |