TotalConcept

# Implementation of the Total Concept method in twelve buildings in Northern European countries

## Evaluation of national results

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## Introduction

This report evaluates the experiences from twelve pilot studies, in five north European countries, implementing the Total Concept method. Results after each step of the Total Concept method are analysed regarding energy savings and cost effectiveness and experiences from the working process are collected with interviews and questionnaires.

## Pilot buildings

Description of the pilot buildings is shown in Table 1. Step 1 was executed for 12 building of which six are office buildings, three are schools, and three are categorised as other types of buildings.

Table 1 Description of the pilot buildings

| | | | |
|---|---|---|---|
| **Denmark** | | | |
| |  |  | |
| Pilot building | Ballerup Town Hall | Lyngby Port | |
| Type of building | Administrative | Office | |
| Year built | 1975 | 1992 | |
| Heated area, m² | 16 321 | 20 630 | |
| **Estonia** | | | |
| |  |  |  |
| Pilot building | Gonsiori 29, Tallinn | Kiriku 2, Tallinn | Pärnu Koidula Gümnaasium |
| Type of building | Office | Office | School |
| Year built | 1950 | 18th century | 1978 |
| Heated area, m² | 6 797 | 1 877 | 8 184 |
| **Finland** | | | |
| |  |  | |
| Pilot building | Oulu Healthcare Centre | Tampere Hall | |
| Type of building | Healthcare Centre | Concert centre | |
| Year built | 1934 | 1990 | |
| Heated area, m² | 5 303 | 28 357 | |
| **Norway** | | | |
| |  |  | |
| Pilot building | Kaarstadbygningen | Vegkontoret Steinkjer | |
| Type of building | University | Office | |
| Year built | 1922 | 1967 | |
| Heated area, m² | 2 800 | 4 330 | |
| **Sweden** | | | |
| |  |  |  |
| Pilot building | Högsbo 20:22 | Norrtälje prison | Segevångsskola |
| Type of building | Office | Prison | School |
| Year built | 1982 | 1958 | 1960-ies |
| Heated area, m² | 14 543 | 8 030 | 5 386 |

## Energy use in the pilot buildings

Energy use in the pilot buildings before the implementation (baseline) of the energy saving measures is shown in Figure 1. One pilot building (Tampere Hall, Finland) has district cooling. The pilot buildings in Norway are heated with hydronic heating from an electric boiler.

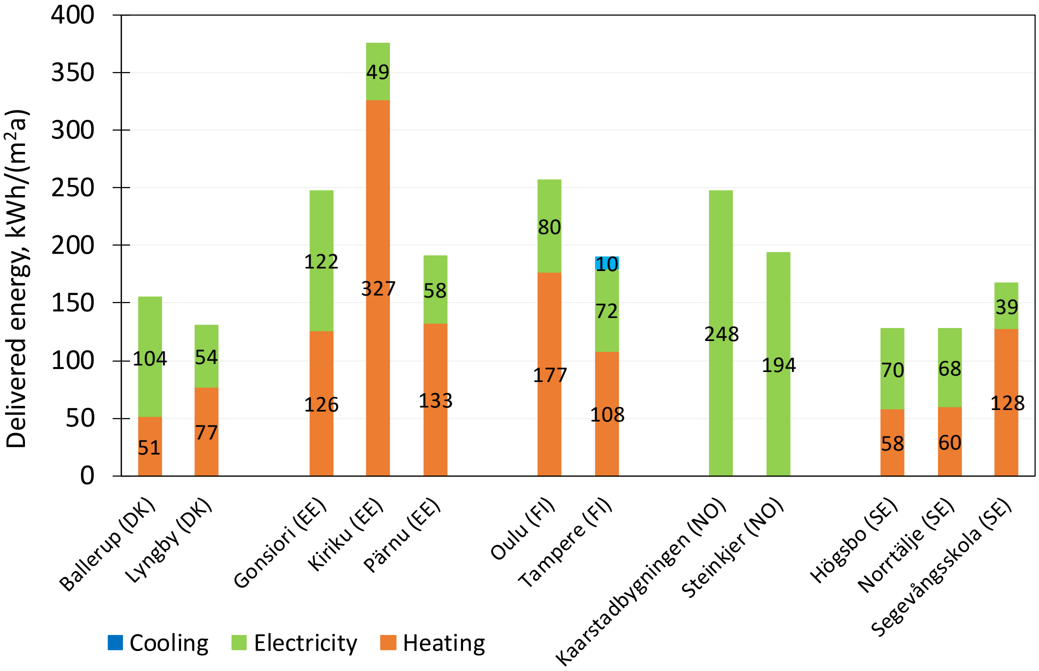


Figure 1 Baseline energy use in the pilot buildings before the implementation of measures

The energy use in the pilot buildings shows that there are no significant differences in the energy use of the pilot buildings in the different countries. Therefore, it is reasonable to analyse the energy consumption of the pilot buildings not by country, but by type of building, see Figure 2.

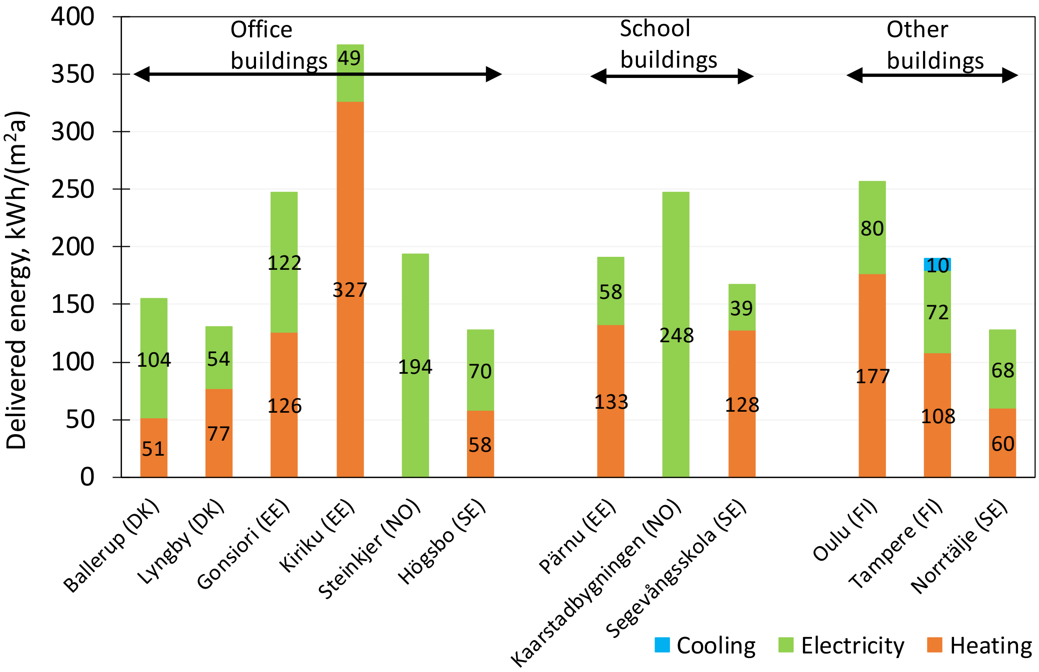


Figure 2 The baseline energy use in the different types of pilot buildings

The median heating energy use of the office buildings was 78 kWh/(m²a) and electricity use was 87 kWh/(m²a). The median electricity use of the pilot office buildings is in the same range as the other office buildings in Estonia (86 kWh/(m²a) [1]) and in Sweden (93 kWh/(m²a) [2]). The median heating energy use of the pilot office buildings was approximately 40% lower than in the other office buildings in Estonia (137 kWh/(m²a) [1]) and 14% lower than in the office buildings in Sweden (91 kWh/(m²a) [2]). This shows that energy consumption the pilot office buildings was lower than the average of the office buildings in the region.

The median heating energy use of the school buildings was 133 kWh/(m²a) and electricity use 58 kWh/(m²a). The heating energy use of the pilot school buildings is in the same range as the other school buildings in Estonia (129 kWh/(m²a) [3]) and in same range as in the school buildings in Sweden (136 kWh/(m²a) [2]). The median electricity use was twice as high as in the other school buildings in Estonia (25 kWh/(m²a) [3]) and slightly lower than in the school buildings in Sweden (68 kWh/(m²a) [2]).

## Energy savings

The estimated energy use of the pilot buildings after implementation of energy saving measures is shown in Figure 3. The estimations after STEP 1 and STEP2 are shown in order to illustrate the changes after the renovation process. The Town Hall of Ballerup, the Kaarstad building, Segevang school and Oulu Centre were not part of STEP 2. The average reduction in the delivered energy use after STEP 1 was 70 kWh/(m²a) and the average reduction after STEP 2 was 60 kWh/(m²a). The decrease in planned delivered energy reduction after STEP 2 occurred because not all the initially planned measures were carried out. Almost all the pilot cases had some measures, which were not carried out (see report "Implementation of the Total Concept method in 12 pilot buildings").

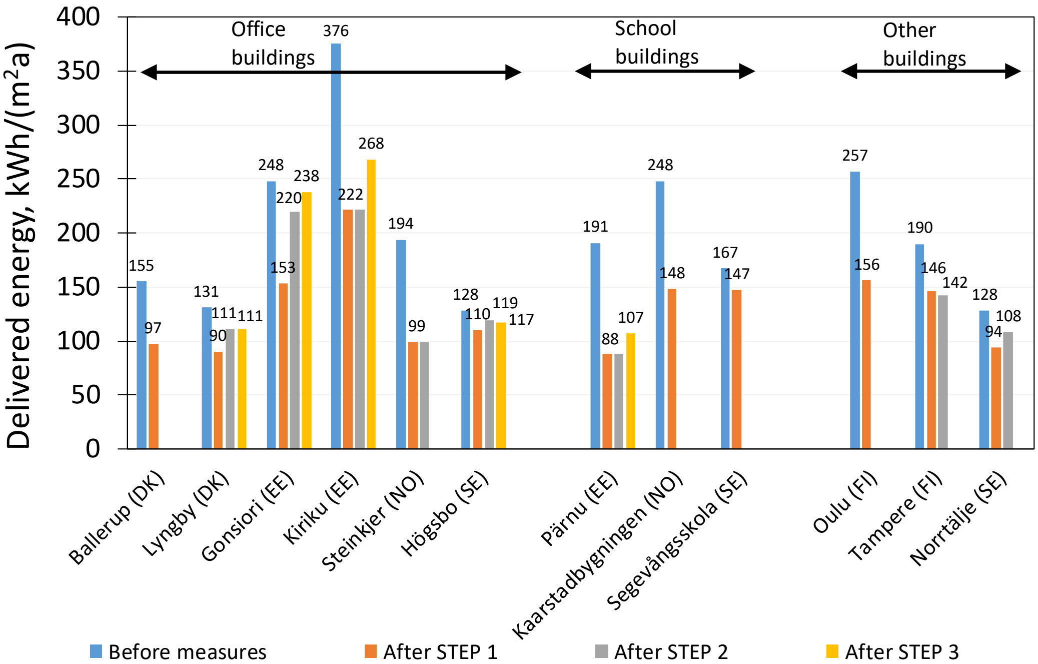


Figure 3 Energy use in pilot buildings before (baseline) and after the energy saving measures

The measured energy consumption data for one-year period after the renovation (After STEP 3) is available for the five pilot buildings. The reasons for the deviation between the estimated and measured energy consumption are discussed in the Follow-up Stage section.

The delivered energy reduction in percentages is shown in Figure 4. The average estimated energy savings of the pilot buildings after STEP 1 was 34% and the estimated savings after STEP 2 was 27%. The initial energy saving target of 50% was not achieved in every pilot building because the energy savings depend to a great degree on the starting point of energy use before the measures are introduced, and most of the pilot buildings were already in a reasonably good state.

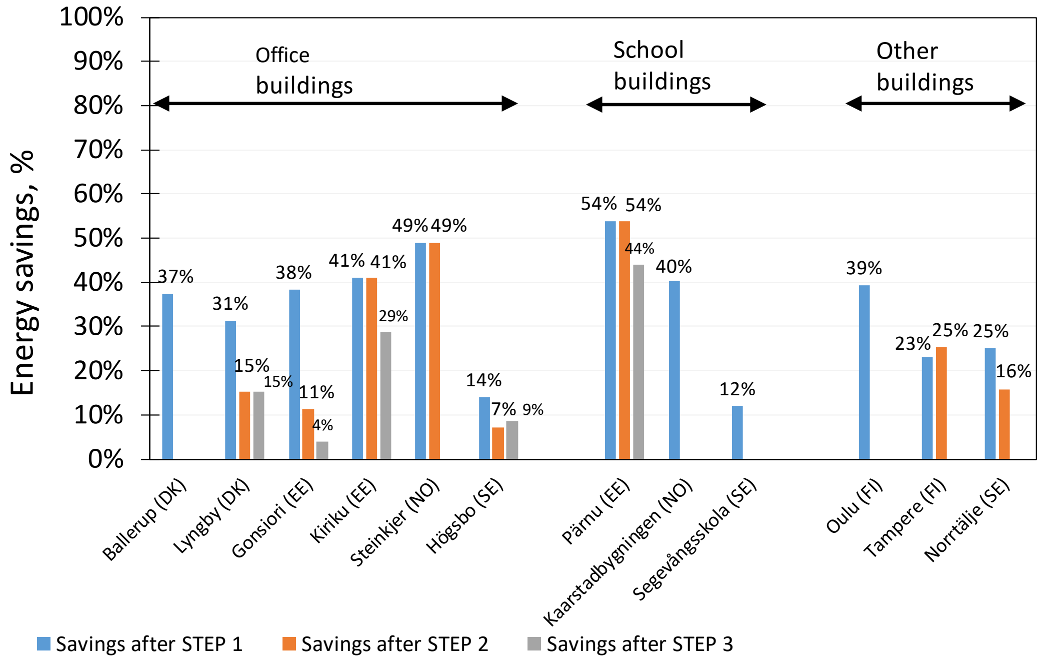


Figure 4 Energy savings in different type of pilot buildings

Most of the action packages that were used in the office buildings (optimisation of BMS systems, installation of thermostats, new ventilation units etc.) provided up to a 30% saving in energy. This major reduction of energy use may also require the renovation of building envelope elements or on-site renewable energy production.

Another important aspect is how the energy savings are expressed and presented. Energy savings expressed in percentages may be misleading. For example, the energy saving in the Kiriku (EE) office building is 41% and 11% in the Gonsiori (EE) office building. This may lead to the conclusion that after the renovation, the Kiriku (EE) office building will be more energy efficient than the Gonsiori (EE) office building. Actually both those buildings will need the same amount of delivered energy, i.e. around 220 kWh/($m^2$a). Therefore, the energy saving should be also expressed in kWh/($m^2$a) and the buildings energy efficiency after the renovation should be evaluated according to the energy use per $m^2$.

It is also important to note that in large buildings, a smaller percentage of energy savings can actually mean a significant reduction in terms of MWh. The Tampere Concert Hall (heated area 28 357 $m^2$) has an estimated energy savings of 25% after the renovation works (replacement of northern glass facade (see Figure 5), replacement of southern glass façade with an opaque wall, installation of heat recovery in the kitchen and the museum's air handling units, replacement of roof extractors and switching to LED lighting). A 255% energy savings is equivalent to approximately 1200 MWh and €96,000 in annual energy and cost savings. An annual savings of 1200 MWh of energy is three times more in terms of MWh as in the Kiriku office building, where the estimated energy saving rate was 40%.

Figure 5 New glass facade of Tampere Concert Hall (U=0.8 W/(m²K))

## Cost effectiveness

The required internal rate of return (IRR) and internal rate of return of action packages are shown in Figure 6. The results show that the profitability requirements are different in different countries, and are usually the same for the pilot buildings in same country. In some cases, the IRR of action package is lower than the initial requirement set by the building owner. In those cases, profitability is not the primary goal for the building owner. Other aspects were taken into account in the decision-making process: the building owner decided to do more renovation work than initially planned (Högsbo, Sweden); the building needed major renovation (Kiriku, Estonia); or renovation work was needed because of the poor indoor climate and tenants complaints (Gonsiori, Estonia). The pilot buildings showed that energy consumption is often not the main reason for renovation. Important aspects include a change of tenants, change of building use, indoor climate conditions and complaints of the tenants. All these reasons affect the choice of renovation work and thereby the profitability of the renovation.

The changes in the estimated IRR of action package between STEP 1 and STEP 2 is caused by the measures that were not carried out, and accurate construction cost data after STEP 2. In STEP 1, construction costs are estimated based on previous experiences and/or tenders. Actual construction costs often differ from the estimations. Therefore, it is important to recalculate IRR after the renovation is completed, when the actual measurements and construction cost data is available.

The profitability results from one year energy consumption measurements from STEP 3 are available for five buildings, and two of them (the office buildings from Estonia) where profitability was not the main aspect. Therefore, the real profitability of the energy savings measures is available for only three of the buildings and it not possible to draw any general conclusions about the achieved profitability of the renovation work.

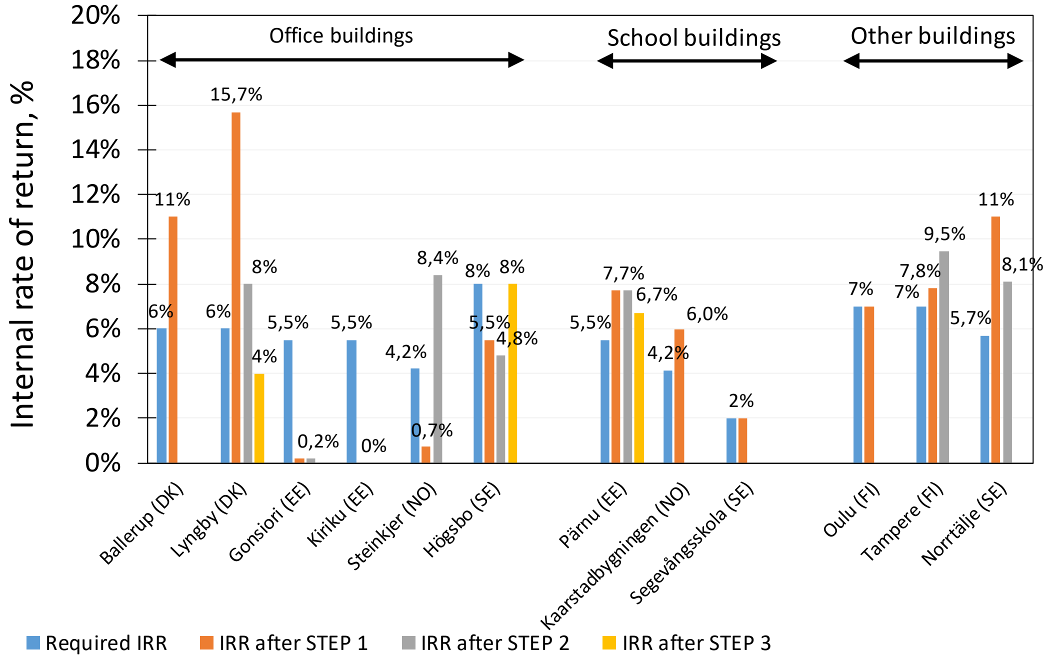


Figure 6 IRR of action packages

* The IRR of Tampere Hall is the estimated profitability after all measures were implemented.

Investments and energy savings per m² are shown in Table 2. The average investment cost after STEP 2 in order to save 1 MWh of energy was €1,500.

Table 2 Investments and energy savings of pilot buildings

| | STEP 1 | | STEP 2 | | STEP 3 |
|---|---|---|---|---|---|
| | Investment, €/m² | Saving, kWh/(m²a) | Investment, €/m² | Saving, kWh/(m²a) | Saving, kWh/(m²a) |
| Ballerup (DK) | 66 | 40 | - | - | |
| Lyngby (DK) | 46 | 39 | 34 | 20 | 20 |
| Gonsiori (EE) | 128 | 95 | 56 | 28 | 10 |
| Kiriku (EE) | 192 | 152 | 192 | 152 | 108 |
| Pärnu (EE) | 73 | 107 | 73 | 107 | 84 |
| Oulu (FI) | 38 | 75 | - | - | |
| Tampere (FI) | 42 | 48 | 11 | 45** | |
| Kaarstadbygningen (NO) | 158 | 99 | - | - | |
| Steinkjer (NO) | 109 | 47 / 95* | 60 | 48 / 95* | |
| Högsbo (SE) | 20 | 18 | 12 | 9 | 11 |
| Norrtälje (SE) | 25 | 34 | 21 | 20 | |
| Segevångsskola (SE) | 29 | 21 | - | - | |

* Total saving is 95 kWh/m², but only the savings from building code standard for passive houses is included in the investment.

** Estimated savings when all renovation works are completed.

## Follow-up stage

An important part of the Total Concept method is the follow-up stage. Experiences from the pilot studies showed that commissioning and continuously measuring energy consumption is crucial for achieving the expected results. Due to the short timeframe of the project, many of the pilot buildings did not reached the follow-up stage or the follow-up time was too short for analysis. Some conclusions can be drawn based on the Högsbo office building in Sweden and the Pärnu school building in Estonia.

The Högsbo office building shows good correlation between the calculated and measured energy consumption, see Figure 7 and Figure 8. The total heat energy use after the renovations is about 53 kWh/m² per year. The estimation in Step 2 was about 52 kWh/m² per year. Minor deviations can be associated with the slight deviations in the indoor temperatures in some sections.

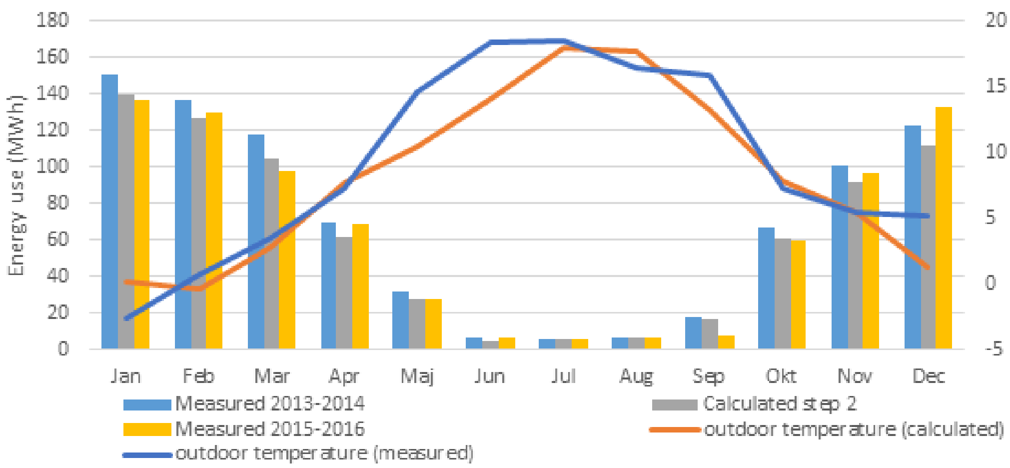


Figure 7 Measured heat energy use (district heating) in the Högsbo office building

The total electricity use for building operation was 29 kWh/m² per year, which was slightly lower compared than the estimation done in Step 2, 31 kWh/m² per year. The somewhat higher savings that were achieved can be accounted for by the more energy-efficient chiller and cooling system pumps installed in the cooling system for Sections C and D.

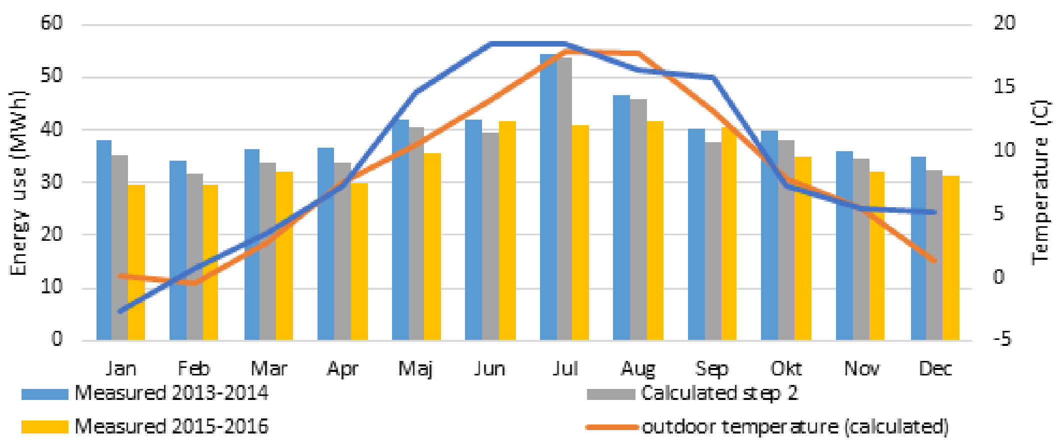


Figure 8 Measured electricity use in the Högsbo office building

The Pärnu school building provides an example of the possible problems and drawbacks, see Figure 9 and Figure 10. In the first months of the follow-up measurements, the deviation between the calculated and measured energy consumption (shown in red circle) was quite significant. The main reasons were the higher indoor temperature; the fact that the working hours of ventilation systems were longer than estimated; and ventilation system was not properly adjusted (ventilation was working on full power during times when building was not in use). After adjustments were made, the deviation decreased (shown in blue circle). This example illustrates the need for a follow-up stage, since the new systems need time to adjust, and the building users also need time to learn how to use the new energy efficient service systems.

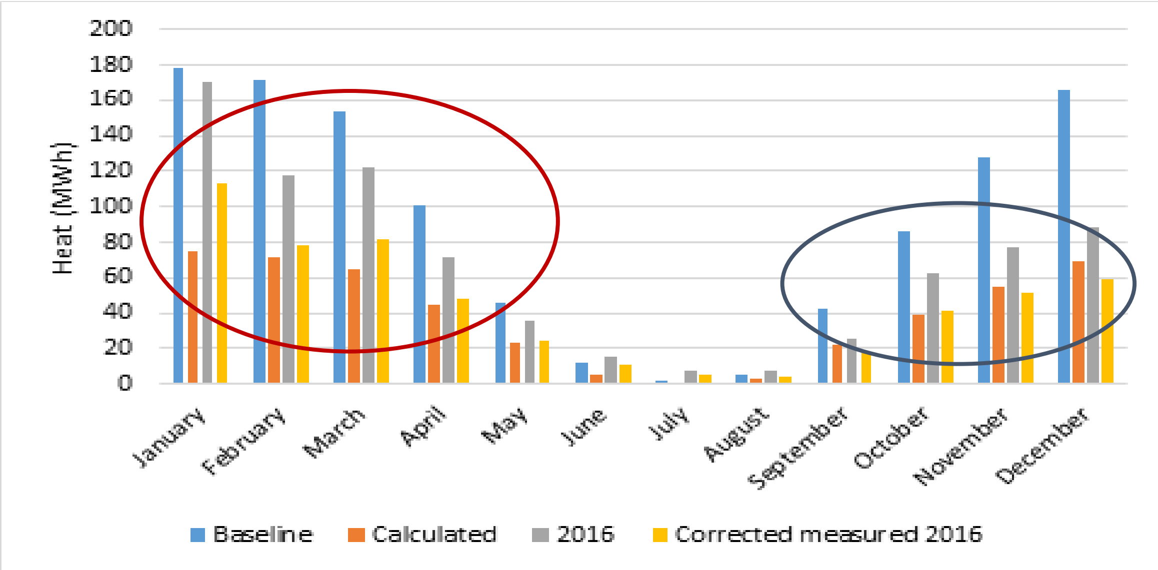


Figure 9 Measured heat energy use (district heating) in the Pärnu school building

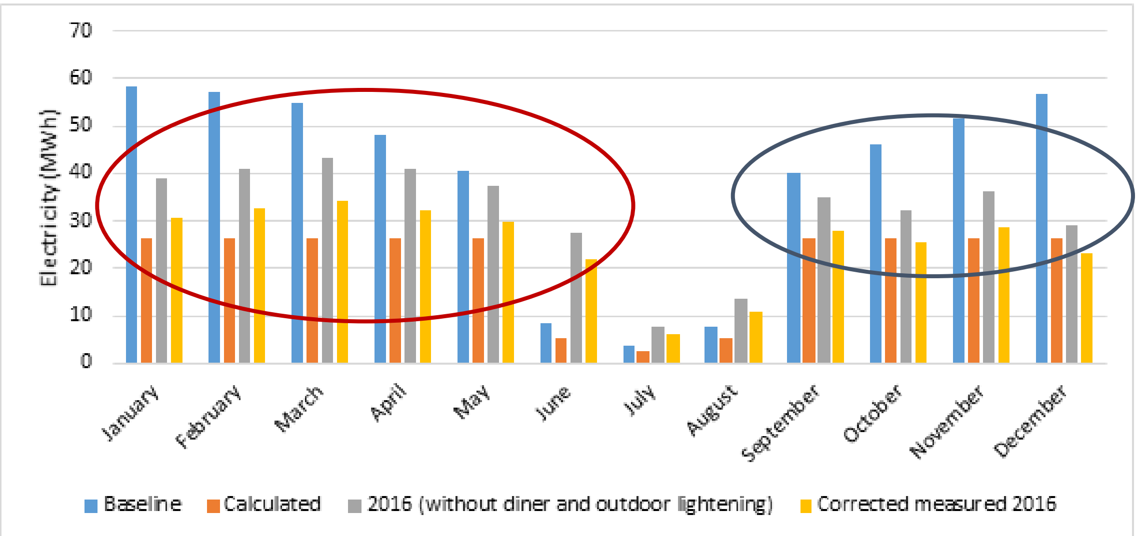


Figure 10 Measured electricity use in the Pärnu school building

## Country-specific conditions

A questionnaire was conducted in the participating countries. The results showed that there were no significant difference in the conditions and regulatory requirements in participating countries. The only exception was Denmark where component-based energy efficiency requirements exist that may affect the choice of energy renovation measures. Measures related to the building envelope are more profitable in Estonia, since the starting point can be worse. For example, in Sweden the worst case scenario for external walls is a U-value around 0.3 W/(m$^2$K). In Estonia, thermal transmittance of external wall can be around 1.0 W/(m$^2$K).

Energy prices given in Table 3, shows the differences between the participating countries. Only Sweden uses power tariffs (€/kW). A comparison of the energy prices shows that Denmark has significantly higher electricity prices than other participating countries. This makes on-site renewable energy production a profitable measure in Denmark. District heating price is not given for Norway because 99 % of the energy demand in the pilot buildings is covered by electricity. The price of the electricity used for heating is 5% lower.

Table 3 Prices of energy sources (excluding VAT)

| | Heating | | Electricity | |
|---|---|---|---|---|
| | €/MWh | €/(kW·a) | €/MWh | €/(kW·a) |
| Ballerup (DK) | 73 | - | 219 | - |
| Lyngby (DK) | 87 | - | 219 | - |
| Gonsiori (EE) | 62 | - | 81 | - |
| Kiriku (EE) | 62 | - | 86 | - |
| Pärnu (EE) | 54 | - | 86 | - |
| Oulu (FI) | 47 | - | 76 | - |
| Tampere (FI) | 60 | - | 90 | - |
| Kaarstadbygningen (NO) | - | - | 90 | - |
| Steinkjer (NO) | - | - | 90 | - |
| Högsbo (SE) | 47 | 70 | 77 | 50 |
| Norrtälje (SE) | 80 | - | 73 | - |
| Segevångsskola (SE) | 50 | 98 | 83 | 91 |

## The process of implementing the method

The survey results show that STEP 1 in the pilot studies of the Total Concept project took a considerable amount of time (between 150 and 370 hours per project). The reasons may be that, for most of the participants, these pilot cases were also study projects and they had no previous experience (except the Swedish consultant). STEP 1 is also time-consuming because of the work required to collect the data on the existing building (interviews with buildings owners, on-site surveys, collection of drawings, indoor climate measurements) and the work required to put together the action packages (energy simulations, investment cost estimations, economic calculations). This time-consuming process can probably not be significantly reduced because the pilot projects showed that the main reasons for the differences between the calculated and measured energy consumption were wrong estimations and inadequate data. STEP 1 is an especially complex task in large buildings where is no fixed user profile; the service systems are controlled on daily basis by maintenance staff; and there is no sub-measuring.

Another important point is that building owners often need to continue using at least some parts of the building. This means a step-by-step renovation process and action package must be divided into suitable smaller packages that can be executed at different times without disturbing the everyday use of the building.

## Conclusions

This report has analysed the main outcomes of implementing the Total Concept method in twelve pilot studies. The main conclusions are:

- Energy consumption is often not the main reason for the renovation. The main reasons are changes in the building use, change of tenants and indoor climate conditions (complaints).
- Even when renovation is planned for other reasons, it provides a possibility for paying more attention to energy efficiency and carrying out energy-related renovation work.
- The renovation of non-residential buildings is long process and adjustments in the energy and profitability calculations must be made throughout the process when more accurate input data becomes available.
- Building owners change their plans during the renovation process and the initial action package may not be realised.
- Energy meters are placed in order to divide energy costs between the tenants, not to analyse the building's energy use. In large buildings with different usage profiles, there may be one energy meter for heating and another for electricity. The installation of additional sub-meters in STEP 1 is helpful for making the energy consumption calculations for the action package.
- The evaluation of indoor climate conditions (indoor temperature, working hours of service systems) is important.
- A follow-up stage and adjustments to the control and service systems are needed at least once a year after the renovation is completed.
- Energy savings that are expressed only in percentages can be misleading and energy efficiency should be also evaluated according to energy use per $m^2$.
- There were no significant differences in the conditions in the participating countries. The Total Concept Method was easily implemented in all the participating countries.

## References


[1] Hani, A. 2012. Investigation of energy efficiency in buildings and HVAC systems. Dissertation, Tallinn University of Technology http://digi.lib.ttu.ee/i/?789

[2] Swedish Energy Agency, STIL2 project, http://www.energimyndigheten.se/statistik/forbattrad-energistatistik-i-bebyggelsen-och-industrin/statistik-i-lokaler-stil2/

[3] ENMAK 2030+Estonian Energy Roadmap 2030+ (in Estonian). http://www.energiatalgud.ee/index.php?title%20=%20ENMAK:Eesti%20pikaajalineenergiamajanduse%20arengukava%202030%2B