



TotalConcept

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

Summary report of technical results



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1. Introduction

This report covers the implementation of the Total Concept method in 12 pilot buildings. The objectives were to carry out pilot studies in each of the five participating countries of the IEE Total Concept project, including identification of energy saving measures with cost estimates and energy saving calculations together with a thorough follow-up of energy use the first year.

The Total Concept method consists of three steps (Figure 1.1). Twelve pilots building were analysed with the Total Concept method in step 1. The outcome of step one is a profitable action package. Eight of the pilots moved on with step 2 and step 3 and reduced energy use by implementation of the action package, or parts of it, within the timeframe of the Total Concept projects. The last four pilots might implement the action package, or parts of it, in the future.

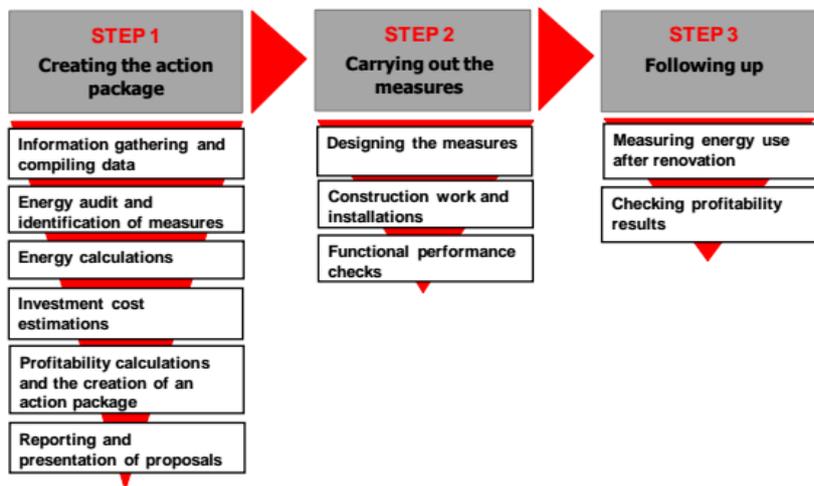


Figure 1.1 The three Total Concepts steps.

This report summarizes all twelve pilots with an overview in chapter 2 and a dedicated chapter for each pilot. All twelve pilots are included in this report with step 1 or 3 marked in the headline.

Details reports in native language and summary reports in English and native language is available on the project website (<http://totalconcept.info/>) for each of the twelve pilot buildings. Evaluation of the results is given in a separate report that also can be found on the website (www.totalconcept.info).

2. Overview of the pilots

2.1 Pilot building and measures

Table 2.1 gives a short description of the pilots chosen for energy ambitious upgrading with the total concept method. Table 2.2 gives an overview of the actual measures carried out in Step 2 with achieved energy reduction and profitability after Step 3.

Table 2.1 Short description the of pilot buildings before Step 1

Building	Country	Year built	Previous refurbishment	Building type	Floor area (m ²)	Building owner
Town hall of Ballerup	Denmark	1975	Major refurbishment in 2011	Office	17000 heated floor area	Ballerup municipality
Lyngby Port	Denmark	1992	-	Office	20630 heated floor area	Nordea ejendomme
Kiriku 2/4	Estonia	1900	-	Office	2365 gross floor area, 1877 heated floor area	State Real Estate Ltd
Pärnu school	Estonia	1979	Windows	School	11187 gross floor area	Pärnu City
Gonsiori 29	Estonia	1951	Windows, insulated roof, ventilation system	Office	7233 gross floor area, 6797 heated floor area	State Real Estate Ltd
Tampere Hall	Finland	1990	Smaller refurbishments incl. cooling system and change to district heating	Congress centre	28357 gross floor area	City of Tampere
Oulu Centre	Finland	1933	1980: Major refurbishment 2005: HVAC 2009: New windows and doors	Health care	4903 gross floor area, 4288 heated floor area	City of Oulu
Vegkontoret Steinkjer	Norway	1967, 1976, 1984	No larger refurbishment	Office	4330 heated floor area excl. controlling hall	Statsbygg
Kaarstad building	Norway	1922, 1982	New extension in 1982 incl. some refurbishment in the old building	University	2800 + 3197 (old +extension) heated floor area	Statsbygg
Högsbo office building	Sweden	1982, 1986	1993, 1998	Office building	14543 heated floor area divided in 2 buildings	Harry Sjögren AB
Norrtälje Criminal institution	Sweden	1958	2002	70% industry, 30% training/WS	7248	Specialfastigheter
Segevång school	Sweden	1962, 2008		School	4807 divided into 6 buildings (A-F)	Malmö Municipality

Table 2.1 Summary of actual measures carried out in Step 2.

Pilot building	Measures carried out/planned	Description of measures	Results
<p>Road office Steinkjer (Norway)</p> 	6/6	<ul style="list-style-type: none"> • Insulation added to walls • Insulation added to roof. • Windows and doors replaced. • Upgraded the ventilation system. • Upgraded the artificial lighting to demand controlled LED. • Replaced the air/water head pump with a ground source heat pump. 	The measures reduced energy use with 43% and provided a 5.5% internal rate of return.
<p>Högsbo office building (Sweden)</p> 	5/6	<ul style="list-style-type: none"> • New ventilation unit installed in Section C • New VAV-dampers installed in Section C. • Chiller replaced in Section D. • Heat system pumps replaced in Section D • Hydronic balancing added to heating system in Section D. 	The measures reduced energy use with 8% and provided an 8% internal rate of return.
<p>Norrtälje Criminal institution (Sweden)</p> 	2/5	<ul style="list-style-type: none"> • Four out of five large doors replaced • Lighting system in smaller areas replaced, ongoing in bigger areas <p>Improved comfort ventilation with reduced airflows, extra insulation on facades and improved process ventilation will be implemented later.</p>	The measures reduced energy use with 15% and provided an 8% internal rate of return.
<p>Norrtälje Segevång school (Sweden)</p> 	0/11	<p>The following measures are planned for the future:</p> <ul style="list-style-type: none"> • Optimizing the ventilation system • New thermostats and hydronic balancing of the heating systems • Occupancy controlled lighting • Demand controlled ventilation with heat recovery • Energy efficient tap water fixtures 	

Pilot building	Measures carried out/planned	Description of measures	Results
<p>Town hall of Ballerup (Denmark)</p> 	0/3	<p>The following measures are planned for the future:</p> <ul style="list-style-type: none"> • Exchanging windows • Optimization of BMS system, including heating, lighting, ventilation and solar shading • Photovoltaic 	
<p>Lyngby Port (Denmark)</p> 	4/7	<ul style="list-style-type: none"> • Ventilators replaced • Extra insulation in the shaft ducts • New BMS system • New cooling system. <p>Converting to district heating and solar panels are planned in spring 2017. The last measure - PIR sensors in the toilets might be implemented.</p>	The measures reduced energy use with 20% and provided a 4% internal rate of return.
<p>Pärnu school (Estonia)</p> 	6/6	<ul style="list-style-type: none"> • New ventilation system • District heating as a heat source for ventilation • New heating systems • Lower SFP • Insulation of whole building envelope • Energy efficient lighting system 	The measures reduced energy use with 46% and provided a 6.6% internal rate of return.
<p>Kiriku 2/4 (Estonia)</p> 	7/7	<ul style="list-style-type: none"> • Adjustment of heating curve • Insulation of the attic floor • New circulation pumps • Ventilation system with heat recovery • New windows • Insulation of ground slab • New T5 lighting 	The measures reduced energy use with 28% and provided a negative internal rate of return.
<p>Gonsiori 29 (Estonia)</p> 	2/8	<ul style="list-style-type: none"> • New windows • new lighting system <p>Because building is planned to be sold in 2018, the owner was interested only in doing measures which could help to increase indoor climate and decrease complaints.</p>	The measures reduced energy use with 3.5% and provided a negative internal rate of return.

Pilot building	Measures carried out/planned	Description of measures	Results
<p>Tampere Hall (Finland)</p> 	<p>5/7</p>	<ul style="list-style-type: none"> • Replaced southern glass wall in the hallway • Replaced northern glass wall • New lighting system • Installed efficient heating system in the Moomin museum • Installation of heat recovery in the kitchen AC <p>The package will be executed in three parts.</p>	<p>After renovation is completed, the measures are expected to reduce energy use by 23%, and to provide an 8.5% internal rate of return.</p>
<p>Oulu Centre (Finland)</p> 	<p>0/5-8</p>	<p>The following measures are identified in a profitable action package:</p> <ul style="list-style-type: none"> • ventilation with heat recovery • temperature controllers • efficient fans • LED lighting • New faucets 	
<p>Kaarstad building (Norway)</p> 	<p>0/5</p>	<p>The following measures are identified in a profitable action package:</p> <ul style="list-style-type: none"> • Replace radiators and new thermostatic valves • Façade insulation • Roof insulation • Demand controlled ventilation • Occupancy controlled lighting 	

3. Road Office in Steinkjer, Norway – Step 3



The road office in Steinkjer consists of three parts built in 1967, 1976 and 1984. The total heated area of this office building is 4 330 m².

The main objective of the renovation was to improve indoor air quality, especially in those parts of the building with the oldest HVAC-systems. Change of layout in the office area has also worsened the indoor climate. The temperature adjusted measured energy use for the building's office section, excluding the control hall was, was 183 kWh/m² per

year. Due to new ventilation rates, the energy use of the building was estimated to increase to about 194 kWh/m² per year. This was set as the new baseline before energy measures.

Six major energy efficiency measures were identified during the auditing, whereas five measures are included in the proposed action package in step 1. The internal rate of return of the proposed action package is 4.2%, above the property owner's profitability demand of 4.1%. The last measure (number 6) is not profitable and included in the action package. However, the building owner, Statsbygg, decided to include all of the six measures in Step 2. The internal rate of return with the last measure included is 0.7%.

The measures are defined as energy savings and investment costs from building code requirements (minimum TEK10-level) up to passive house level. Therefore, only part of the investment cost and energy savings are included in the profitability analysis. The reason for this is that Statsbygg must upgrade in accordance with the building requirement (up to TEK10-level) and this is not an option.

3.1 Summary tables

Figure 3.1 shows the measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2. The space heating was previously distributed through a conventional radiator system, but since the main hydronic heating source was an electric boiler, the measured net energy is 100% electricity. To be correct, 99% of the energy use was electricity in 2013 and 1% was from oil.

One of the measures was a new ground source heat pump introducing thermal energy from a hydronic system. This thermal energy is denoted district heating in Figure 1 even though it is a local system for the building. There is no split between electricity for building operation and tenants.

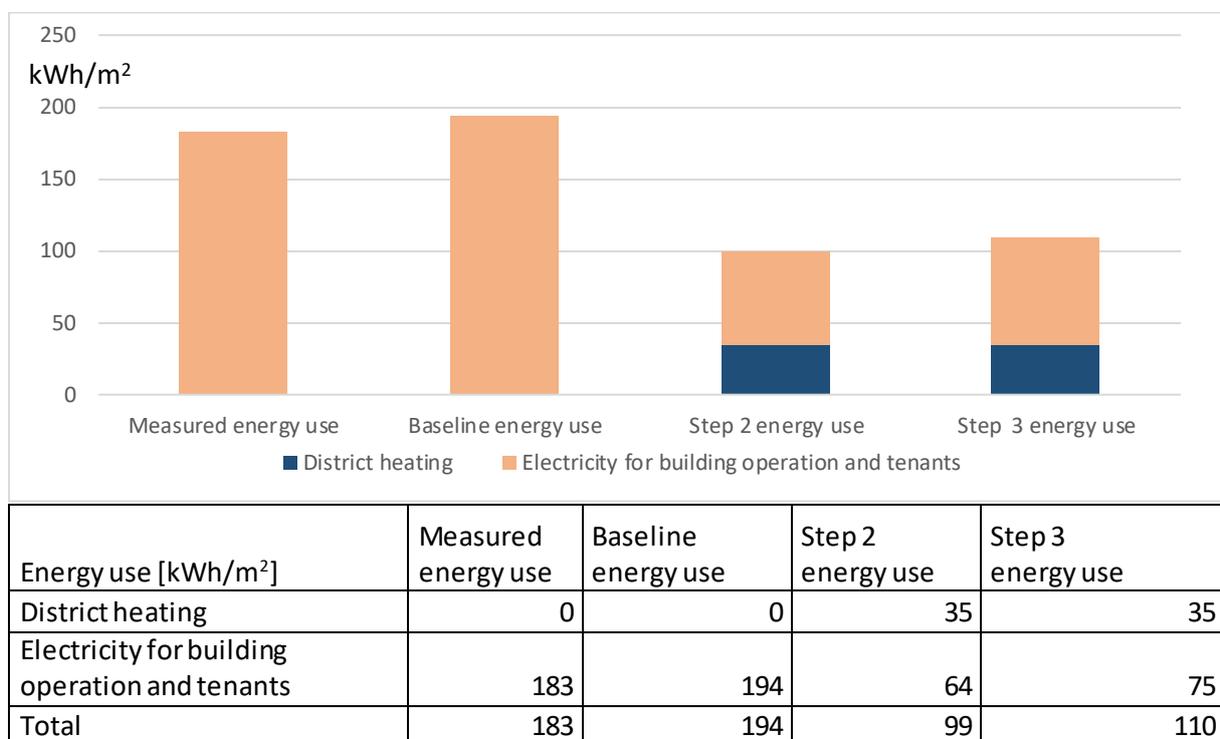


Figure 3.1 Outcomes in Step 3 compared to baseline.

According to the measurement outcomes in Step 3, the total energy use is approx. 110 kWh/m². This is an estimation from the first two operation months. We expect the energy use to be further reduced due to operational experiences and optimization.

The action package carried out in Step 2 was estimated to reduce the energy use by approximately 49%. The measured outcomes in Step 3 show the actual savings to be approximately 43%.

The profitability outcomes are presented below in Table 3.1 and Figure 3.2. The diagram in Figure 3.2 shows the calculated profitability for the action package in Step 2 together with the actual profitability after Step 3. The calculated profitability for the package in Step 2 was 8.4%. The actual profitability based on the actual costs for the energy efficiency measures and savings from measured energy use in Step 3 was approx. 5.5%.

Table 3.1. Summary of the outcomes of the action package carried out in Road Office - Steintjer compared to the estimations made in Step 2. Presented savings are compared to the new baseline.

	Step 2	Step 3
Total annual energy savings:	49%	43%
Total annual cost savings:	370.2 kNOK/yr	327.3 kNOK/yr
Energy investment cost:	2 356 kNOK	2 356 kNOK
Internal rate of return for the package:	8.4%	5.5%

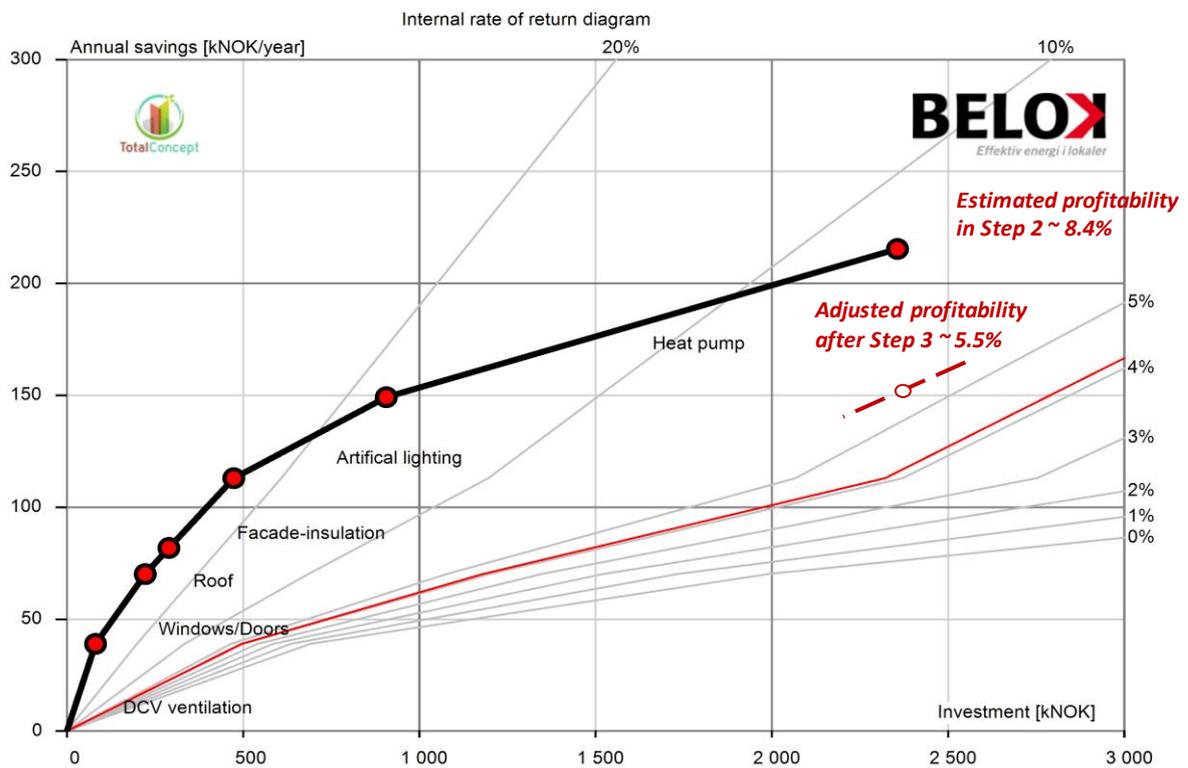


Figure 3.2 Outcomes of the profitability of the action package carried out at the Road office Steinkjer. Relative energy price increase is 2%. Estimated internal rate of return for the action package became 8.4%. Actual internal rate of return for the action package is approx. 5.5%.

3.2 Measures carried out in Step 2

The proposed action package in Step 1 consisted of five identified measures that satisfied the building owner's requirement of the internal rate of return of 4.15%. However, the building owner, Statsbygg, decided to include all six measures in Step 2. The internal rate of return with the sixth measure included was 0.74% based on investment costs in Step 1. Table 3.2 shows the estimated investments, cost and energy savings from Step 1 compared to real investments and with adjusted savings.

Table 3.2 Cost savings for the measures in the action package for Road officeSteinstjer.

Measure	Step 1			Step 2		
	Estimated investment [kNOK]	Estimated Cost saving [kNOK/year]	Energy saving [MWh/yr]	Real Investment [kNOK]	Adjusted Cost saving [kNOK/year]	Energy saving [MWh/yr]
1 Windows and doors	109	35	39	141	31	35
2 Roof - add isolation	58	4	5	67	13	13
3 Artificial lighting	286	29	27	433	35	35
4 Ventilation –from CAV to DCV	1 335	116	129	81	43	43
5 Walls – add isolation and air tightness	1 038	3	3	184	35	35
6 Energy supply - ground source heat pump	1 400	5	6	1 450	74	74
SUM	4 227	195	211	2 356	215	235
Internal rate of return			0.7%			8.4%

The measures were defined as energy savings and investment costs from building code requirements (minimum TEK10-level) up to passive house level. Therefore, only part of the investment cost and energy savings was included in the profitability analysis. The reason for this is that Statsbygg must upgrade in accordance with the building requirement (up to TEK10-level), thus this is not an option. This is the reason for reduced investment costs in step 2. A much larger share of the ventilation cost was necessary to reach a minimum level of indoor quality, and this share is not included in the profitability analysis. In addition, we discovered a mistake in the investment cost for the façade-upgrading. This changed the profitability rank order between the measures. This resulted in adjusted energy savings for all measures.

4. Högsbo office building, Sweden – Step 3



The Högsbo 20:22 property consists of two office buildings divided into four building sections: A, B, C and D. Total heated area of the buildings is 14 543 m². Besides the office areas there is also a lunch restaurant and an underground garage in the property.

The main objective of the renovation in Högsbo 20:22 was to incorporate energy performance improvements to the general upgrade of the building for upcoming tenant adjustments.

Total measured energy use before renovations was 121 kWh/m² year (including tenants' electricity). Due to planned tenant adjustments in Section C, the energy use of the building was estimated to increase to about 128 kWh/m² per year. This was set as a new baseline for energy efficiency measures. The proposed action package in Step 1 contained six energy saving measures for building Sections C and D, which were planned to be carried out as part of the upcoming renovation for the tenant adjustments. Five measures were carried out in Step 2 with some modifications to the initial plans.

4.1 Summary of the results

Figure 4.1 presents the measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2.

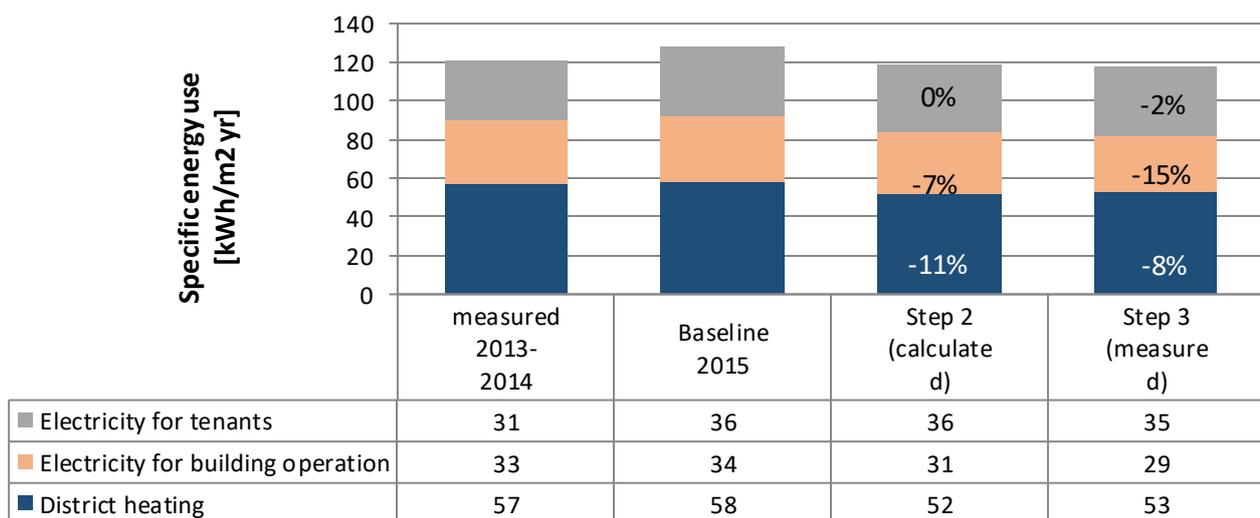


Figure 4.1 Total energy use of Högsbo. Measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2.

According to the measurement outcomes of Step 3 the total specific energy use of the Högsbo 20:22 property after renovations is about 117 kWh/m² per year. The outcomes are mostly in accordance with the estimations done in Step 2. The total heat energy use after renovations is about 53 kWh/m²

per year. The estimation in Step 2 was about 52 kWh/m² per year. Minor deviations can be connected to the slight deviations in the indoor temperatures in some sections.

The action package carried out in Step 2 the total building energy use was estimated to decrease about 7% compared to the new baseline and about 2% compared to the energy use before renovation. The measured outcomes in Step 3 show the savings to be about 8% and 3% respectively. The energy use for building operation (according to Swedish building regulations, BBR) decreased about 11% compared to the baseline and about 9% compared to measured energy use before renovation.

The actual profitability outcomes are summarized in Table 4.1 and presented in Figure 4.2 below. The diagram on Figure 4.1 shows the calculated profitability for the action package in Step 2 together with the actual profitability that was calculated after Step 3. The calculated profitability for the package in Step 2 was 4.8%. The actual profitability based on the actual costs for the energy efficiency measures and calculated savings from measured energy use in Step 3, was about 8% and fulfils property owner's profitability demand.

Table 4.1. Summary of the outcomes of the action package carried out in Högsbo 20:22 office buildings compared to the estimations made in Step 2. Presented savings are compared to the new baseline.

	Step 2	Step 3
Total annual energy savings:	7%	8%
Total annual energy savings for building operations (BBR):	9%	11%
Calculated energy savings – district heating:	90 MWh/yr	70 MWh/yr
Calculated power savings – district heating:	79 kW	86 kW
Calculated energy savings – electricity:	37 MWh/yr	75 MWh/yr
Calculated power savings – electricity:	50 kW	38 kW
Total annual cost savings:	12.5 kEUR/yr	16.9 kEUR/yr
Energy investment cost:	180.7 kEUR (28%)	180.7 kEUR (28%)
Internal rate of return for the package:	4.8%	8%

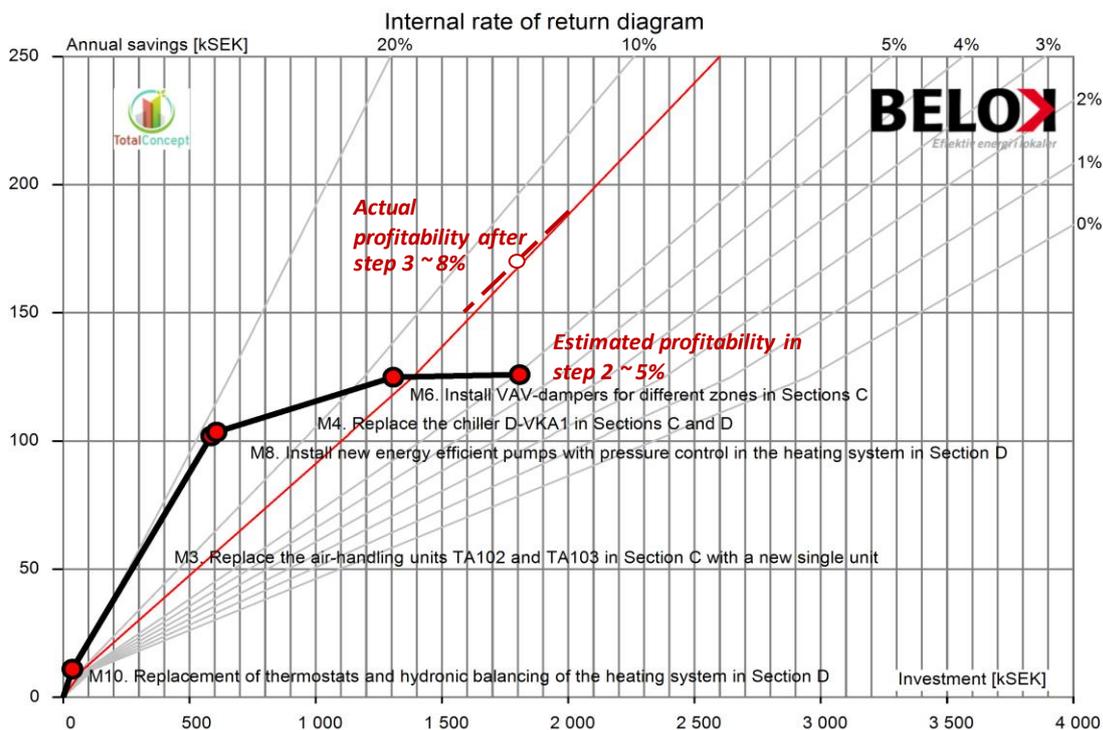


Figure 4.1. Outcomes of the profitability of the action package carried out in the Högsbo 20:22 office building presented in an internal rate of return diagram. Actual internal rate of return for the action package is about 8%.

4.2 Measures carried out in Step 2

The proposed action package in Step 1 contained six energy saving measures for building Sections C and D, which were planned to be carried out as part of the upcoming renovation for the tenant adjustments. A number of adjustments were made to the action package in Step 2. The changes included the following:

- *Measure 3* (Replace the air-handling units 102 and 103 in Section C) has been carried out as planned.
- *Measure 4* (Replace the chiller in Sections C and D) has been carried out as planned.
- *Measure 5* (Replace the air-handling units 104 and 105 in Section D) will probably be implemented during 2017.
- *Measure 6* (Install VAV-dampers to ventilation in Sections C and D) have only been implemented in Section C.
- *Measure 8* (New pumps in the heating system in Section D) has been carried out as planned.
- *Measure 10* (Hydronic balancing of the heating system in Sections C and D) has been implemented in Section D. Section C is on hold until further notice.

Table 4.2 and 4.3 show the estimated investments, cost and energy savings from step 1 compared to real investments and with adjusted saving in Step 2.

Table 4.2. Cost savings for the measures in the action package

Measure		Step 1		Step 2	
		Estimated investment [Euro]	Estimated Cost saving ¹⁾ [Euro/year]	Real Investment ²⁾ [Euro]	Adjusted Cost saving [Euro/year]
1	M3. Replace the air-handling units TA102 and TA103 in Section C with a new single unit	55 000	9 000	55 000	9 100
2	M10. Replacement of thermostats and hydronic balancing of the heating systems in Sections C and D (only in Section D)	6 500	1 100	3 700	1 010
3	M5. Replace the air-handling units TA104 and TA105 in Section D with a new single unit	60 200	6 200	-	-
4	M8. Install new energy efficient pumps with pressure control in the heating system in Section D	2 100	150	2 100	150
5	M4. Replace the chiller D-VKA1 in Sections C and D with energy efficient one	70 000	2 800	70 000	2 140
6	M6. Install VAV-dampers for different zones in Sections C and D (has been performed only in Section D)	100 000	2 400	50 000	70
SUM		293 800	21 650	180 700	12 470

Notes: ¹⁾ Based on the calculated new baseline. ²⁾ Investment costs need to be checked and adjusted with the outcomes from Step 2.

Table 4.3. Energy savings for the measures in the action package.

Measure		From step 1		Adjusted after Step 2	
		Thermal energy ¹⁾ [MWh/year]	Electrical Energy ¹⁾ [MWh/year]	Thermal ²⁾ energy [MWh/year]	Electrical ²⁾ energy [MWh/year]
1	M3. Replace the air-handling units TA102 and TA103 in Section C with a new single unit	108	7	72	8
2	M10. Replacement of thermostats and hydronic balancing of the heating systems in Sections C and D	21	0	18	0
3	M5. Replace the air-handling units TA104 and TA105 in Section D with a new single unit	28	42	-	-
4	M8. Install new energy efficient pumps with pressure control in the heating system in Section D	0	2	0	2
5	M4. Replace the chiller D-VKA1 in Sections C and D with energy efficient one	0	30	0	26
6	M6. Install VAV-dampers for different zones in Sections C and D	16	10	0	0,6
SUM		173	91	90	37

Notes: ¹⁾ Based on the calculated new baseline. ²⁾ Energy calculations have been updated according to design values

5. Norrtälje prison, Sweden – Step 3



The Norrtälje prison is a high security institution for male prisoners. The building of interest – Building 9 – has 8 030 m² heated floor area and holds several activities. The greater part of the building is for stock-keeping, carpentry and mechanical work where wood furniture and all sorts of sheet-metal work is carried out. The rest of the building is for office and educational use. Since there is only one energy meter for district heating for the entire site then the energy use before measures have been calculated. Based on the calculations, the specific annual energy use for the building is today about 121 kWh/m², including electricity for tenants.

According to the energy audit in Step 1, it was difficult to meet the indoor climate requirements set for the premises. For improving thermal comfort the room temperature set points needed to be increased in some areas of the building. The new baseline for the total specific annual energy use for Building 9 will be 128 kWh/m² yr. The proposed action package in Step 1 contained five energy efficiency improvement measures. In December 2016 some of the measures have been partly carried out and some of the measures are ongoing. Therefore, only partial results of the outcomes will be presented here.

5.1 Summary of the preliminary results

Figure 5.1 presents the preliminary outcomes of Step 2 compared to estimated baseline in Step 1. Only few measures have been carried out so far from the proposed action package. Step 2 will be ongoing also in 2017.

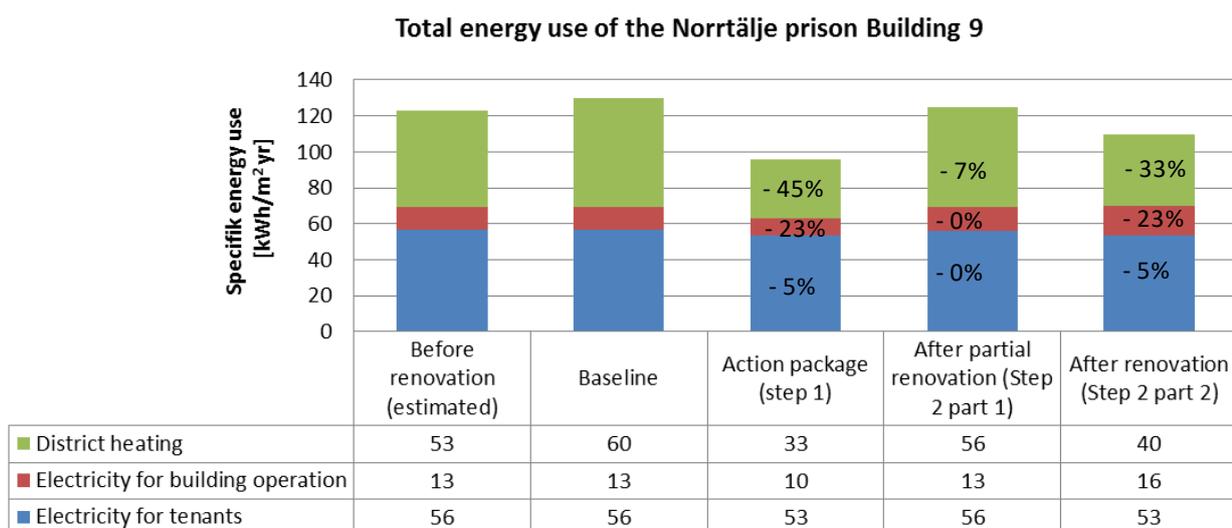


Figure 5.1 Estimated outcomes of Step 2 in Norrtälje prison building 9 compared to calculations made in Step 1.

According to the estimations, the action package with planned measures in Step 2 will lead to a total specific energy use of the building of about 110 kWh/m² per year. The total heat energy use after renovations will be about 40 kWh/m² per year and total electricity use about 69 kWh/m² per year, where majority is used by the tenants.

With the action package carried in Step 2 the total building energy use is estimated to decrease about 15% compared to the new baseline and about 10% compared to the energy use before renovation. The energy use for building operation (BBR) will decrease about 23% compared to the baseline and about 15% compared to measured energy use before renovation.

The estimated profitability outcomes in Step 2 are summarized in the Table 5.1 and presented in Figure 5.2. The diagram in Figure 5.1 shows the calculated profitability for the action package in Step 2. The calculated profitability for the package in Step 2 is 8.1%.

Table 5.1. Summary of the outcomes of Step 2 in the Norrtälje prison compared to the estimations made in Step 1. Presented savings are compared to the new baseline.

	Step 1	Step 2 – part 1	Step 2 – part 2
Total annual energy savings:	26%	4%	15%
Total annual energy savings for building operation (BBR):	42%	6%	23%
Energy savings- electricity:	51 MWh/yr	4 MWh/yr	-2 MWh/yr
Energy savings- district heating	222 MWh/yr	38 MWh/yr	163 MWh/yr
Total annual cost savings:	203 kSEK/yr	31 kSEK/yr	121 kSEK/yr
Energy investment cost:	1993 kSEK	0 kSEK ¹⁾	1683 kSEK ¹⁾
Internal rate of return for the action package	11%	-	8%

¹⁾ Values are based on preliminary data and estimations.

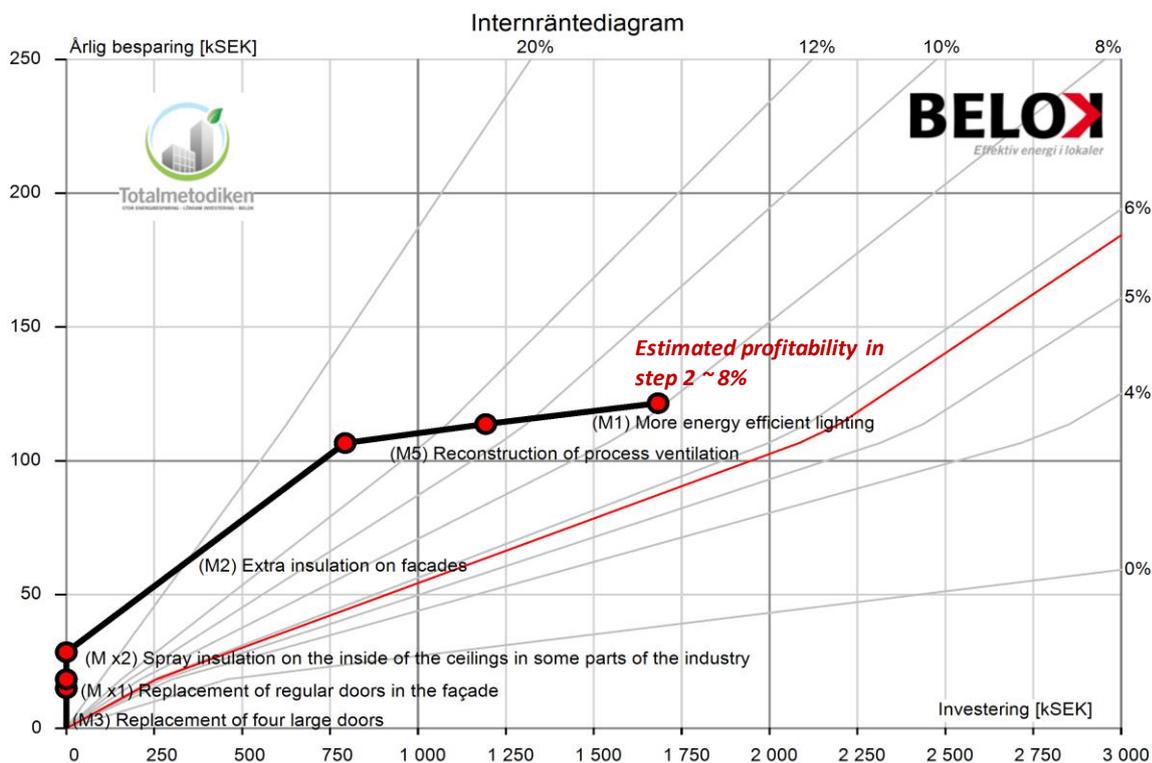


Figure 5.2. Calculated profitability of the action package in Step 2 in the Norrtälje prison presented in an internal rate of return diagram. The property owner's profitability requirement is 5.7% and the estimated relative energy price increase is 2%. The calculated profitability for the package in Step 2 is 8.1%.

5.2 Status of the measures carried out in Step 2

According to discussions with the property owner, the status of the proposed measures is as follows:

- *Measure 3:* Replacement of five large doors, is mostly completed. Four big doors out of five are replaced.
- *Measure 1:* More energy efficient lighting, is partly completed. Lighting system has been replaced in two smaller side areas. In the two main areas, the lighting will be replaced within the next months.
- *Measure 4:* Replacement of air handling unit for comfort ventilation and reduced airflow, will be implemented in the future, no final decisions have been made.
- *Measure 2:* Extra insulation on facades, will be implemented within the next months.
- *Measure 5:* Reconstruction of process ventilation, will be implemented within the next months.

In addition to the proposed measures also two other measures have been carried out. The property owner has changed three regular doors in the façade and plans to go ahead with the replacement of all of the doors. In addition, also 100 mm spray insulation has been sprayed onto the inside of the

industry area roof (360 m²) and to another part close by (54 m²) to create better insulation and to improve the acoustics. Furthermore, a small parts of the exterior facade has been insulated with the spray insulation.

Tables 5.2 and 5.3 show the estimated investments, cost and energy savings from Step 1 compared to real investments and with adjusted savings in Step 2. The outcomes are still preliminary since the Step 2 process is still ongoing.

Table 5.2 Cost savings for the measures in the action package of the Norrtälje prison.

Measure		Step 1		Step 2	
		Estimated investment [SEK]	Estimated Cost saving ¹⁾ [SEK/year]	Real Investment ²⁾ [SEK]	Adjusted Cost saving [SEK/year]
1	M3. Replacement of five large doors (four doors replaced)	0	19 000	0	15 000
2	M1. More energy efficient lighting in production zones (measure partly done, is planned to be carried out)	60 000 ³⁾	8 000	490 000 ³⁾	8 000
3	M4. Replacement of air handling unit (comfort ventilation) and reduced airflows (no decisions or planning yet)	740 000	91 000	-	-
4	M2. Extra insulation on facades (planning is ongoing)	793 000 ⁴⁾	78 000	793 000 ⁴⁾	78 000
5	M5. Reconstruction of process ventilation (planning is ongoing)	400 000 ³⁾	7 000	400 000 ³⁾	7 000
X1	Mx1. Replacement of regular doors in the façade	-	-	0	3 000
X2	Mx2. Spray insulation on the inside of the ceilings in some parts	-	-	0	10 000
SUM		1 993 000	203 000	1 683 000	121 000

Notes: ¹⁾ Based on the calculated new baseline. ²⁾ Prices need to be checked after step 2 is finished in 2017. ³⁾ 20% of the total investment. ⁴⁾ 30% of the total investment.

Table 5.3. Energy savings for the measures in the action package of the Norrtälje prison Building 9.

Measure		Step 1		Step 2	
		Thermal energy ¹⁾ [MWh/year]	Electrical Energy ¹⁾ [MWh/year]	Thermal ²⁾ energy [MWh/year]	Electrical ²⁾ energy [MWh/year]
1	M3. Replacement of five large doors (four doors replaced)	25	0	20	0
2	M1. More energy efficient lighting in production zones (measure partly done, is planned to be carried out)	-13	25	-13	25
3	M4. Replacement of LB01 (comfort vent) and reduced airflows (no decisions or planning yet)	72	53	-	-
4	M2. Extra insulation on facades (planning is ongoing)	104	0	104	0
5	M5. Reconstruction of process ventilation (planning is ongoing)	34	-27	34	-27
X1	Mx1. Replacement of regular doors in the façade	-	-	5	0
X2	Mx2. Spray insulation on the inside of the ceilings in some parts of the industry	-	-	14	0
SUM		222	51	163	-2

Notes: ¹⁾ Based on the calculated new baseline ²⁾ Energy savings need to be checked and calculations updated after all measures are carried out (by end of 2017)

6. Segevångs school, Sweden – Step 1



The Segevångs school is an elementary school located in Malmö. The property consists of six buildings: Building A, B, C, D, E and F. Most of the buildings were built in the 1960s. Two of the buildings were built or fully renovated in 2006 (Buildings E and F). The buildings incorporate classrooms, gymnastic hall and a canteen for about 260 students in total.

Measured total energy use of the building in 2011-2014 was in an average about 186 kWh/m² per year inclusive tenants' electricity (corrected to normal year). According to the energy audit, it can be difficult to meet the indoor climate requirements set for the school premises with the current system solutions in Buildings B, C and D. Therefore, upgrading of ventilation systems is recommended. The new baseline will be about 167 kWh/m² per year inclusive tenants' electricity.

The proposed action package in Step 1 included the following measures:

- Optimizing the ventilation system in Building B
- New thermostats and hydronic balancing of the heating systems in Building A, B, C and D
- Occupancy control of the lighting system in the corridors and additional areas in Building B
- Installation of supply and exhaust air system with heat recovery and demand controlled ventilation in Building B, C and D
- New energy efficient tap water fixtures in the toilets
- Occupancy control of the lighting system in the corridors and additional areas

The total energy saving potential with the proposed action package is approximately 12% compared to the new baseline. Annual district heating use can be reduced by 12% and electricity use by 13%.

Total energy use of the Segevångs school property

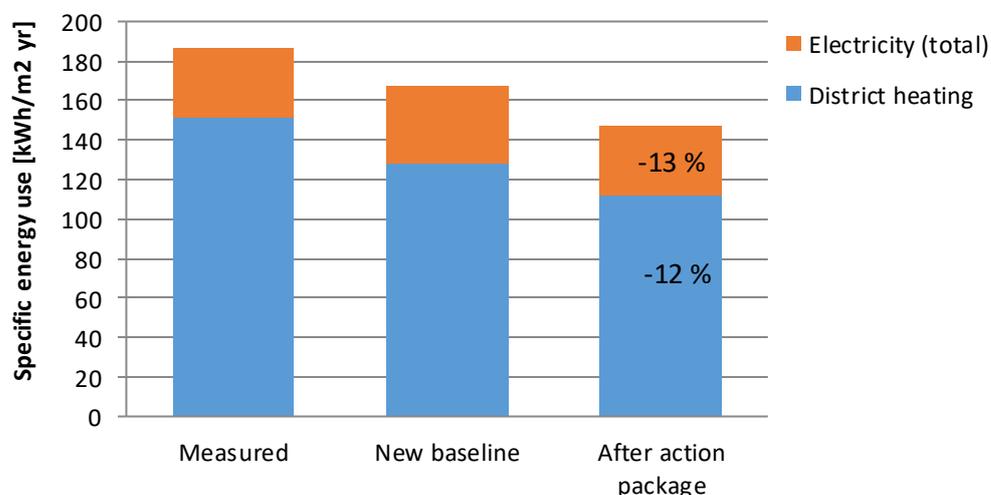


Figure 6.1 Outcomes of Step 1 in the Segevångs school property.

In Building A the energy saving potential with the action package is about 6%, in Building B about 34%, in Building C about 18% and in Building D about 12%. The internal rate of return of the proposed action package is 2%. The property owner's profitability demand is 2%.

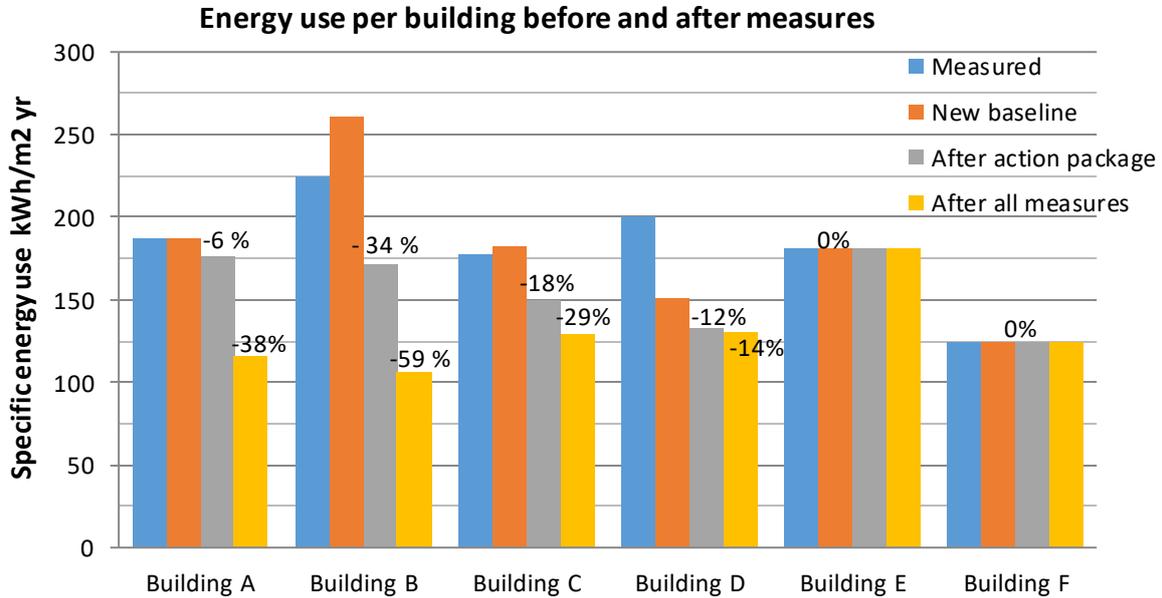


Figure 6.2 Outcomes of Step 1 in the Segevångs school property.

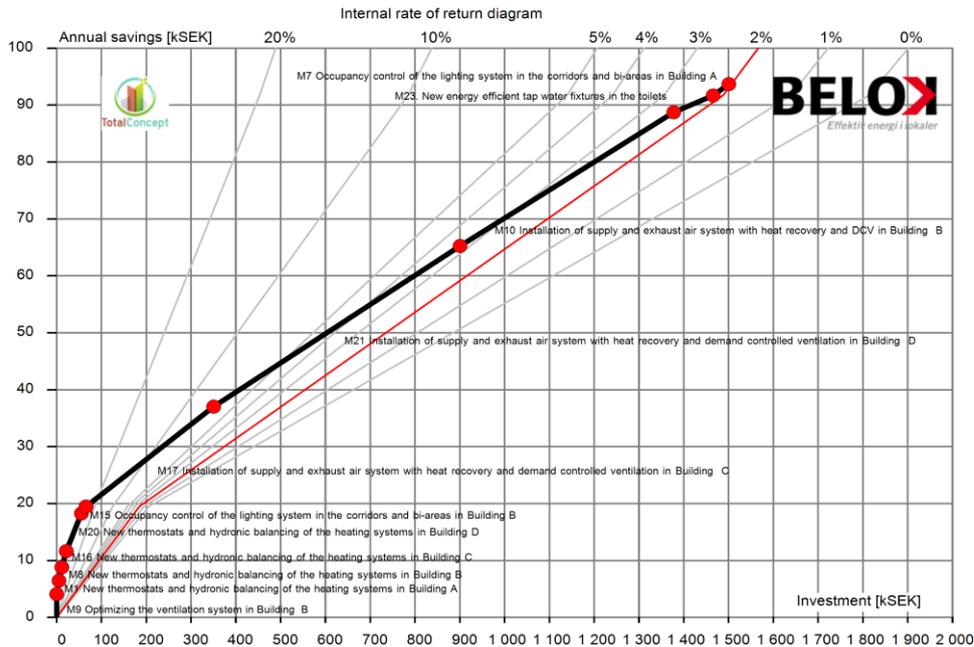


Figure 6.3. Calculated profitability of the action package in Step 1 in the Segevångs school property. The internal rate of return of the proposed action package is 2%. The property owner's profitability demand is 2% and relative energy price increase above inflation is estimated to be ca 1%.

According to the property owner the proposed action package will not be carried out now, but it is planned for the future.

7. Town hall of Ballerup, Denmark – Step 1



The office and administration building is owned by and situated in Ballerup municipality in Denmark. It is built 1975. The building occupies 600 persons on a heated floor area of 17000 m². There was one major extension and refurbishment of the building and the building service systems in 2011.

Baseline energy use was 155 kWh/m². The following action package was identified:

- Exchanging windows
- Optimization of BMS system, including heating, lighting, ventilation and solar shading
- Photovoltaic

Successful implementation of the action package will reduce energy use with 37% to a designed total energy use of 97 kWh/ m². The estimated energy saving is 50% for the heating energy and 30% for the electricity (see figure 7.1)

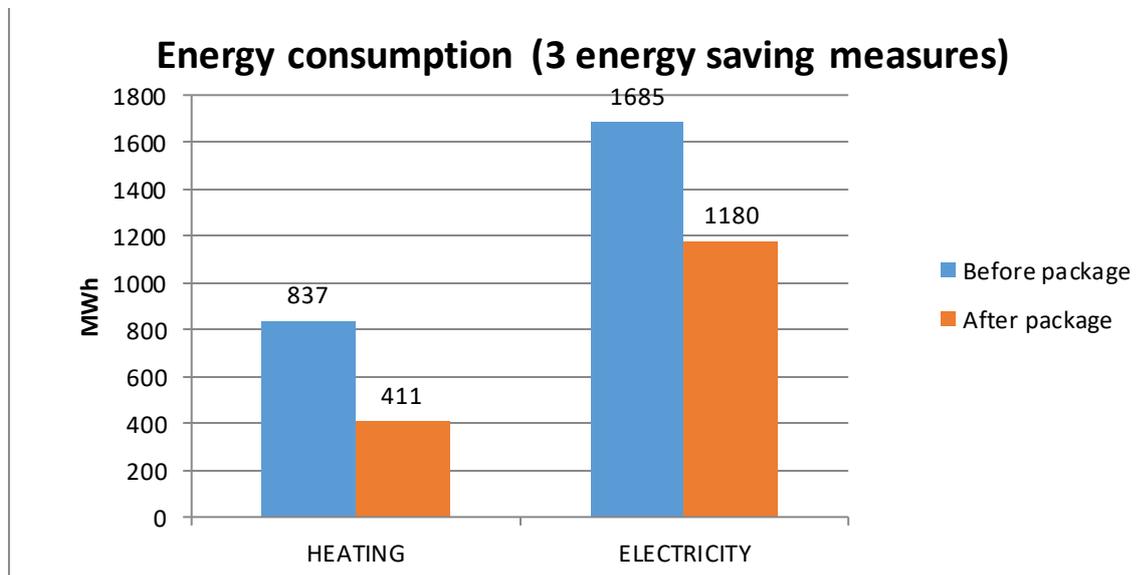


Figure 7.1 Energy use in Ballerup Town Hall when three measures are implemented.

The action package identified in step 1 would result in an IRR of approximately 10% (see figure 7.2).

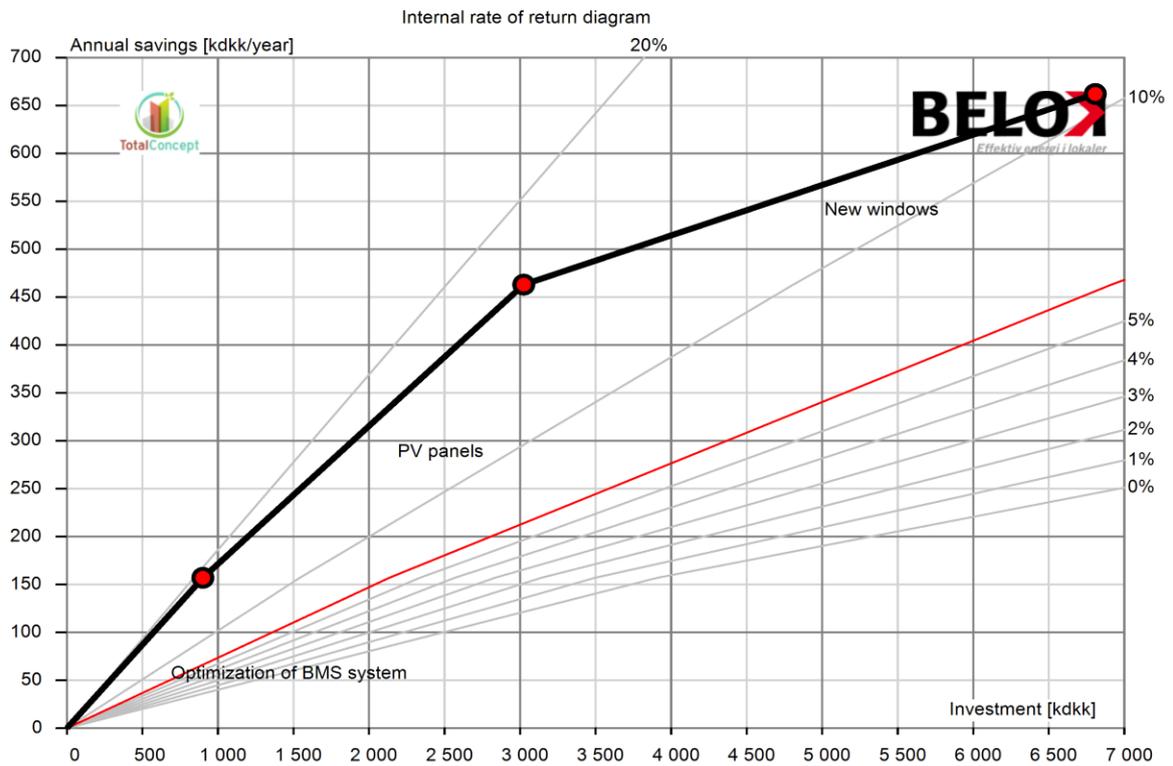


Figure 7.2. Outcomes of the profitability of the action package carried out in the Ballerup Town Hall building presented in an internal rate of return diagram. Estimated internal rate of return for the action package is approx. 10%.

8. Lyngby Port, Denmark – Step 3



Lyngby Port is an office building in portfolio of a Danish property company Nordea Ejendomme. The building is built in 1992 and divided into 3 building segments; A, B and C at Lyngby Hovedgade 94, 96 and 98 - each of them have main energy meters installed. In Lyngby Port segment A has seven floors, B has six floors and C has five floors.

Before renovation the building consisted of cell offices grouped in modules and had several tenants. The intensity of occupancy was around 25m² per person. The office building Lyngby Port was prepared for a new tenant in larger parts of the building with more open office areas and higher number of employees.

Total measured energy use before renovations was 2549 MWh (124 kWh/m²) per year (including tenants' electricity). Due to planned tenant adjustments of indoor climate and number of occupants that requires a higher ventilation rate, the energy use of the building was estimated to increase to about 2703 MWh (131 kWh/m²) per year. This was set as a new baseline for energy efficiency measures. The proposed action package in Step 1 contained seven energy saving measures, which were planned to be carried out as part of the upcoming renovation for the tenant adjustments. Four of the six suggested measures were carried out in Step 2 with some modifications to the initial plans.

The renovation finished entirely in 2016 only for section A and B of the building. Furthermore, section A remained empty in 2016. The renovation in section C finished in October 2016. The presented results are therefore only valid for section B (and partly section C) and they were scaled for section A and C. The scaling of the results from section B is based on assumption that the energy decrease would be similar in section A and C when fully occupied.

8.1 Summary of the results

Figure 8.1 presents the measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2.

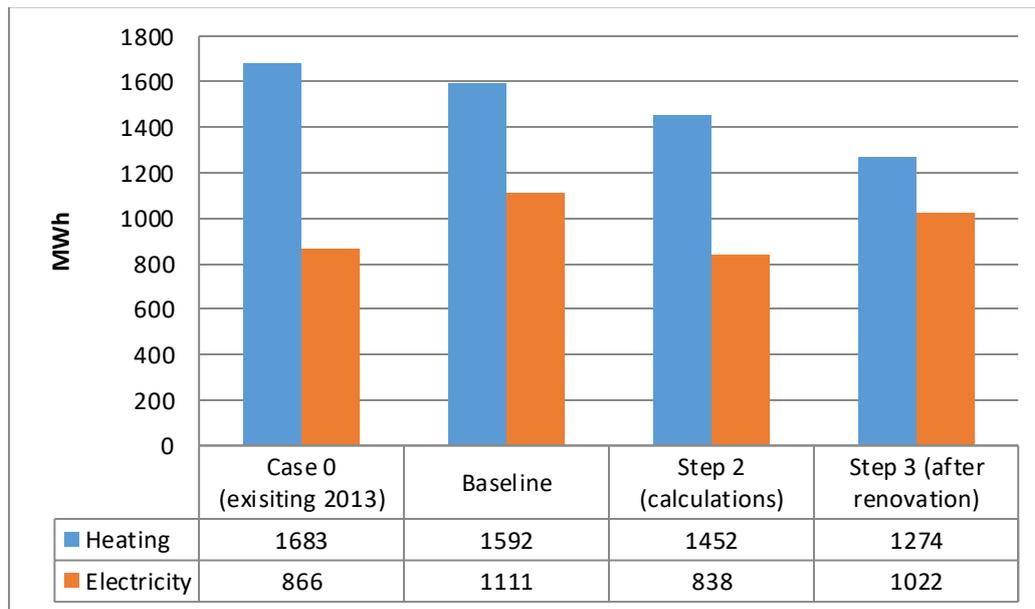


Figure 8.1 Energy use in Lyngby Port when four measures are implemented. Measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2.

According to the measurement from section B during the complete 2016, 2 months of measurements for section C and estimation for section A assuming that the building is fully occupied and the rest of section C, the total specific energy use of the property after renovations is about 2296 MWh (111 kWh/m²) per year.

The total heat energy use after renovations is about 1274 MWh (62 kWh/m²) per year (decrease by 19% comparing to the baseline's 77 kWh/m²). The estimation in Step 2 was 1452 MWh (70 kWh/m²) per year. The total electricity use after renovations is about 1022 MWh (50 kWh/m²) per year (decrease by 8% comparing to the baseline's 54 kWh/m²). The estimation in Step 2 was about 838 MWh (41 kWh/m²) per year. The missing saving is likely to be due to higher electricity use for ventilation. There are two probable reasons for this: higher occupation rates are handled with more air instead of lower temperature (this was priority programmed in the BMS then we checked) as well as higher pressure loss in the ventilation units than originally calculated. The high pressure loss in the ventilation units will be reduced by increasing size of openings after ventilators as well as removing unnecessary bendings after the air handling units. This is planned to be carried out in March 2017 (including measurements before and after).

The calibration of the systems is still needed and data for the full year of measurements should be analysed. Moreover, the tenant for section B is characterized by higher fluctuations in use of the building (there are more persons and longer operation time). The results show unexpected increase in heating demand in December 2016 compared to 2013. To check the results the internal gain, operation hours, set points and climate data must be examined. The results for electricity show fluctuations and it is suggested to follow-up electricity use the next months. A more regular use of the office environment (section A and C) could give results that are more reliable.

For the action package carried out in Step 2, the total building energy use was estimated to be with the internal rate of return about 8%. The measured/scaled outcomes in Step 3 show that the savings for now will give an internal rate of return of 4%. The result is only informative as there are still some unclarified issues. After solving the problem with high pressure loss in the ventilation system, the internal rate of return will be higher.

The actual profitability outcomes are presented in Table 8.1 below. The diagram in Figure 8.2 shows the calculated profitability for the action package in Step 2 together with the true profitability that was calculated after Step 3.

Table 8.1. Summary of the outcomes of the action package carried out in Lyngby Port compared to the estimations made in Step 2. Presented savings are compared to the baseline.

	Step 2	Step 3
Total annual energy savings:	15%	15%
Calculated energy savings – district heating:	140 MWh/yr	318 MWh/yr
Calculated energy savings – electricity:	273 MWh/yr	89 MWh/yr
Total annual cost savings:	72 kEUR/yr	29 kEUR/yr (+ maintenance costs)
Internal rate of return for the package:	8%	4%

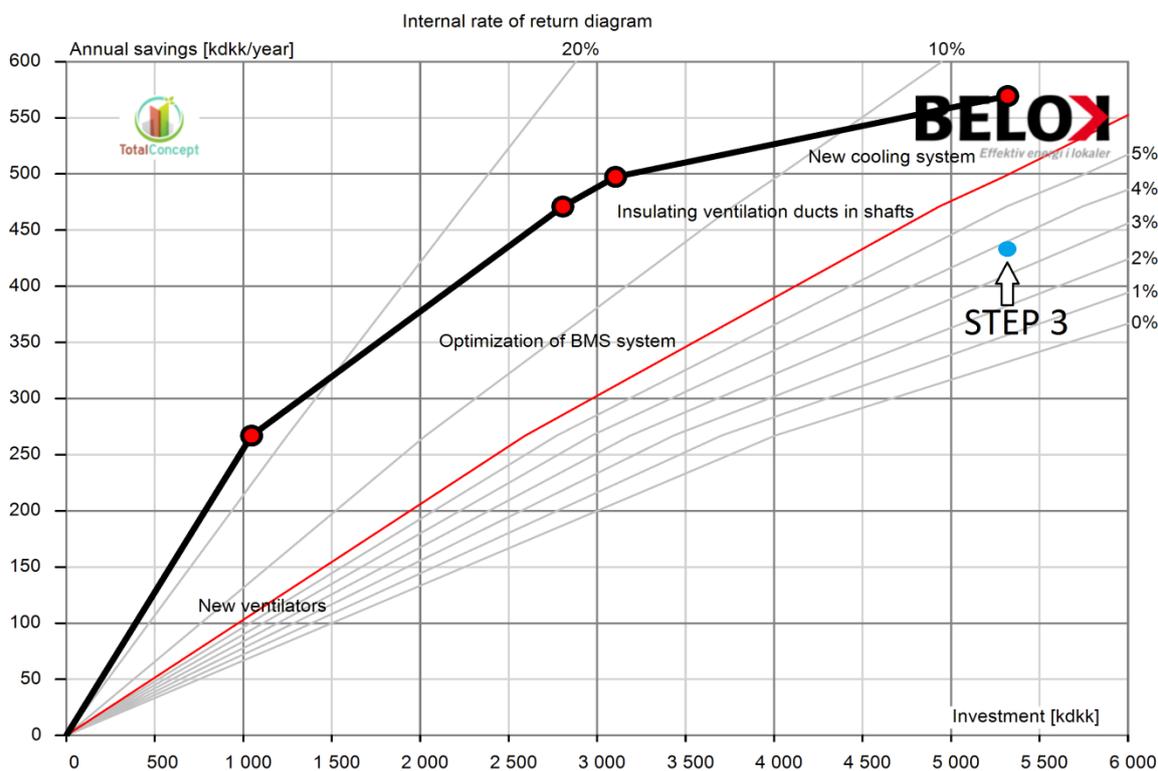


Figure 8.2. Outcomes of the profitability of the action package carried out in the Lyngby Port office building presented in an internal rate of return diagram. Estimated internal rate of return for the action package after Step 3 is approx. 4%.

8.2 Measures carried out in Step 2

The proposed action package in Step1 contained seven energysaving measures, which were planned to be carried out as part of the upcoming renovation for the tenant adjustments. A number of adjustments were made to the action package in Step2 and in the end four measures were carried out.

Table 8.2 and 8.3 show investments, cost and energy savings from Step 1 compared to real investments (including consulting costs) and with calculated, adjusted saving. The reasons and consequences for all major adjustments are specified in Table 8.4.

Table 8.2. Cost savings for the measures in the action package.

No	Measure	Step 1		Step 2	
		Estimated investment [Euro]	Estimated Cost saving [Euro/year]	Real Investment [Euro]	Adjusted Cost saving [Euro/year]
1	Conversion to district heating	20 000	31 200	-	-
2	New ventilators	73 400	38 300	139 600	36 000
3	Insulating ventilation ducts in shafts	14 300	2 200	39 730	3 000
4	PV panels	233 400	37 500	-	-
5	Optimization of BMS system	300 000	28 500	234 530	27 000
6	PIR sensors in toilets	9 400	500	-	-
7	New cooling system	295 500	10 900	293 300	10 000 (incl. maintenance saving)
	Sum	946 000	149 100	707 200	76 000
	Internal rate of return	15.7%		8%	

Table 8.3. Energy savings for the measures in the action package.

No	Measure	Step 1		Step 2	
		Thermal energy [MWh/year]	Electrical energy [MWh/year]	Thermal energy [MWh/year]	Electrical energy [MWh/year]
1	Conversion to district heating	187	0	-	-
2	New ventilators	-45	164	-45	180
3	Insulating ventilation ducts in shafts	0	16	0	16
4	PV panels	0	166	-	-
5	Optimization of BMS system	183	138	186	51
6	PIR sensors in toilets	0	3	-	-
7	New cooling system	0	58	0	25
	Sum	325	545	141	272

Table 8.4. Deviations from step 1 – Reasons and consequences.

No	Measure	Step 1	Step 2	Consequence
		Presumptions	Adjusted	
1	Conversion to district heating	-	Not implemented yet	Lack of saving
2	New ventilators	Replacement of old ventilators with axial ventilators	Replacement old ventilators with centrifugal ventilators. Replacing rusty plates in the AHU units, installing extra submeters and performance test to check SFP factor. The replacement will be done in a weekend in order to not cause problems for tenants – the price of the measure was increased by weekend rates that have to be paid to the workers	The IRR for the single measures reduced
3	Insulating ventilation ducts in shafts	30 mm insulation, around 100 mm ducts	50 mm insulation, around 630 mm ducts The owner decided to insulate not only ducts in the shafts but also ducts in the basement and at the roof as well as distributing ducts in the shafts areas.	The IRR for the single measures reduced
4	PV panels	-	Not implemented yet	Lack of saving
5	Optimization of BMS system	-	Implemented as suggested	-
6	PIR sensors in toilets	-	Not implemented yet	Lack of saving
7	New cooling system	-	Implemented as suggested	-

Explanatory comments:

- Measure 1 will be implemented in spring 2017 (problems with electrical cables in the ground caused by a construction of a new light rail line in the neighbourhood and thereby delay of works for district heating)
- Measure 4 - will be implemented in spring 2017

9. Pärnu high school, Estonia – Step 3



Metsa 21. Pärnu school building was built in 1978. It has a total heated area of 8184 m². The main objective of the renovation was to renovate a depreciated building, which has several IAQ problems. During Step 1, the building is not in use. Previously performed analysis concluded that indoor climate did not meet the requirements. Moisture issues and mould problems indicate that the ventilation system is insufficient. The heating system did not have thermostatic valves and therefore it was estimated that the building was overheated by 1-2 °C. Measured existing energy use was 176 kWh/m² per year. Due to new ventilation rates, the energy use of the building was estimated to increase to about 199 kWh/m² per year. This was set as the new baseline before energy measures.

Overall, six major energy efficiency measures were identified during the auditing. Whereas all indicated measures are included in the proposed action package in step 1. The internal rate of return of the proposed action package is 7.7%, slightly above the property owner's profitability demand of 5.5%.

9.1 Summary tables

Figure 9.1 presents the measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2. There is no split between electricity for building operation and tenants.

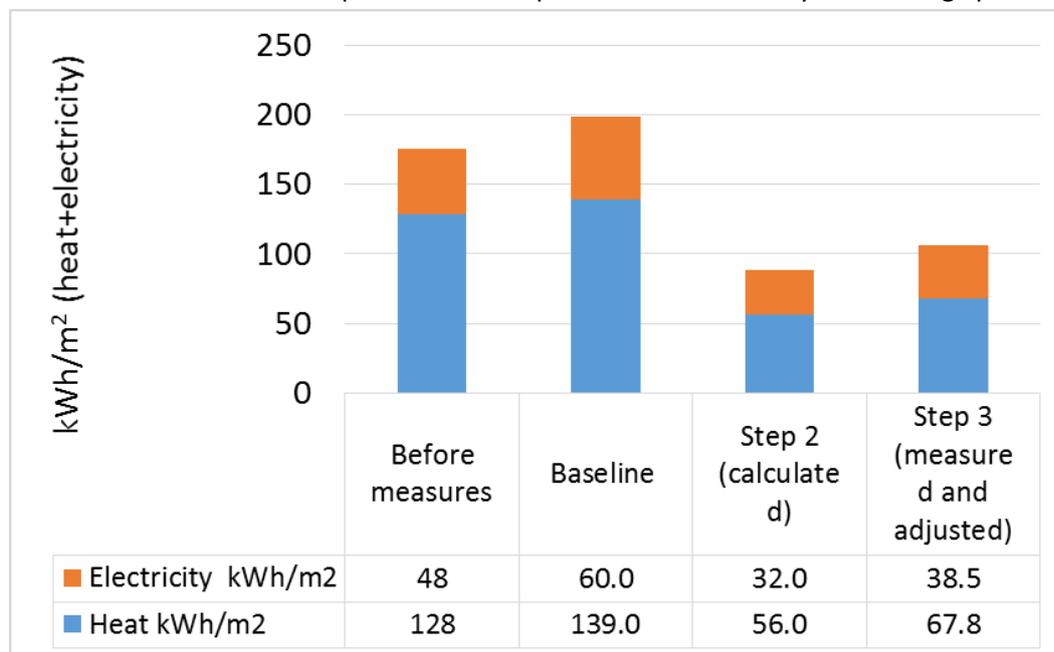


Figure 9.1 Estimated outcome in Step 3 compared to baseline.

According to the measurements outcomes of Step 3 the total adjusted net energy use is about 106 kWh/m².

The action package carried out in Step 2 was estimated to reduce the net energy use about 56% compared to the baseline. The measured outcomes in Step 3 show the savings to be about 46%.

The actual profitability outcomes are summarized in Table 9.1 and presented below in Figure 9.2 below. The diagram in Figure 9.2 shows the calculated profitability for the action package in Step 2 together with the true profitability that was calculated after Step 3. The calculated profitability for the package in Step 2 was 7.7%. The actual profitability based on the actual costs for the energy efficiency measures and calculated savings from measured energy use in Step 3 was about 6.6%, which is higher than building owner's profitability demand of 5.5%.

Table 9.1 Summary of the outcomes of the action package carried out in Metsa 21. Pärnu school buildings compared to the estimations made in Step 2. Presented savings were compared to the baseline.

	Step 2	Step 3
Total net annual energy savings:	56%	46%
Calculated energy savings – district heating:	657 MWh/yr	558 MWh/yr
Calculated power savings – electricity:	221.7 MWh/yr	169 MWh/yr
Total annual cost savings:	54.6 kEuro/yr	44.7 kEuro/yr
Energy investment cost:	602 kEuro/yr	602 kEuro/yr
Internal rate of return for the package:	7.7%	6.6%

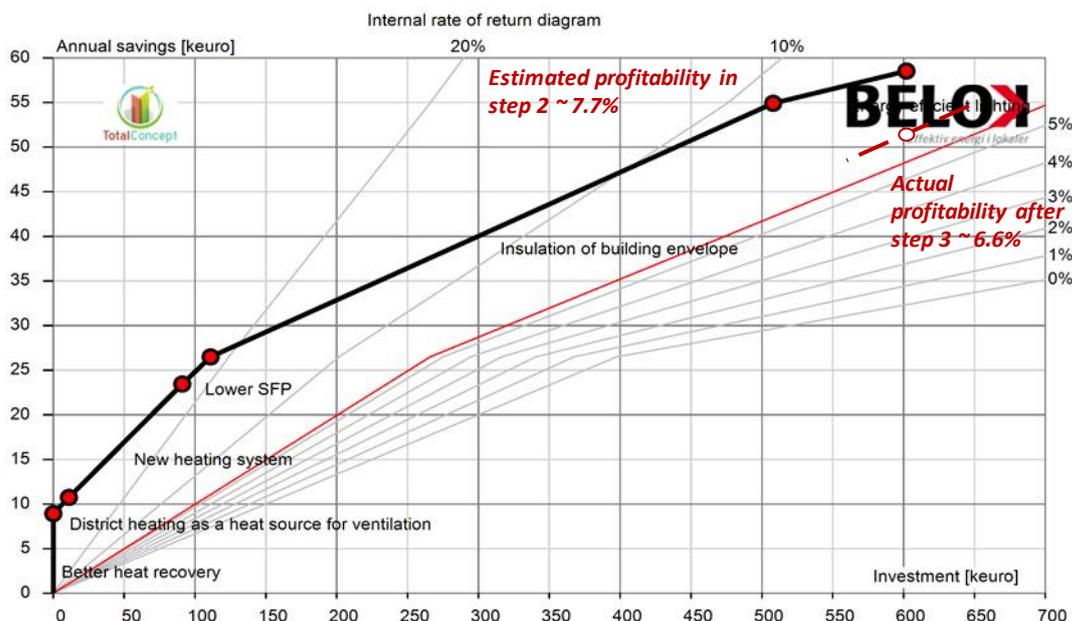


Figure 9.2 Outcomes of the profitability of the action package carried out at the Pärnu School building. Relative energy price increase is 2%.

9.2 Measures carried out in Step 2

The proposed action package in Step 1 consisted of eight energy saving measures and all measure was implemented in step 2.

Table 9.2. Cost savings for the measures in the action package.

Measure	Step 1		Step 2	
	Estimated investment [Euro]	Estimated Cost saving [Euro/year]	Real Investment [Euro] ¹⁾	Adjusted Cost saving [Euro/year] ¹⁾
1 Better ventilation heat recovery	0	8 000	0	8 000
2 AHU coil heat source from district heating	11 000	1 000	11 000	1 000
3 New heating system	80 000	12 000	80 000	12 000
4 Lower SFP	20 000	3 000	20 000	3 000
5 Insulation of building envelope	397 000	28 000	397 000	28 000
6 Energy efficient lighting	94 000	3 000	94 000	3 000
SUM	602 000	55 000	602 000	55 000
Internal rate of return	7.7%		7.7%	

Table 9.3. Energy savings for the measures in the action package.

Measure		From step 1		Adjusted after Step 2	
		Thermal energy [MWh/year]	Electrical energy [MWh/year]	Thermal energy [MWh/year]	Electrical energy [MWh/year]
1	Better ventilation heat recovery		104		104
2	AHU coil heat source from district heating	+32.2	29.8	+32.2	29.8
3	New heating system	216.9	-	216.9	-
4	Lower SFP	+6.7	39.7	+6.7	39.7
5	Insulation of building envelope	508	-	508	-
6	Energy efficient lighting	+28.2	48.2	+28.2	48.2
SUM		658	222	658	222

+ means additional energy (e.g. new lightening systems produce less internal gains and it increase heat need for ensuring proper indoor temperature);

10. Kiriku 2/4, Estonia – Step 3



Kiriku 2-4. Tallinn office building was built in 18th century. It has a total heated area of 1877 m².

The main objective of the renovation was to renovate an empty depreciated building with a perfect location in medieval city centre. Measured existing energy use was 282 kWh/m² per year. Due to new ventilation rates, the energy use of the building was estimated to increase to about 376 kWh/m² per year. This was set as the new baseline before energy measures.

Overall, seven major energy efficiency measures were identified during the auditing. Whereas all indicated measures are included in the proposed action package in Step 1. The internal rate of return of the proposed action package is negative, below the property owner’s profitability demand of 5.5% but the main objective of the owner is to renovate the building.

10.1 Summary tables

Figure 10.1 presents the measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2. There is no split between electricity for building operation and tenants.

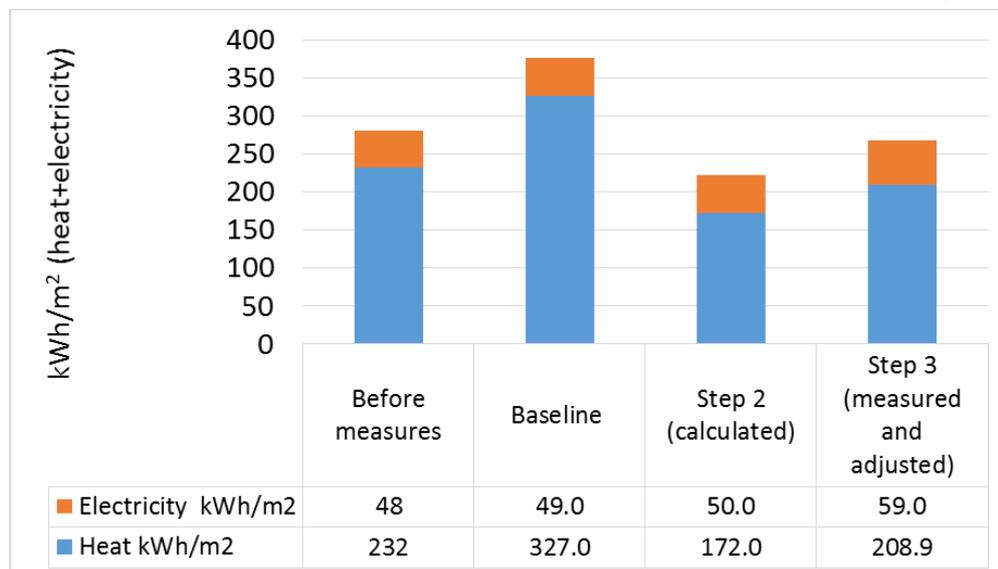


Figure 10.1. Estimated outcome in Step 3 compared to baseline.

According to the measurements outcomes of Step 3 the total net energy use is about 268 kWh/m².

The action package carried out in Step 2 was estimated to reduce the net energy use about 41% compared to baseline. The measured outcomes in Step 3 show the savings to be about 28%.

The actual profitability outcomes are summarized in Table 10.1 and presented in Figure 10.2 below. The diagram in Figure 10.2 shows the calculated profitability for the action package in Step 2 together

with the true profitability that was calculated after Step 3. The calculated profitability for the package in Step 2 was negative. The actual profitability based on the actual costs for the energy efficiency measures and calculated savings from measured energy use is even lower than calculated – the measures were not financially attractive.

Table 10.1 Summary of the outcomes of the action package carried out in Kiriku 2-4. Tallinn office buildings compared to the estimations made in Step 2. Presented savings were compared to the baseline.

	Step 2	Step 3
Total net annual energy savings:	41%	28%
Calculated energy savings – district heating:	289 MWh/yr	219.6 MWh/yr
Calculated power savings – electricity:	-2 MWh/yr	-19.2 MWh/yr
Total annual cost savings:	17.6 k€/yr	11.6 k€/yr
Energy investment cost:	360 k€/yr	360 k€/yr
Internal rate of return for the package:	Less than 0%	Less than 0%

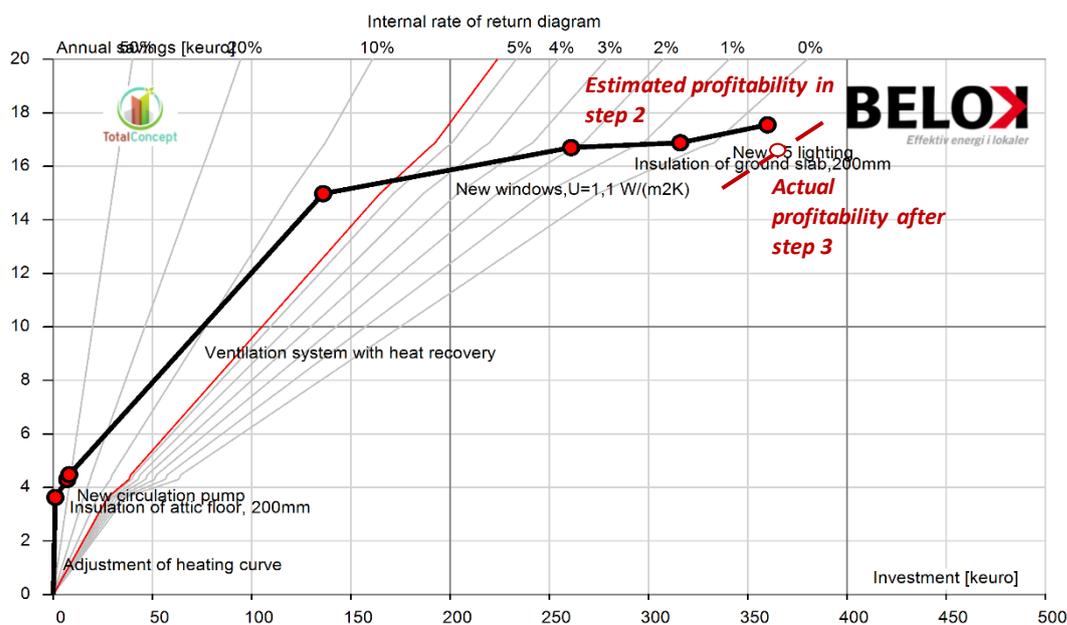


Figure 10.2 Outcomes of the profitability of the action package carried out at the Kiriku 2-4. Tallinn office building. Relative energy price increase is 2%. Actual internal rate of return for the action package is negative.

10.2 Measures carried out in Step 2

The proposed action package in Step 1 consisted of eight energy saving measures, all measures were selected in step 2.

Table 10.2. Cost savings for the measures in the action package.

Measure		Step 1		Step 2	
		Estimated investment [Euro]	Estimated Cost saving [Euro/year]	Real Investment [Euro] ¹⁾	Adjusted Cost saving [Euro/year] ¹⁾
1	Adjustment of heating curve	1 000	3 000	1 000	3 000
2	Insulation of attic floor. 200mm	6 000	670	6 000	670
3	New circulation pump	1 000	1 980	1 000	1 980
4	Ventilation system with heat recovery	128 000	10 490	128 000	10 490
5	New windows U=1.1 W/(m2K)	125 000	1 720	125 000	1 720
6	Insulation of ground slab.200mm	55 000	180	55 000	180
7	New T5 lighting	44 000	670	44 000	670
SUM		360 000	18 710	360 000	18 710
Internal rate of return		-%		-%	

Table 10.3. Energy savings for the measures in the action package.

Measure		From step 1		Adjusted after Step 2	
		Thermal energy [MWh/year]	Electrical energy [MWh/year]	Thermal energy [MWh/year]	Electrical energy [MWh/year]
1	Adjustment of heating curve	59	-	59	-
2	Insulation of attic floor. 200mm	11	-	11	-
3	New circulation pump	-	2.2	-	2.2
4	Ventilation system with heat recovery	197	+19	197	+19
5	New windows U=1.1 W/(m2K)	28	-	28	-
6	Insulation of ground slab.200mm	3	-	3	-
7	New T5 lighting	+10	15	+10	15
SUM		288	+2	288	+2

+ means additional energy (e.g. new lightening systems produce less internal gains and it increase heat need for ensuring proper indoor temperature).

11. Gonsiori 29, Estonia - Step 3



Gonsiori 29. Tallinn office building was built in 1950. It has a total heated area of 6797 m².

The main objective of the renovation was to improve indoor air quality – old windows causes a cold draughts and cold radiation and old lights were flickering. IAQ measurements during the Step 1 shows that ventilation rates were enough. The existing situation describes the baseline of measures.

Overall, eight major energy efficiency measures were identified during the auditing. Whereas two measures are included in the proposed action package in Step 1. The internal rate of return of the proposed action package is 0.2%, below the property owner's profitability demand of 5.5%. These measures were necessary for the owner to solve IAQ problems.

11.1 Summary tables

Figure 11.1 presents the measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2. There is no split between electricity for building operation and tenants.

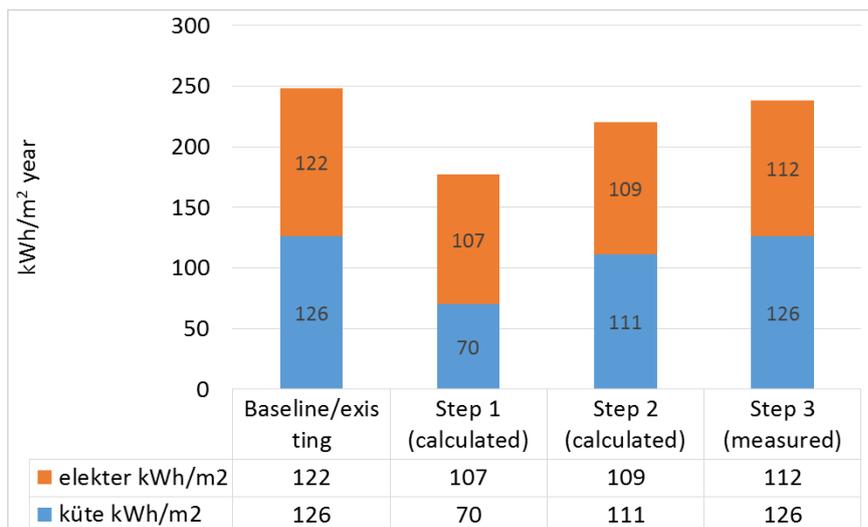


Figure 11.1 Estimated outcome in Step 3 compared to baseline. Elekter means electric energy and küte means thermal energy.

According to the measurements outcomes of Step 3 the total net energy use is about 238 kWh/m². The action package carried out in Step 2 was estimated to reduce the net energy use about 12% compared to baseline. The measured outcomes in Step 3 show the savings to be about 3.5%.

The actual profitability outcomes are summarized in Table 11.1 and presented below in Figure 11.2. The diagram in Figure 11.2 shows the calculated profitability for the action package in Step 2 together with the true profitability that was calculated after Step 3. The calculated profitability for the package

in Step 2 was 0.2%. The actual profitability based on the actual costs for the energy efficiency measures and calculated savings from measured energy use in Step 3 was negative.

Table 11.1 Summary of the outcomes of the action package carried out in Gonsiori 29. Tallinn office buildings compared to the estimations made in Step 2. Presented savings are compared to the baseline.

	Step 2	Step 3
Total net annual energy savings:	12%	3.5%
Calculated energy savings – district heating:	109 MWh/yr	+1 MWh/yr
Calculated power savings – electricity:	90 MWh/yr	65 MWh/yr
Total annual cost savings:	14 k€/yr	6 k€/yr
Energy investment cost:	382 k€/yr	382 k€/yr
Internal rate of return for the package:	0.2%	-%

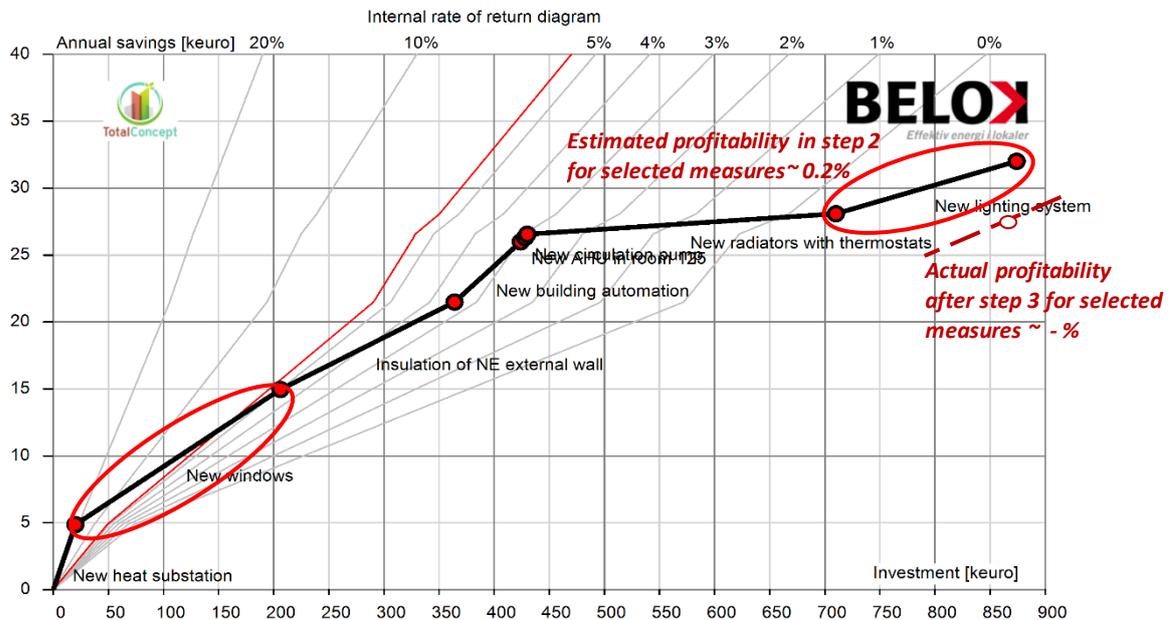


Figure 11.2 Outcomes of the profitability of the action package carried out at the Gonsiori 29. Relative energy price increase is 2%. Actual internal rate of return for the action package is negative.

11.2 Measures carried out in Step 2

The proposed action package in Step 1 consisted of eight energy saving measures, but only two measures were selected in Step 2.

Table 11.2 Cost savings for the measures in the action package.

Measure		Step 1		Step 2	
		Estimated investment [Euro]	Estimated Cost saving [Euro/year]	Real Investment [Euro] ¹⁾	Adjusted Cost saving [Euro/year] ¹⁾
1	New heat substation	20 000	4 000		
2	New windows	186 000	10 100	237 000	10 100
3	Insulation of NE external wall	158 000	6 600		
4	New building automation system	60 000	4 700		
5	New AHU system in room 125	4 000	300		
6	New circulation pump	2 000	300		
7	New radiators with thermostats	280 000	2 700		
8	New lightening system	164 000	3 700	145 000	3 700
SUM		874 000	32 100	382 000	13 800
Internal rate of return		-%		0.2%	

Table 11.3 Energy savings for the measures in the action package.

Measure		From step 1		Adjusted after Step 2	
		Thermal energy [MWh/year]	Electrical energy [MWh/year]	Thermal energy [MWh/year]	Electrical energy [MWh/year]
1	New heat substation	229	-		
2	New windows	164	-	164	-
3	Insulation of NE external wall	106	-		
4	New building automation system	65	8		
5	New AHU system in room 125	-	4		
6	New circulation pump	-	3		
7	New radiators with thermostats	44	-		
8	New lightening system	+67	91	+67	91
SUM		541	106	97	91

+ means additional energy (e.g. new lightening systems produce less internal gains and it increase heat need for ensuring proper indoor temperature);

12. Tampere Hall Congress & Concert Centre, Finland – Step 3



Tampere Hall Congress & Concert Centre was built in 1990 and has a total area of 28 357 m². Shortly after completion, an adjacent hall, the Sorsapuisto hall was built. In 2005, the Sorsapuisto hall was connected to the main building with a glass tunnel . An extension between Sorsapuisto hall and the main building will be built between 2015 and 2016 and this extension is denoted part 9 in figure 12.3. During the ongoing phase of the renovation, a museum (Muumilaakso) will move to the building. Additional office spaces are also to be constructed. There is also a restaurant and a café open to the public during the working hours of the centre. In the future, a permanent museum and a new restaurant will open in the ground floor. Total measured district heating consumption in 2013 was 3050 MWh (heating 2930 MWh and warm water 130 MWh).

Due to building owner's and users' business targets and financial reality it was not possible to close the whole building at once for a renovation. Therefore, the proposed action package was divided into several parts that would influence only certain parts of the building per time period. The whole action package, the different stages of the renovation and its related areas of the building are shown in Figure 12.1 and 12.2.

After Step 1, seven measures, listed in chapter 12.2, were implemented in part 1 of the renovation. Measure 1, 2 and 9.6 were completed in 2016. Measure 6 and 9.3 are ongoing and planned to be finalized in 2017. Measure 3 has been rejected. The other eight measures are planned to be completed in 2019. The energy consumption is estimated to decrease 23% to 142 kWh/m².

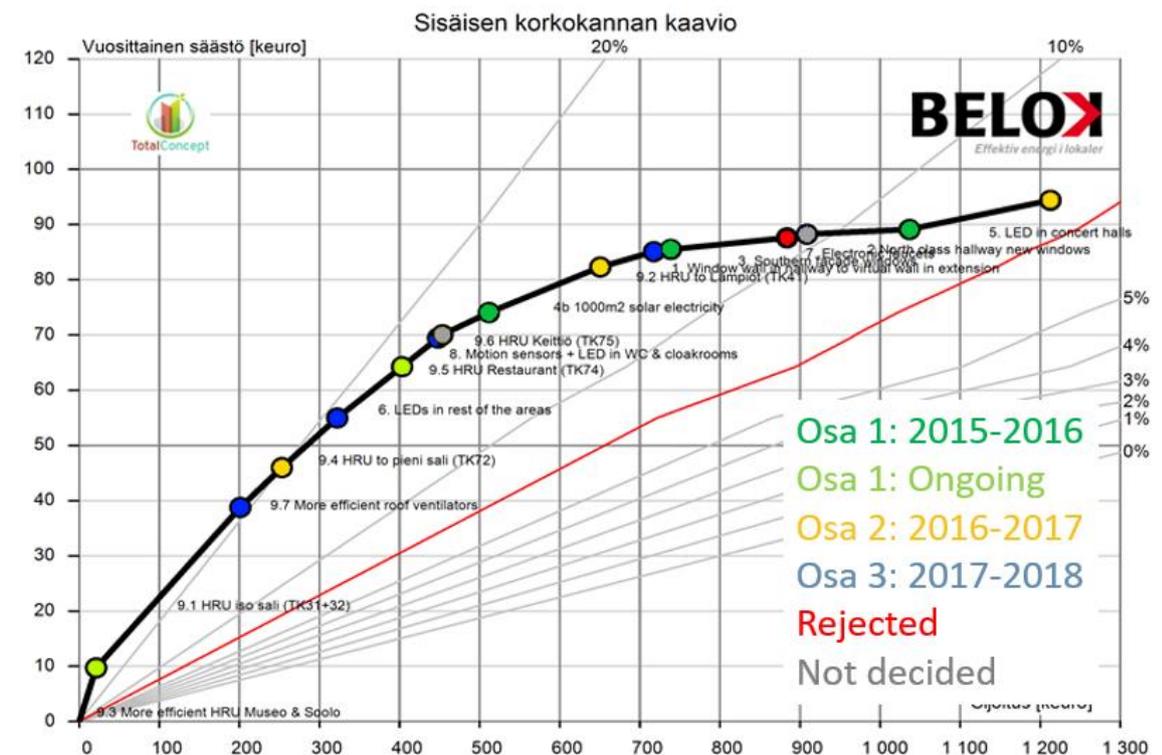


Figure 12.1. The proposed measures and the different phases of the sequencing of the renovation. Measure 1, 2 and 9.6 were completed in 2016. Measure 6 and 9.3 are ongoing and planned to be finalized in 2017. Measure 3 has been rejected. The other eight measures are planned to be completed in 2019.

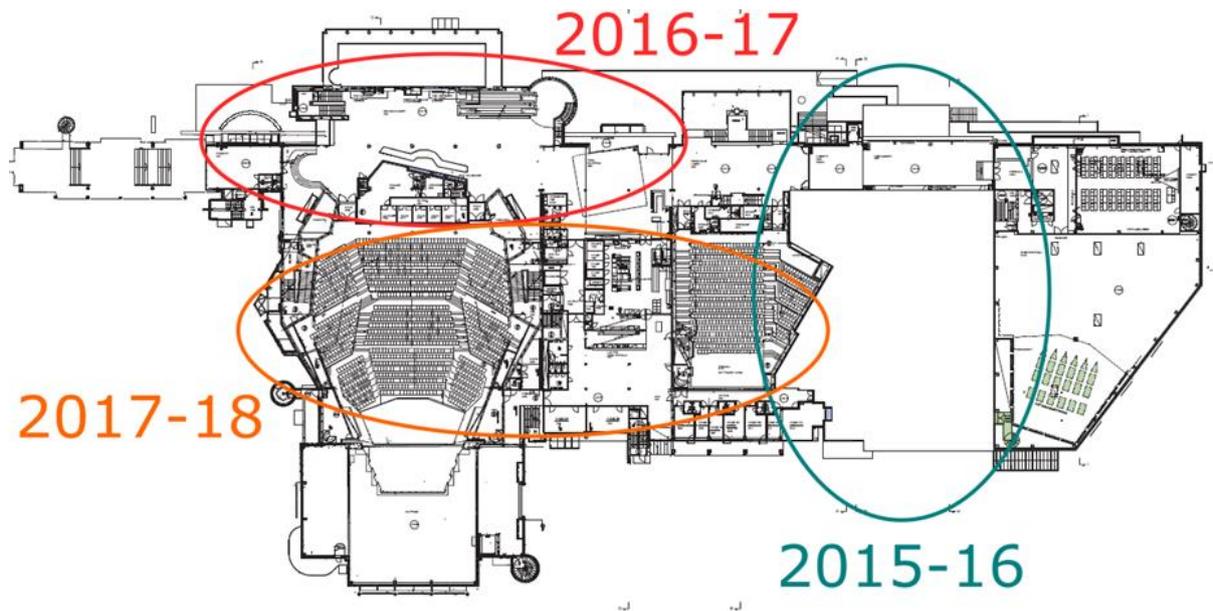


Figure 12.2 Overview of building areas. The action package is divided in three parts. Measure 1, 2 and 9.6 is in part 1 marked 2015-2016. Measure 6 and 9.3 are in part 2 marked -2016-2017. Measure 3 has been rejected. The other eight measures are in part 3 marked 2017-2018.

12.1 Summary of the preliminary results

Figure 12.3 shows the outcomes of the latest measured step compared to estimated baseline in Step 1 and the estimation of the final result once the building renovation has been completed.

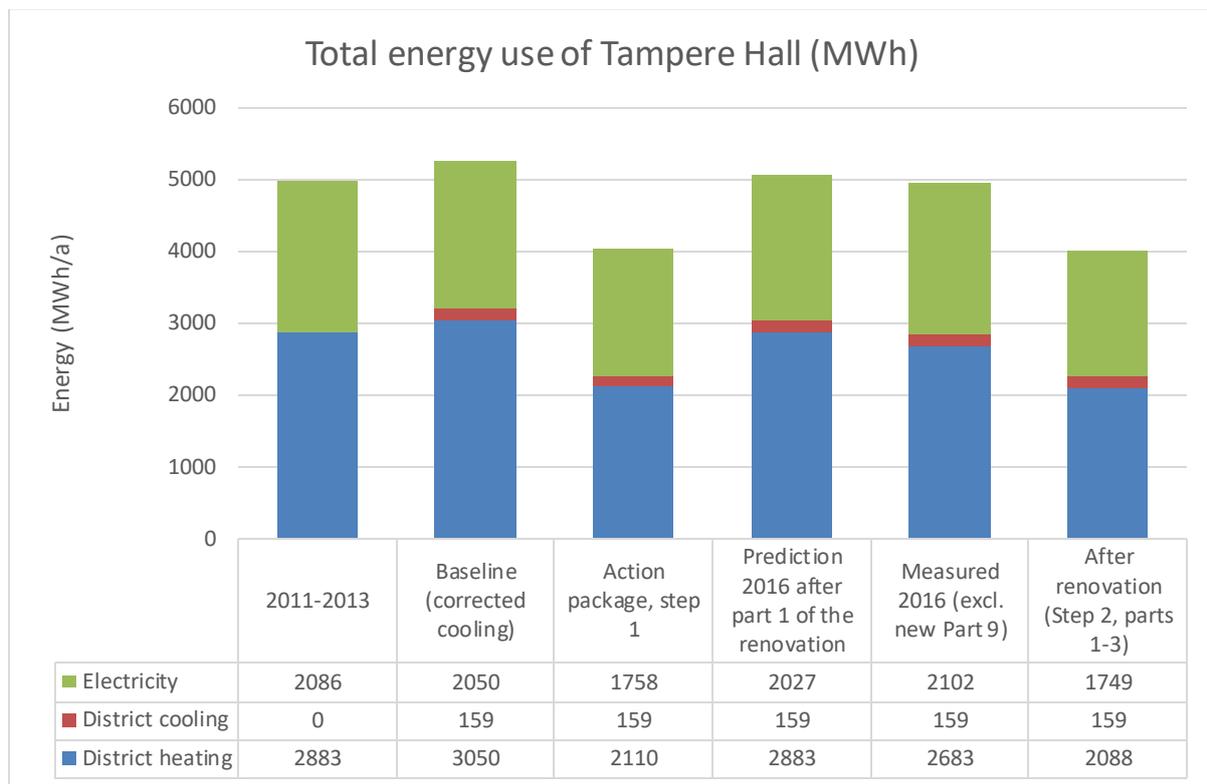


Figure 12.3 Energy use after different stages of the action package. Measure 1, 2 and 9.6 has been carried out and measured (column "Measured 2016") and compared with predicted energy use (column "Prediction 2016 after part 1 in Figure 12.2"). Part 9 is new built extension between Sorsapuisto hall and the main building and this is not included.

Since the building is still under renovation, the measured energy consumption was compared to a prediction made for 2016. In general, the predicted and measured were similar in 2016. However, as the actual heat consumption in the building in 2016 was somewhat lower than expected: 7 kWh/m² and 7% less. This resulted in an extra electricity consumption of 3 kWh/m² per year which is 4% higher. The likely reasons for the difference in heat consumption lies in that the areas that are under renovation are not heated that much compared to expected and to the rest of the building. This difference was taken into account in the prediction but as the renovated areas there different during the year and different building parts are linked to each other, estimating this was possible only in a rough level. Therefore, the difference between the results can be considered to be within the error margins. Also, the changes in the electricity consumption are estimated to be linked to the renovation. The construction site electricity consumption was measured separately but it could be possible that not all of it was tracked. The tracked site electricity consumption was 37 MWh.

The measured outcomes of those measurable individual measures were concluded to be approximately in line with estimations done in Step 2.

The estimated profitability outcomes after completing the renovation are summarized in Table 12.1 and presented in Figure 12.4. For the action package carried out in Part 1-3 of Step 1, the internal rate

of return was estimated to be 7.8%. The diagram in Figure 12.4 shows that the calculated profitability after part 1-3 of Step 2 is completed is estimated to be approximately 8.5%.

Due to the ongoing renovation in the building during the measurement period, the changing use patterns, and the big size and the complexity of the building, it is currently impossible to draw any final conclusions on the energy savings. Instead, the building should be reassessed after the first part of the renovation has been completed by spring 2017.

Table 12.1 Summary of the outcomes of Step 2 in the Tampere Hall compared to the estimations made in Step 1. Presented savings are compared to the new baseline.

	Part 1 - Step 1	Step 2, part 1 – already executed measures	Step 2, part 1-3 – after renovation is completed
Total annual energy savings:	1 233 MWh	174 MWh	1 264 MWh
Total annual energy savings for building operation (BBR):	1 233 MWh	174 MWh	1 264 MWh
Energy savings- electricity:	293 MWh	7 MWh	302 MWh
Energy savings- district heating	940 MWh	167 MWh	962 MWh
Total annual cost savings:	94 kEuro	13 kEuro	96 kEuro
Energy investment cost:	1 230 kEuro	273 kEuro	1 044 kEuro
Internal rate of return for the action package	7.8%	-	8.5%

¹⁾ Values are based on preliminary data and estimations.

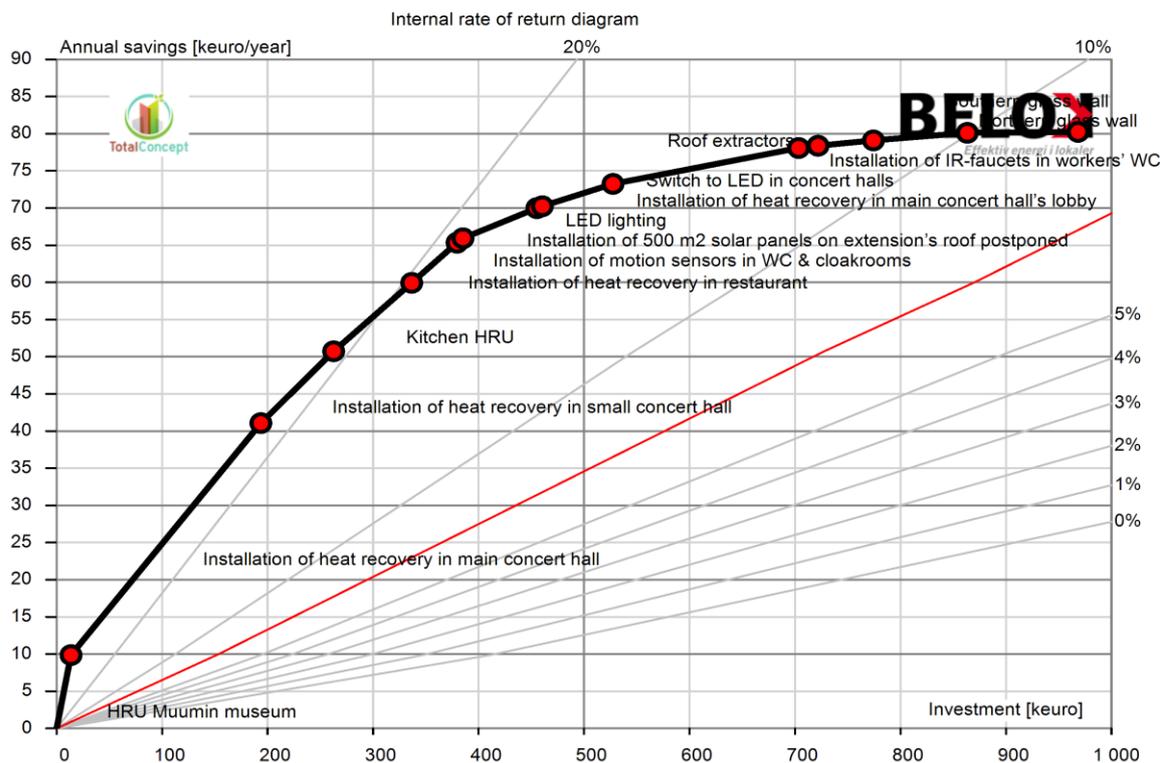


Figure 12.4. Outcomes of the profitability of the action package carried out at the Tampere Hall. The internal rate of return after for part 1-3 of Step 2 is completed is estimated to be approximately 8.5%.

12.2 Status of the measures carried out in Step 2

The proposed action package in Step 1 contained the following measures:

- *Measure 1:* Replacing the southern glass window in hallway,
- *Measure 2:* Replacing northern glass window in hallway
- *Measure 3:* Replacing southern facade windows,
- *Measure 6:* Switching to LEDs in remaining areas,
- *Measure 9.3:* More efficient heat recovery for new ventilation for Moomin Museum,
- *Measure 9.6:* Adding heat recovery for kitchen ventilation unit
- *Measure 9.7:* Replacing roof extractors with more efficient ones.

Table 12.2 and Table 12.3 show the estimated investment, cost and energy savings from Step 1 compared to real investments and with adjusted savings in Step 2. The reasons and consequences for all adjustments are specified in Table 12.4. Figure 12.5 shows the outcomes of the latest measured step compared to the estimated baseline in Step 1 and the estimation of the final result once the building renovation has been completed.

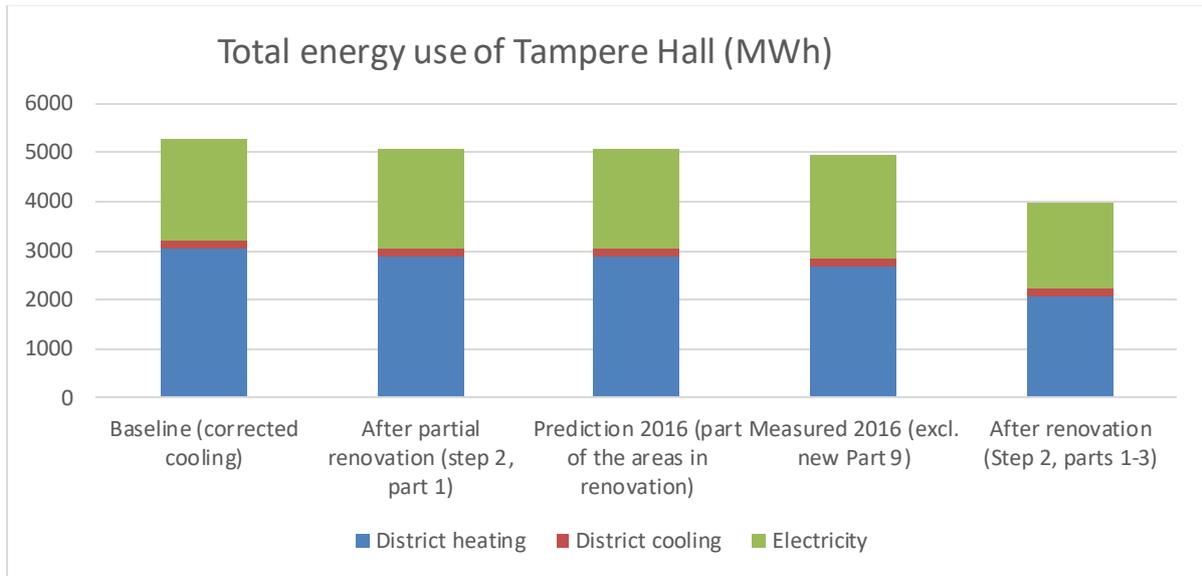


Figure 12.5 Overview of the total energy consumption in baseline, the estimated consumption of the package 1 implemented (October 2016) and the actual consumption in 2016.

Table 12.2. Cost savings for the measures in the action package (2015-16)

Measure		Step 1		Step 2	
		Estimated investment [Euro]	Estimated Cost saving ¹⁾ [Euro/year]	Real Investment [Euro]	Adjusted Cost saving [Euro/year]
1	Replacement of southern glass wall in hallway	21 000	400	105 000	130 /y
2	Renovation of northern glass wall	128 000	900	89 000	1000
3	Replacement of the windows on the southern façade (left out)	145 000	2 100	-	-
6	Complete switch to LED in the whole building (in progress)	81 000	1 300	5 200 ³⁾	260 ³⁾
9.3	Installation of efficient heat recovery in the Moomin museum	13 600	9 700	13 600 ²⁾	9700 ²⁾
9.6	Installation of heat recovery in kitchen AC systems	56 000	4 000	74 000	9 900
9.7	Installation of more efficient roof air extractors (postponed)	52 500	720	Note 4)	Note 4)
	Installation of 500 m ² solar panels on extension's roof postponed	70 000	4 100		
	Switch to LED in concert halls	176 000	5 300		
	Installation of IR-faucets in workers' WC & cloakrooms	18 400	700		
	Installation of motion sensors in WC & cloakrooms	5 600	600		
	Installation of heat recovery in main concert hall	180 000	29 600		
	Installation of heat recovery in main concert hall's lobby	67 000	2 800		
	Installation of heat recovery in small concert hall	69 000	9 000		
	Installation of heat recovery in restaurant	43 000	5 000		
SUM		1 126 000	76 000	273 000	10 600
Internal rate of return		7.8%		-	

Notes:¹⁾ Based on the calculated new baseline ²⁾ Based on current information. Final investment cost and saving still need to be confirmed when the measure is completed ³⁾ Number contains the part of the measure that was already completed. The final numbers will be added when the whole measure is completed. ⁴⁾ The measure was postponed, schedule is open.

Table 12.3. Energy savings for the measures in the action package.

Measure		From step 1			Adjusted step 2	
		Thermal energy ¹⁾ [MWh/year]	Electrical energy ¹⁾ [MWh/year]	Cooling energy ¹⁾ [MWh/year]	Thermal energy [MWh/year]	Electrical energy [MWh/year]
1	Replacement of southern glass wall in hallway	7.3			2.3	
1	Renovation of northern glass wall	15.4			17.2	
2	Replacement of the windows on the southern façade (left out)	38				
3	Complete switch to LED in the whole building (in progress)	-142	174	48	Note ³⁾	Note ³⁾
6	Installation of efficient heat recovery in the Moomin museum (in progress)	169	3		Note ⁴⁾	Note ⁴⁾
9.3	Installation of heat recovery in kitchen AC systems	72			152	
9.6	Installation of more efficient roof air extractors (postponed)		8		Note ⁵⁾	Note ⁵⁾
9.7	Installation of 500 m ² solar panels on extension's roof		45		Note ⁵⁾	Note ⁵⁾
	Switch to LED in concert halls	-91	105	28	Note ⁵⁾	Note ⁵⁾
	Installation of IR-faucets in workers' WC & cloakrooms	5			Note ⁵⁾	Note ⁵⁾
	Installation of motion sensors in WC & cloakrooms	-7	11	1	Note ⁵⁾	Note ⁵⁾
	Installation of heat recovery in main concert hall	520			Note ⁵⁾	Note ⁵⁾
	Installation of heat recovery in main concert hall's lobby	50			Note ⁵⁾	Note ⁵⁾
	Installation of heat recovery in small concert hall	161			Note ⁵⁾	Note ⁵⁾
	Installation of heat recovery in restaurant	90			Note ⁵⁾	Note ⁵⁾
SUM		940	292	77	172	0

Notes:¹⁾ Based on the calculated new baseline ²⁾ Energy calculations need to be updated according to "as built" technical data ³⁾ This measure is in progress and the number of lamps changed to LED has to be assessed. ⁴⁾ This measure is in progress and the device will be taken into use by May 2017 ⁵⁾ These measures will be implemented in the next phase of the renovation; their final characteristics cannot be assessed.

Table 12.4. Deviations from step 1 – Reasons and consequences.

Measure		Step 1 Presumptions	Step 2 Adjusted
1	Replacement of southern glass wall in hallway	In the absence of specific detail structural drawing, the U-value of the original glass wall was estimated at 1.4 W/m ² K.	From the original drawings that were found only afterwards, the U-value was adjusted to 0.25 W/m ² .K. On the other hand, the surface measured from the construction plans was larger.
Consequence: The adjusted heat saving is lower than the original presumption.			
2	Renovation of northern glass wall	The total surface area of the windows to be changed was estimated at 195 m ² . The U-value of the new glass wall was estimated at 0.8 W/m ² K.	The renovated surface area was lowered to 117 m ² , but the manufacturer produced a lower U-value than expected at 0.17 W/m ² K, which does more than compensating.
Consequence: The adjusted heat saving is higher than the original presumption.			
3	Replacement of the windows on the southern façade (left out)	-	-
Consequence: This measure was left out because it was not in the same area of the building.			
4	Complete switch to LED in the whole building (in progress)	The number of LEDs and other lamps were assessed in December 2014.	A new assessment needs to be made in order to control the numbers of lamps changed and their characteristics when measure is finalized.
Adjustment of the numbers will happen during the summer.			
5	Installation of efficient heat recovery in the Moomin museum		The device's efficiency is 80% but the running schedule was extended compared to the original assumptions. The low SFP compared to predictions cancels the rise in running time.
Consequence: The adjusted changes in heat consumption are minimal compared to the original estimation. Due to the low SFP, the electricity consumption remains equal.			
6	Installation of heat recovery in kitchen AC systems	The efficiency of the heat recovery unit was estimated at 37% due to the difficulty of retrieving heat from dirty and grease kitchen air.	In cooperation with the manufacturer, Tampere-talo was able to find a unit that matched the specifications, was small enough for the space and showed a heat recovery unit has an efficiency of 65%.
Consequence: The heat savings were adjusted to increase to 167 MWh instead of 72 MWh, in addition to electricity savings.			

13. Oulu health care station, Finland – Step 1



The health care station in Oulu is from 1933. It has a heated floor area of 4288 m². The objective of the refurbishment was to improve the indoor air quality with an air cooling system. The building has undergone a major refurbishment in 1980. The HVAC system was refurbished in 2005 and the windows were replaced in 2009.

The proposed action package in Step 1 consisted of 6 measures mainly related to the building technology. The largest savings potential was the ventilation system as the equipment did not include heat recovery or it could be replaced with more efficient equipment. In addition, the energy consumption of the equipment could be reduced with changes in control methods and by replacing old, energy intensive fans with new, more efficient ones. In addition to the ventilation devices, profitable energy saving measures were also identified in replacing the existing lighting with more energy efficient LED lighting and changing faucets into electronic ones.

Baseline energy use was 257 kWh/ m². The identified action package had an IRR of approximately 7%. Successful implementation of the action package will reduce energy use with 39% to a designed energy use of 156 kWh/ m².

14. Kaarstad building, Norway – Step 1



The Kaarstad building is a historical university college building situated in Volda. It is built in 1922. The gross floor area is 3606 m². The objective of the refurbishment was to improve the poor indoor climate due to no or old mechanical ventilation. An extension of the building was built in 1982 and included some refurbishment in the old building. Baseline energy use was 248 kWh/ m². With the help of the Total Concept method, the following action

package with 5 energy efficiency measures defined as profitable with an IRR of 6%.

- 1 Heating system- replace radiators (50%) and new thermostatic valves
- 2 Added insulation wall internally 50mm (requires building physical assessment)
- 3 Added insulation in roof floor 200 mm (requires state of cultural heritage professional)
- 4 Demand controlled ventilation
- 5 Lighting

The action package reduces the delivered energy by 277 200 kWh/year, 100 kWh/m²year.

Successful implementation of the action package will reduce energy use with 40% to a designed energy use of 148 kWh/ m².