

Property name: Road Office - Steinkjer
Property owner: Statsbygg
Consultants: SINTEF Byggforsk

Total Concept method

Step 3. Follow-up

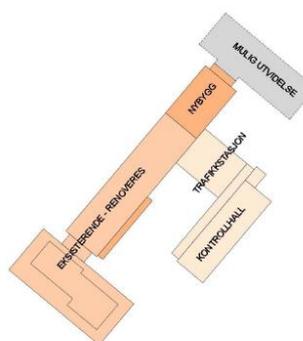
Building and its use

Year built: 1967, 1976, 1984
Area: 4 330 m² heated area
Type of building: Office Building

The building consists of three wings built in different building phases; 1967, 1976 and 1984. The original part is a one-floor building including a control hall and a northeaster wing with three floors. The southwest wing was built in 1967 originally with three floors, and was expanded with two floors in 1984.

The building consists mainly of offices for the Public Roads Administration and a canteen on the first floor. The company is expanding and requires more office space, thus a new wing is needed. One part of the building is a control hall, but this will not be included in further evaluations (the retrofitted and new parts are marked with "peach"-colors in the figure).

The triggering factor for renovation was to improve indoor air quality, especially in those parts of the building with the oldest HVAC-systems.



Indoor climate

The staff complained of poor 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. Requirements for indoor climate after retrofitting are based on the Working Environment Act and Class 2 in NS-EN 15251.

The status of the building and its technical systems before measures

Building envelope

The building consists of concrete with covers, beams, columns and walls as primary building components. The facades are of 150 mm thick concrete internally insulated with 100 mm and have a U-value of 0.41 W/m²K. Some concrete pillars are located in the facade and create large thermal bridges. Air tightness is not measured, but estimated to 3.5 h⁻¹. There are large horizontal window bands between the concrete walls. The windows are original coupled windows with an average U-value of 2.4 W/m²K.

All wings have a flat roof with 150 mm insulation of 150 mm concrete. The roofs have a U-value of 0.23 W/m²K, except over technical rooms with a U-value of 0.33 W/m²K.

The floor is a concrete slab on ground floor and has an estimated insulation of 100 mm with an equivalent U value of 0.15 W/m²K.

Heating

The building has two oil boilers of 350 kW and one electric boiler of 225 kW. The boilers cover space heating, heating coil for ventilation and domestic hot water. The electric boiler is prioritized and covers 99% of the demand for heating. The space heating is distributed through a conventional radiator system and hydronic heating coil to ventilation (80/60 °C). The extension of the west wing (4th-5th. Floor) has local electrical heating units.

Ventilation

The building has six ventilation units in total, whereas two of them are from 1976 and in poor condition. These two also have a low heat recovery rate of 42 % and 62 %. The units have an average SFP of 3.7 kW/(m³/s).

Cooling

The building is air-conditioned and has a cooling system consisting of a chilled water plant from 1975. The latter covers comfort cooling via chilled beams in the 2nd floor, as well as comfort cooling via ventilation, for the entire building. The eastern wing is air-conditioned via the ventilation system and locally placed DX-units.

Smaller local DX units at the room/installations provide process cooling of server rooms, telecommunication center, waste areas and UPS room. There are altogether 15 cooling units in the building. The DX-units have a total capacity of 119 kW and the chilled water plant at 100 kW.

Lighting

The building has mainly office spaces, with T5 and T8 lighting fixtures in the offices and corridors. The required power used in energy simulation is 8 W/m² and for equipment 11 W/m². Passenger load is estimated to 4 W/m².

Energy and resource use before renovation and baseline for energy savings

Statsbygg has documented measured energy use for the entire building for the last 10 years. Total measured delivered energy was 226 kWh/m² for the entire building including the control hall (Energy report, 2013), this value is temperature adjusted. Total heating is 79 kWh/m² for the whole building, whereas 99% comes from electricity and only 1% from oil. Total delivered energy from electricity, excluding heating, is 140 kWh/m².

However, if we look at the energy use for the retrofitted part only adjusted for normalized operating hours. The baseline energy use is:

Specific energy use before measures 194 kWh/m², Year

Whereas

- Heat energy 99 kWh/m², Year
- Electricity for building operation and tenants 95 kWh/m², Year

Identified energy saving measures

Six major energy efficiency measures were defined for the Road Office in Steinkjer. The measures were defined as energy savings and investment costs from building code requirements (TEK10 minimum) to passive house level. The measures were:

1. Walls - added insulation, improved air tightness and thermal bridges
2. Roof added insulation

3. New windows and doors
4. Upgrading the ventilation system from CAV to demand controlled ventilation (DCV)
5. Artificial lighting - demand controlled LED
6. Installation of ground source heat pump instead of an air/water heat pump

Energy simulation is performed for the existing building, for energy efficiency measures up to the building code requirement and up to the passive house level. The dynamic baseline procedure is used to find the step 1 action package. This means that the most profitable measure is selected as the first action. Furthermore, a new energy simulation is made with a new ranking of the remaining measures, measure 2 is selected and a new energy simulation is made, etc.

Profitability calculations were based on the building owner’s internal rate of return requirement of 4.15%. Furthermore, a relative increase of energy prices by 2% above inflation is estimated and economic lifetime is set to 60 years.

Summary of the measures in the action package

With the help of the Total Concept method, an action package with five energy efficiency measures was found profitable and is shown in Figure 1.

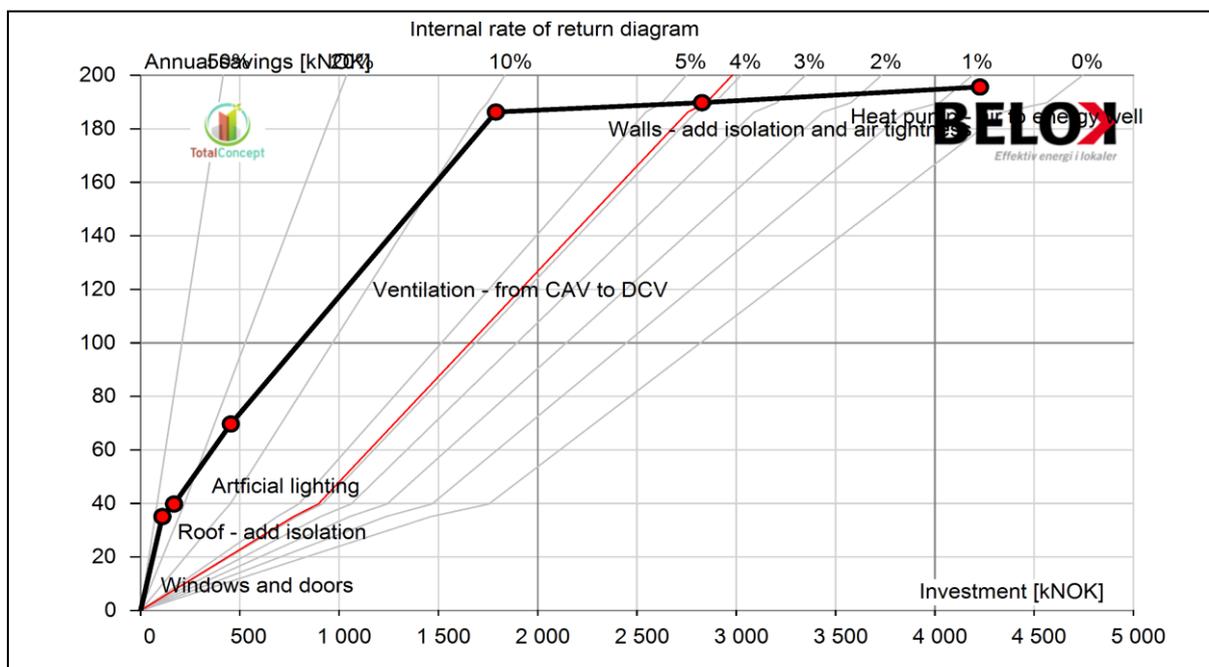


Figure 1. The internal rate of return diagram for the Road Office in Steinkjer after Step 1.

Five measures had an internal rate of return of 4.22 %. This satisfied the building owner’s requirement of internal rate of return.

However, the building owner, Statsbygg, decided to include all of the six measures in Step 2. The internal rate of return with the sixth measure included is 0.74 % based on investment costs in Step 1.

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 will upgrade in accordance with the building requirement (up to TEK10-level) and this was not an option.

This is the reason why investment costs were reduced in Step 2. A much larger share of the ventilation costs was necessary to reach a minimum level of indoor quality, and this share was not included in the profitability analysis. In addition, we discovered a mistake in the investment cost for the facade-upgrading. This changed the

profitability rank order of the measures and all measures were recalculated after Step 2 according to the new rank order, which led to adjusted energy savings. Results are shown in Table 1.

Table 1. Investment costs and savings after Step 1 and Step 2.

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 %		

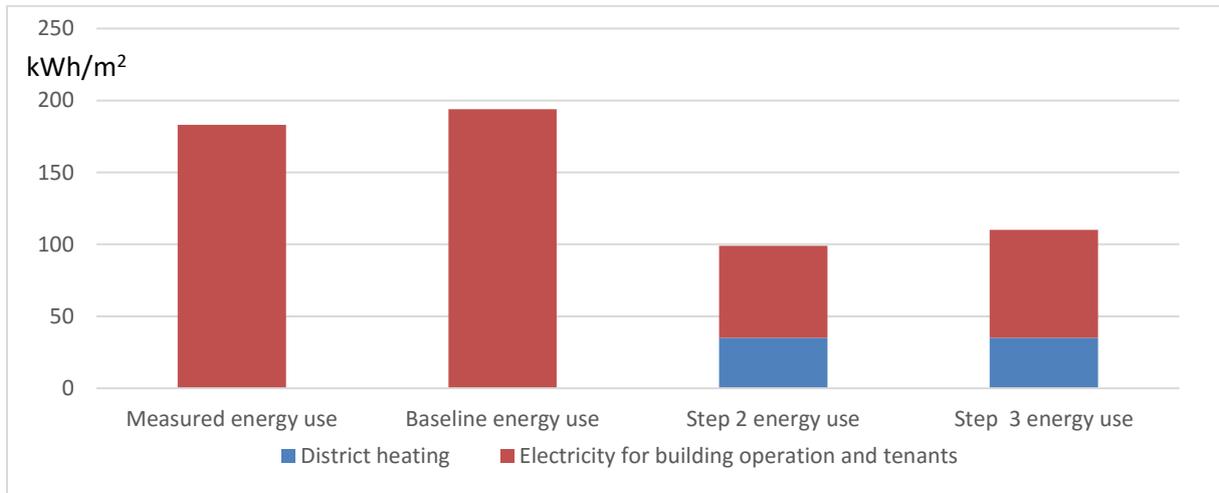
Summary of the outcome of measurements and follow up in Step 3

Figure 2 shows the measurement outcomes in Step 3 compared to estimated baseline in Step 1 and calculated values in Step 2. The space heating was distributed through a conventional radiator system before, but since the main hydronic heating source was an electric boiler the measured net energy is 100 % electricity. 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 buildings. There is no split between electricity for building operation and tenants.

According to the measurement outcomes of Step 3, the total energy use is approximately 110 kWh/m². This is an estimation after the first two operation months. We expect the energy use to be further reduced due to operational experiences and fine-tuning.

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

Figure 3 shows the calculated profitability for the action package in Step 2 together with the true profitability based on estimated energy use after Step 3. The calculated profitability for the package in Step 2 was 8.4 %. The adjusted internal rate of return after Step 3 is approximately 5.5 %, well above the building owner's internal rate of return requirement of 4.15 %.



Net energy use [kWh/m²]	Measured energy use	Baseline energy use	Step 2 energy use	Step 3 energy use
District heating	0	0	35	35
Electricity for building operation and tenants	183	194	64	75

Figure 2. Outcome after Step 3 compared to Step 2 and baseline.

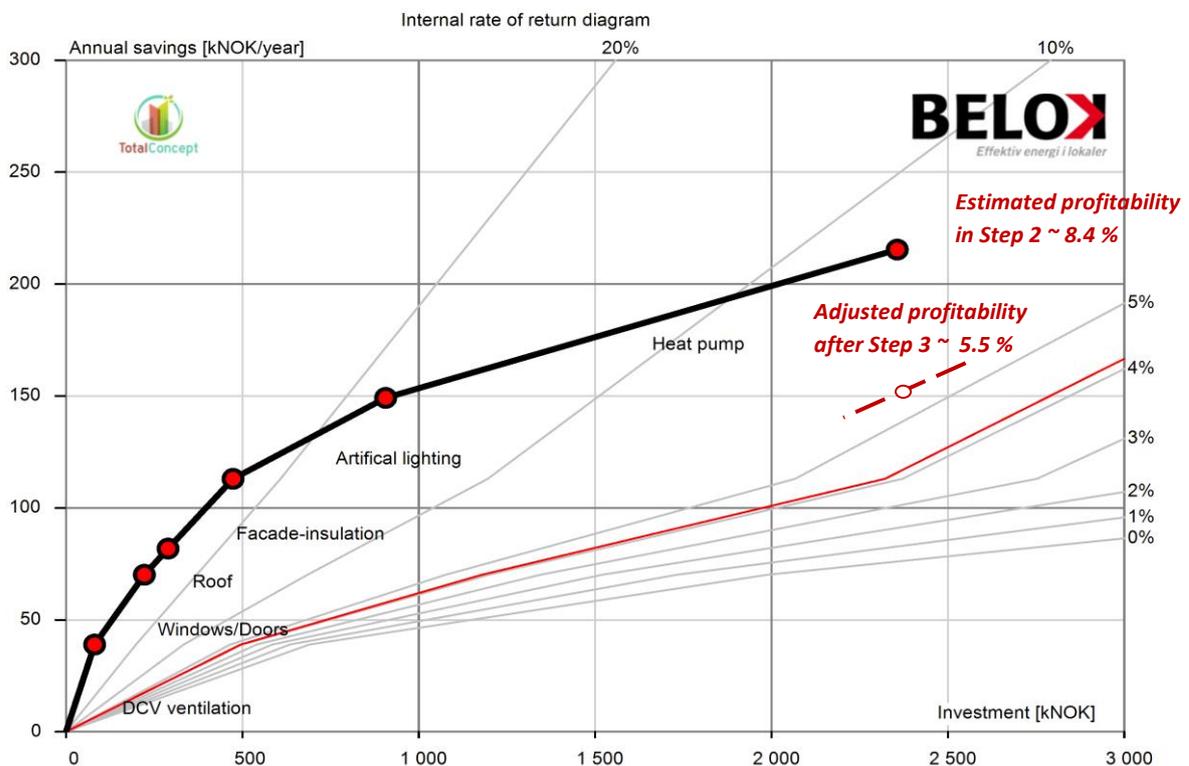


Figure 3 Outcomes of the profitability of the action package carried out at the Road office Steinkjer after Step 2 (8.4 %) and Step 3 (5.5 %).