Prospects to reduce the use of energy by 50% in existing office buildings

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ABSTRACT

A comprehensive feasibility study indicates that it is possible to reduce the energy used in Swedish office buildings by 50% within an acceptable economic framework.

A recent project managed by an advisory group to The Swedish Energy Agency comprises comprehensive audits, calculations and implementation with the focus to reduce the use of energy in five different office buildings.

The average annual use of energy (heat + electricity) before measures is of the order of 200 kWh/m^2 and the expected resulting use of energy after measures is on average of the order of 100 kWh/m^2 total building area. The required investments to reduce the use of energy by 50% is estimated to be of the order of 100 €/m^2 total building area. The paper presents a description of the overall project approach, the studied buildings and the most typical measures, associated investment costs and internal rate of return on the investments.

INTRODUCTION

The Swedish Energy Agency has formed an advisory group with representatives for a number of large Swedish facility managers. The advisory group, called Belok, has an assigned R&D budget and is carrying out a number of R&D projects. The recent project "Totalkontor" is aimed to investigate the potential for energy efficiency measures in typical service buildings. The prerequisites are that the indoor environment (thermal comfort, air quality, etc.) should be improved due to the efficiency measures or at least be the same as before renovation. The measures should further meet the building owners demand for return on investments.

The project started mid 2007 and has so far comprised comprehensive audits and energy calculations in five different service buildings. The proposed renovation measures will be carried out 2008-2009 and the evaluation is supposed to be finished in 2011 (Abel, 2008).

METHOD

The project is carried out in three major steps where the first and third steps are part-financed by the project budget (Belok) and the building owner finances the second step.

First, a comprehensive audit is carried out to identify possible measures to lower the use of energy for each building. The investment costs and the energy savings are estimated for all identified measures. The most feasible measures that together, seen as a renovation package, meet the owners demand for return on investments are determined. Second, the renovation package is implemented along with a transparent evaluation of the actual investment costs. Third, the energy use after renovation is evaluated in detail during one year of operation.

The audits and the cost estimates are assigned to local consultants that are familiar with the local conditions, while the energy calculations are performed by one specialised consultant in the same way for all buildings. The calculations are based on input, i.e. building and

system data, present energy use, etc., gathered by the local consultants.
The internal heat gains from lighting, computers, etc. as well as the actual operation of heating, ventilation and air-conditioning systems, have a strong influence on the use of energy, especially in services buildings, but are hard to determine in an audit. The calculations are based on simulations with a model that has been "calibrated" against the actual measured use of energy as far as possible. The calculations have further been carried out so that the influences of individual measures, as well as the influence of combined measures have been determined.

All project partners have before hand agreed to use 6% rate of return and 2% annual increase of the energy prices (equals about 4% real rate of return) as a common base for the economic evaluation.

BUILDINGS AND MEASURES

There is about 150 million m^2 of service building area in Sweden. The average total annual use of heat and electricity is about 210 kWh/m^2 total building area. The project comprises five building blocks with different activities but all with about average use of energy. The main project data are summarised in Table 1.

Table 1.
Main data for selected building blocks.

ID block (Owner)	**Built** [Year]	**Total area** (Rented area) [m^2]	**Annual energy use before measures** [kWh/m^2]
Pennfäktaren (AP Fastigheter)	1975	14 000 (11 000)	255 excl. tenant electricity
Prismahuset (Akademiska Hus)	1995	17 200 (14 460)	District heat 98 Electricity 90 all included
Getholmen (Castellum)	1975	8 500 (-)	District heat 95 Electricity 65 excl. tenants District cooling 21
Fyrfotan (Diligentia)	1970	18 400 (15 470)	District heat 138 Electricity 78 all included District cooling 25
Glaven (Locum)	1955	10 250 (-)	District heat 125 Electricity 75 all included

Pennfäktaren, Stockholm comprises a building with offices and restaurants from 1977. See Figure 1.

This building will be reconstructed with a completely new facade. The investments related to the complementary energy measures show 8% rate of return. See Table 2.

Prismahuset, Örebro University, comprises nine linked buildings with lecture halls, laboratories, offices and a restaurant from 1995. See Figure 2.

Initial investigations indicated energy savings of the order of 15% with 25% rate of return mainly related to improved control.

A further more detailed audit has now been carried out to investigate the possibilities to improve heat recovery and change from Constant Air Volume (CAV) to Variable Air Volume (VAV) systems in some of the buildings. The study result is estimated energy savings of the order of 40% with 3% rate of return. See Table 2.

Figure 1. *Pennfäktaren* with offices and restaurants in the centre of Stockholm.

Figure 2. *Prismahuset* with lecture halls, laboratories and offices at Örebro University.

Getholmen, Stockholm is an office building from 1975. See Figure 3.

The audit and the calculations show major possibilities to reduce the use of energy, e.g., by improved thermal insulation on the roofs and improved ventilation systems, within 6% rate of return. See Table 2.

Fyrfotan, Stockholm is a building with offices and shops from 1970. See Figure 4.

Here a major renovation including improved roofs, facades and windows together with the installation of a new ventilation system, is proposed.

Figure 3. *Getholmen* with offices in Stockholm.

Figure 4. *Fyrfotan* with offices and shops in Stockholm.

Figure 5. *Glaven* with wardrooms and offices in Stockholm.

The approved rate of return regarding energy savings will however only cover a part of the required investment. The other part will be regarded as necessary to cover by other means in order to improve the indoor environment, a measure that would have been carried out in any way. See Table 2.

Glaven, Stockholm is a high-rise hospital building with wardrooms and offices. See Figure 5.

In the case of *Glaven* the local consultant has made feasibility calculations that are in fair agreement with calculations made by the specialised consultant. Both studies show about 15% rate of return. See Table 2.

The main results from the feasibility studies are summarised in Table 2. The detailed evaluation chart for *Glaven* is shown as an example in Figure 6.

The left diagram shows that it is feasible to apply several measures with around 0% rate of return seen as single measures, as all measures seen together as a package meet the criteria of 6% rate of return on the total investment. The right diagram shows that the need for district heat, as well as the need for electricity, can be reduced by about 50%, i.e. from just above 200 down to just above 100 kWh/a.m^2 total building area.

Table 2.
Main result from the feasibility studies for the selected building blocks.

ID block (Owner)	**Investment** [MSEK]	**Cost Savings** [MSEK/a]	**Rate of return** [%]	**Energy Savings** [%]
Pennfäktaren (AP Fastigheter)	6	0.62	8	~ 50
Prismahuset (Akademiska Hus)	8.9	0.56	3	~ 40
Getholmen (Castellum)	5.5	0.55	7.5	> 50
Fyrfotan (Diligentia)	> 50	< 2	< 0	> 50
Glaven (Locum)	5	0.75	14	~ 50

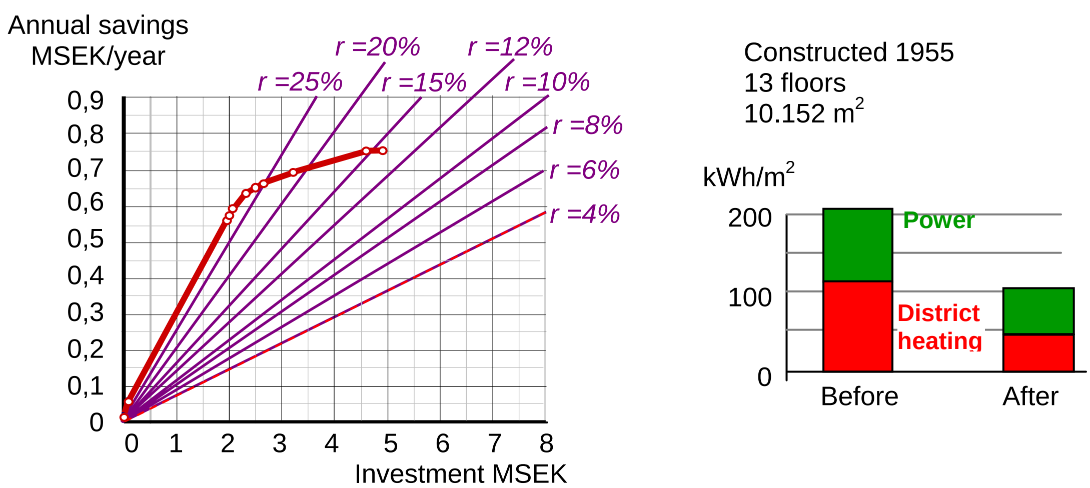

Figure 6. Evaluation chart showing annual savings related to investments (left), as well as the annual specific use of energy before and after (right), for *Glaven*.

RESULTS

The incentives to carry out energy efficiency measures in service buildings are in general rather low even though energy prices are increasing. However, comprehensive part-financed feasibility studies for selected service buildings indicate that it is possible to reduce the energy used in Swedish service buildings by 50% within an acceptable economic framework, here 6% rate of return.

The average annual use of energy (heat + electricity) before measures is here of the order of 200 kWh/m^2 and the expected resulting use of energy after measures is on average of the order of 100 kWh/m^2 total building area. The required investments to reduce the use of energy by 50% is estimated to be of the order of 1 000 SEK/m^2 (~100 €/m^2) total building area.

The majority of measures are related to improved heating, ventilation and air conditioning systems, improved lighting and improved control. Measures related to the building envelope are in general not yet profitable from an energy point of view (and 6% rate of return). Such measures are more related to the age of the building, the general indoor environment and the outside appearance and maintenance of the building.

REFERENCES

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