# DOES POSTPONED RETROFITTING SAVE MONEY?

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**Abstract**

When a building is to be retrofitted, or refurbished, it is always of importance to study the building as a complete energy system. At least in Sweden, the building process is divided in different profession categories, such as HVAC and ordinary building contractors. It is therefore not surprising that the HVAC contractor wants to maximise his profit by installing large and sophisticated equipment at the same time as the builder or architect wants to design a house with very thick walls and high performing windows. These competing interests will often result in a building where the heating system is not adjusted to the rest of the house, but is instead far too powerful. The recommendation from life-cycle cost analysts has therefore always been to study the building as a whole system and to apply an optimal solution at one specific base year. This is probably always the best solution, in order to minimise the life cycle cost, but experience shows that the proprietor of the building many times hesitates in doing so. The reason for this is his lack of money. Changing the building into an optimal energy system many times requires a heavy investment at one specific year, albeit it is the best solution in the long run. This paper will discuss what happens to the life-cycle cost when retrofits are postponed as to fit into the proprietors ”ten year budget”.

## INTRODUCTION

By the introduction of faster computers more interest has been focused at mathematical simulations of buildings and Life-Cycle Cost, LCC, calculations. One program for such calculations is called OPERA, Optimal Energy Retrofit Advisory, which is used for elaborating the optimal retrofit strategy for a multi-family building. The building is dealt with as an energy system and therefore building, ventilation as well as heating measures are treated at the same time. The model, or program, has been described in international publications, see e. g. References [1], [2], [3] and [4] and will therefore not be shown in detail here. Instead, we will show how part of the calculations are elaborated and what happens to the LCC when different energy conserving measures are postponed from the base year, which year is almost always assumed to be at present time. In order to explain how the calculations are made an example is shown for a standard building, also used in Reference [4]. The building which contains 14 apartments is now heated by use of an oil boiler of 110 kW. The LCC for this existing building, when no retrofits at all are introduced exept for those which are unavoidable, consists of the parts shown in Table 1.

| | |
|---|---|
| Salvage value for the old boiler | 0 |
| Unavoidable retrofit cost | 408 |
| New boilers cost | 80 |
| Energy cost | 989 |
| Total existing life-cycle cost | 1 477 |

Table 1: Details of the life-cycle cost for the existing standard building in kSEK.

Eight Swedish Kronor, SEK, equal about one US dollar. Firstly, in Table 1, the salvage value for the existing boiler is shown. This value is now zero because the existing boiler is changed when it is worn out and must be changed to a new one. In the standard building this will happen five years from now.

A new boiler is assumed to cost 55,000 + 60$\times P$ SEK, where $P$ equals the power of the boiler, which is 110 kW as told above. Calculations of the need in the building revealed that about 72 kW was sufficient. In the following LCC calculations this lower value is used instead.The cost for a new boiler is therefore 59,318 SEK. However, there is no need for installing the new boiler now, and thus net present calculations must be used for finding the proper value of the invested money. In our example, the real interest rate equals 5 % while the period of optimization is 50 years. It is also assumed that the boiler has a new life of fifteen years. The net present calculation for the boilers will therefore become:

$$59,318 \times (1.05^{-5} + 1.05^{-20} + 1.05^{-35}) = 79,587 \qquad \text{SEK}$$

Compare this with the value found in Table 1. It is not possible to postpone this retrofit because the boiler is worn out at year number five. It is, however possible to introduce the retrofit earlier, for instance at this very moment. The net present calculation will for that case change to:

$$59,318 \times (1.05^{-0} + 1.05^{-15} + 1.05^{-30} + 1.05^{-45} - \frac{2 \times 1.05^{-50}}{3}) = 104,729 \qquad \text{SEK}$$

Important is to note that the existing boiler is taken out of operation before it is actually necessary which implies that one third of the cost for a new boiler is still present, which equals 20,533 SEK. This cost is called the salvage cost. Here a boiler power of 110 kW has been used because that was the one actually installed. Introducing the boiler retrofit now will therefore lead to a significant increase of the net present cost, i. e. 46 kSEK which must be balanced by the more efficient heating system.

It is also necessary to emphasize the term unavoidable cost, in Table 1. The building retrofit cost in OPERA has been devided i three parts, one part showing how much money must be spent if, for instance, the facade must be refurbished. This part does not include any cost for more insulation but instead demolition costs for the old facade, new surface costs, et c. The second part of the retrofit cost shows a step in the cost function when insulation measures are added, and the third part shows how much the cost will increase when extra insulation is added. In Table 2 the unavoidable cost is shown in more detail.

| Retrofit type | Cost [SEK/m$^2$] | Area [m$^2$] | Existing life [years] | New life [years] | Present value [SEK] |
|---|---|---|---|---|---|
| Attic floor insulation | 0.0 | 273.0 | 0.0 | 50.0 | 0.0 |
| Floor insulation | 0.0 | 273.0 | 50.0 | 50.0 | 0.0 |
| External wall insulation | 300.0 | 616.0 | 0.0 | 50.0 | 184,800 |
| Wall insulation, inside | 50.0 | 616.0 | 0.0 | 0.0 | 30,800 |
| Window retrofits, west | 1100.0 | 75.6 | 0.0 | 30.0 | 99,984 |
| Window retrofits, east | 1100.0 | 69.6 | 0.0 | 30.0 | 92,048 |
| Total | | | | | 407,632 |

Table 2: Unavoidable cost details in SEK for different retrofit measures.

As is found in Table 2 all but one retrofit must be dealt with immediately and that specific one did not have a cost component. It is therefore not possible to use the "standard" building as an example. In order to examplify, it is therefore assumed that the external wall retrofit has 10 years of existing life left. The unavoidable cost will thus decrease from 184,800 SEK to 110,228 SEK. The total will likewise decrease to 333,060 SEK as will the LCC in Table 1, to 1,402 kSEK.

# POSTPONING RETROFITS

First, consider what will happen when a retrofit is introduced at the base year, i. e. at this very moment. In the OPERA model, the optimal amount of extra insulation applied at the external wall has been calculated to 0.07 m. The details of the LCC are shown in Table 3.

| Measure | Year 0 | Year 1 |
|---|---|---|
| Unavoidable retrofit cost | 407,632 | 398,510 |
| Boilers cost | 78,177 | 78,177 |
| Energy cost | 730,813 | 744,268 |
| Insulation cost | 209,440 | 199,101 |
| Salvage value existing wall | 36,960 | 33,264 |
| Total | 1,463,022 | 1,453,320 |

Table 3: Details of the LCC when 0.07 m extra insulation is applied to the external wall at the year number zero or year number one.

The new LCC in Table 3 for year number zero is lower than the one in Table 1 and therefore the retrofit is profitable. Note that the boilers cost has decreased, as well as the energy cost due to less need for energy and power. However, the retrofit also introduced two new costs, i.e. the insulation cost and the salvage value for the existing external wall. Further, the unavoidable cost has increased to its original value in Table 1. Most interesting is now to examine the LCC if the retrofit is postponed one year. The unavoidable cost will decrease, as well as the insulation cost and the salvage value, At the same time the energy cost will increase but not enough to balance the other costs. The LCC for the building with a postponed retrofit is therefore lower than the

LCC for the base year retrofitted building. In this case it was thus an advantage to postpone the retrofit. The fact is that even if this retrofit is postponed to year no 10, the LCC for the total optimization period is lower than those found in Table 3. The LCC details for year number 10 and 11 is found in Table 4.

| Measure | Year 10 | Year 11 |
|---|---|---|
| Unavoidable retrofit cost | 333,061 | 444,331 |
| Boilers cost | 79,000 | 79,000 |
| Energy cost | 839,910 | 848,179 |
| Insulation cost | 124,925 | 118,437 |
| Salvage value existing wall | 0.0 | 0.0 |
| Total | 1,376,896 | 1,489,947 |

Table 4: LCC details for postponed retrofitting of 0.07 m extra external wall insulation to year number 10 and 11. Values in SEK.

Some details from Table 4 must perhaps be clarified. The unavoidable cost increases rapidly between year number 10 and 11. This is so because the wall must be retrofitted at year number 10, resulting in a present value of 113,451 SEK. When the insulation is added at year number 11 the newly applied facade must be demolished again which, of course, results in a very high cost, calculated to 108,048 SEK for the unavoidable part and 118,437 SEK for the actual insulation. In Table 2 it is shown that the unavoidable cost, external wall excluded, is 222,832 SEK. Adding the costs at years no 10 and 11 results in the value found on the first line found in Table 4. The boilers cost has increased but this happened already at year no 5 because that was the year when the boiler had to be changed. If the wall was insulated before that year, a smaller boiler could have been chosen. The important thing to notice is, however, that it might be profitable to postpone retrofits until they must be applied for other than energy conservation reasons. Above it was mentioned that an optimal level of extra insulation was 0.07 m. This amount has ben calculated assuming a 50 year optimization period. When the retrofit is postponed 10 years, as shown above, a period of 40 years would be more accurate. This will also imply that slightly less extra insulation should be added. Testing with 0.06 m shows that the LCC will increase albeit with a very small amount. The influence of those far away years is, of course, very small due to the present value calculations.

# CHANGING BOILER

Up to now only one, of several, possible heating systems have been tested. By postponing building retrofits the existing thermal power must be prevailed until the energy conservation measure actually occurs. This could be of disadvantage if very expensive heating systems are considered. If the building is of some size, say more than 20 apartments, our experience shows that so called bivalent, or dual fuel, heating systems are of interest. In a bivalent system a heat pump is supposed to take care of the base load, while an oil boiler provides the peak. When the energy retrofit is applied, the need for energy will get lower and therefore the boiler will be too large for some years, i.e. until the boiler is changed again. For the case we have examined, it seems that postponing retrofits is more profitable than choosing a boiler of the precise size. The situation could of course be different for other interest rates, insulation levels or escalating energy prices, just to mention a few varying input data.

In Sweden we have state subsidized renovation loans. The proprietor will only pay a part of the interest rate if certain requests are fulfilled. One such request is that the building has not been renovated using the same type of loans for the last period of thirty years. This design makes it very hard to achieve profitability for postponed retrofit which otherwise would have been optimal.

## CONCLUSIONS

In this paper it is shown that postponing energy retrofits might result in a lower Life-Cycle Cost, LCC, compared to the scenario when all measures are applied at one specific year. If the proprietor at all occasions when a retrofit is nesessary implements the optimal solution, i.e. chooses the optimal level of extra insulation, he will decrease the total LCC in certain steps. However, other circumstances e. g. escalating energy prices, might change this situation. In Sweden there is a system with subsidized loans for building retrofits which will decrease the interest rate for all measures added at the time of reconstruction. In such a case the best strategy will be to change the energy system in its entirety at one specific occasion.

## References

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