4. INFLUENCE OF THE SWEDISH SUBSIDIARY SYSTEM

In previous chapters the optimal strategy has been studied for building costs, energy prices etc found in literature dealing with these subjects. If these prices are adequate from the societal point of view is very hard to know. Wrong prices, of course, can lead to misoptimization.

Using the input data from the case study will regrettably lead to severe misoptimization considering the private economy for a landlord in Sweden. Here, as in many other countries, there is a subsidiary system in order to encourage the owner of a building to implement retrofit measures on the house. This system must be taken into proper consideration in private economy optimization.

In Sweden the subsidiaries can be split up in three types:

- Renovation loans
- Interest subsidiaries
- Energy retrofit subsidiaries.

The most advantageous part is the renovation loans and therefore these will be described in further detail. There are a number of restrictions for the loans.

- The measures must result in considerable improvement of the functional or technical performance of the building.

- The building must be older than 30 years.

- The owner of the building must be able to administer the building in a proper way.

- The building must, after the renovation, have the same standard as a new building.

- The building site or real estate must have been sold by the municipality.
- Etc, Etc.

The constraints above and other information about the subsidiary system, can be found in [42 and 82].

The municipality accepts or rejects the application in the first consideration by the society. It is also authorized to reject some of the constraints, e g the constraint concerning the site.

If you are entitled to these renovation loans the society gives you a loan up to 30 % of the renovation cost. The remaining 70 %, must be covered by a credit institution, like a mortgage bank. The rate of interest of the 30 % loan was 11.75 % and for the second loan 11.20 %, in January 1986. Both loans are of the type fixed-yearly-instalment, i e the sum of the amortization and interest payments are the same every year. The amortization payment however, is calculated as if the rate of interest was 8 %. The first loan has a pay-off time of 30 years and the second 40 years or less, if decided by the mortgage institution. However, the second loan does not exactly follow the fixed-yearly-instalment method. A pay-off plan is decided for each case.

The society will subsidize the interest payments and the first year the rate is warranted to a value between 2.15 - 2.6 %. After this the rate is incremented by 0.25 % each year. The cost however is calculated on the total sum of the loan, as if no pay-off was made. This means that after some years the guaranteed interest payments will get higher than the real interest and by then the subsidiary will be abandoned.

When the influence of the subsidiary system is elaborated it is necessary to transfer all the future payments to the base year, using the present value method. First however, the cost must be evaluated in running prices. In order to simplify the calculations it is assumed that there only is one loan with an interest rate of 12 %. The annual amortization is calculated for an 8 % fixed-instalment loan with 30 years pay off time. The inflation is assumed to be 7 % and the real discount rate to 5 %. The total loan is estimated to be 100 000 SEK, and the guaranteed rate of interest in the beginning 2.6 %.

When the annual payment, i e the sum of the pay-offs and the interest cost, must be the same year by year, this can be calculated:

$$FIP = A_{loan} \cdot r \,/\, (\, 1 - (\, 1 + r\,)^{-\,p}\,) \qquad (\,10\,)$$

where FIP = the fixed instalment payment,
A_{loan} = the total loan,
r = the discount rate and
p = the pay-off time.

Using A_{loan} = 100 000, r = 0.08 and p = 30 the annual cost will be 8 883 SEK. The discount rate cost, 0.08 · 100 000, is 8 000 SEK, and thus the amortization will be 883 SEK. The following year the loan has decreased to 99 117 SEK and the interest cost, 8 %, will become 7 929 SEK. The amortization will be 8 883 - 7 929 = 953 SEK.

Year	FIP	Int. cost 8 %	Amortization	Warr. int. cost 2.6 %+.25%	To pay	Next year loan	Real int. 12 %
1	8 883	8 000	883	2 600	3 483	99 117	12 000
2	8 883	7 929	953	2 850	3 803	98 164	11 894
3	8 883	7 853	1 029	3 100	4 129	97 135	11 759
20	8 883	5 073	3 809	7 349	11 159	59 603	7 609
21	8 883	4 768	4 114	7 599	11 266	55 489	7 152
29	8 883	1 267	7 615	-----	9 517	8 225	1 901
30	8 883	657	8 225	-----	9 211	----	986

Table XIX. Swedish subsidiary system. Running prices.

From table XIX it is obvious that the subsidiary system is abandoned at year 21, i e when the real cost of interest is lower than the guaranteed one.

However, table XIX shows the running prices with an inflation estimated to 7 %. Using the net present value method, equation (AIII 2) at page 144, the annual payments can be transferred to fixed prices, and furthermore transferred to the base year using expression (AIII 2) once more with a real discount rate of 5 %. Table XX shows this.

Year	Running prices	Fixed prices 7 % inflation	Present value 5 % real disc. rate
1	3 483	3 254	3 013
2	3 803	3 322	3 013
3	4 129	3 371	2 912
4	4 462	3 404	2 800
29	9 517	1 338	325
30	9 211	1 210	280
Present value at the base year			46 660

Table XX. Swedish subsidiary system. Present value calculation.

In table XX the present value is calculated for the annual payment found in table XIX. The initial cost, 100 000 SEK, has decreased to approximately 50 000 SEK by the simplified subsidiary system. It is possible to calculate the precise situation in the same way as shown above but here the approximate situation is sufficient.

If the proprietor of the building is entitled to renovation loans all of the building and installation measures may be included in the loan as long as the total price for the retrofitted building does not exceed the price for a new building. The cost for the measures will thus be approximately half the real cost.

An OPERA running with these new cost functions implemented in the earlier presented case study, will result in a new bivalent heating system, the ground water coupled heat pump combined with an oil-boiler. The envelope retrofits combining this heating system are 0.26 meter attic floor insulation, 0.20 meter external wall insulation and weatherstripping. The total LCC is 0.86 MSEK.

It was thus optimal to change the existing heating system while the envelope measures were kept almost the same as before, although the optimal insulation thickness, was increased.

If the existing heating system, i e the oil-boiler, is not changed, an extensive envelope strategy should be implemented. This is of course natural because all the building costs have been devided by 2.

From the above discussion it is obvious that the subsidiary system has a very big influence on the optimal solution. The heating system is changed and the insulation thickness is increased by approximately one third. However, changing the heating system to a low running cost system, will still make e g exhaust air heat pumps unprofitable.

5. CONCLUSIONS

The optimal retrofit strategy for a unique multi-family house can be calculated. The best strategy is then characterized by the lowest possible remaining life-cycle cost for the building.

This building is considered as an energy system and both envelope, ventilation and heating system retrofits are dealt with simultaneously.

Difficulties with uncertainties in input data can be solved by a sensitivity analysis. For a fixed set of input data there is an optimal solution and the OPERA model, described in this thesis, enables the finding of it.

The OPERA model is used for optimization of the retrofit strategy concerning a unique building. However, some general conclusions can be drawn from this thesis and a number of OPERA runnings:

1. The conventional method with retrofit ranking due to the saving-to-cost ratio is wrong.

   OPERA runnings show that essential for a low LCC is a low running cost. If the heating system provides this to an acceptable installation cost the first step is taken towards a low LCC. Such heating systems can be district heating with a rate that reflects the cost for producing the heat, or bivalent oil-boiler - heat pump systems. These kinds of heating systems shall be combined with a few cheap envelope retrofits. If the other method is used, where the retrofit with the highest saving-to-cost ratio is implemented first and after this the second highest, the demand of heat in the building might become too low. The profitability with a more complex heating system, which from the beginning was optimal, might vanish and misoptimization will occur.

2. Optimal energy retrofits shall be implemented when the building is subject for renovation from other reasons than energy conservation.

   If a low running cost heating system is implemented, very few envelope retrofits are profitable. Weatherstripping and attic floor insulation might emerge as plausible retrofits. However, more expensive retrofits can be profitable, i e when the remaining life of the considered building part is very short. Very poor windows might e g be changed to new ones with a better thermal standard.

   Most important is, that the best solution is implemented, if the envelope of the building is the subject for renovation measures. This means that the optimal solution, e g the optimal amount of insulation, must be applied. If a lower degree of insulation is chosen this will lead to misoptimization and this cannot be changed with any profitability, until next time the building part has to be renovated for other reasons than energy conservation. This is the situation for many buildings in Sweden today, where 0.05 to 0.10 meter of insulation is applied on the external walls.

3. A combination of heating system, envelope and ventilation retrofits leads to the optimal solution.

   It is necessary to consider the building as an energy system. One example of this is that weatherstripping is not always part of the optimal retrofit strategy. It might be better to take care of the extra ventilation flow in an exhaust air heat pump. The marginal cost for the extra thermal power in the heat pump is lower than the cost for caulking the windows and doors.

4. The result of envelope retrofit combinations differs from calculations made for retrofits added one by one but the difference is minute and can mostly be neglected.

OPERA calculates if a retrofit is profitable, i e if the LCC is decreased when the retrofit is introduced. If this is the situation, the retrofit is a candidate for the optimal solution. A number of retrofits are examined. The combination of the retrofits found profitable will not result in exactely the same life-cycle cost as if the savings for each retrofit were added to each other and then subtracted from the original cost. This difference is enhanced if a lot of retrofits are combined and if a lot of free energy, from e g appliances, is present in the building. In this thesis it is shown that the optimal solution is mostly characterized by a low running cost heating system with only a few retrofits implemented at the envelope, and thus the difference will be very small, about 5 % of the resulting LCC, and subsequently they mostly can be neglected. However, using OPERA it is possible to find the true optimal strategy with the significance required.

In most cases the order of implementation can also be neglected. To insulate the attic floor first and after this implement extra insulation at the external wall will yield almost the same result as if the order was the opposite.

5. Bivalent heating systems and insulation measures can be optimized simultaneously.

When a bivalent heating system is considered it is very important that the thermal power of the oil-boiler and the power of the heat pump as well as the amount of insulation are optimized. In this thesis it is shown how this can be elaborated. If the insulation is found profitable, up to 0.2 meter of extra insulation might be optimal. This is surprising because of the very low running cost for the bivalent system.

6. <u>The ordinary degree hour concept must be abandoned.</u>

Energy balance calculations are necessary in order to find proper optimization parameters. The insulation measures shall be optimized for a higher amount of degree hours than the heating system. This is due to the influence of free gains from solar radiation, appliances etc.

7. <u>District heating and electricity rates must reflect the real cost for producing an extra unit of energy. Marginal cost pricing might be essential for the optimization.</u>

It is important that the utility uses a tariff that reflects the real cost for producing the energy. The distribution between the firm and the running part in the rate is essential. A high energy price per MJ, higher than it is in reality, will lead to more conservation measures in the buildings. This however also will lead to misuse of the utility investment, less energy will be produced than is optimal.

Differential, or time-of-use rates might be of importance considering retrofit measures. If a differential rate is introduced it will slightly advantage insulation measures but will give severe disadvantage to competing energy production in the building.

8. <u>Subsidiary systems might lead to misoptimization.</u>

Subsidiary systems that encourage energy saving measures are important for the strategy. Cheaper insulation will make it profitable to add more insulation to the building.

However, also more efficient heating systems might be profitable, which will provide heat to a lower cost. This will influence the insulation level in the opposite direction and thus the optimal insulation level might have been higher if the subsidiary system had not existed.

The subsidiary system might lead to suboptimizations from a societal point of view. Complex heating systems will be combined with an extensive envelope retrofit strategy. This will lead to a higher LCC than is necessary.

9. Optimization periods longer than 30 years exert very small influence on the retrofit strategy.

Due to the present value calculations costs appearing in a distant future, have a very small influence on the solution. The retrofit strategy will be almost identical if 30 or 50 years are considered.

10. The LCC for different optimal solutions due to future changes of the input data differs less than could be expected.

Future changes of energy prices etc might considerly change the LCC for a building. The sensitivity analysis elaborated in an OPERA running shows that the LCC, for optimal solutions will not change as much as could be expected. Consider the influence of changes in the insulation cost. A low cost leads to a thick insulation while a high cost leads to the opposite or no insulation at all. In figure 11 page 74, it is shown that the resulting LCC is almost constant, as long as the optimal amount of insulation is chosen.

The influence of higher energy prices on the LCC follows a straight line when only one heating equipment is considered, see figure 10 at page 72. If it is possible to change the heating system this is not the case and the LCC will increase slower after the heating system is changed. The LCC continues to follow a straight line but less blunt than the original one.

11. Changes in the time constant of the building will not influence the retrofit strategy very much.

    A high constant makes it possible to decrease the dimensioning outside temperature for the building site and subsequently smaller heating equipment can be chosen. However it is not very easy to calculate this temperature adequately but the influence can be simulated by testing a number of alternatives. The influence on the optimal solution is very small due to the rather low installation cost for the heating equipment.

12. The climate conditions at the building site are important.

    The climate of the building site is important for the optimal retrofit strategy. In a cold climate more heat is consumed in the building. The total life-cycle cost however will not be affected in the same way. This is due to changes in the optimal strategy. The insulation levels are increased and a more sophisticated heating system is profitable to install. This will lead to a slower increase of the LCC than could be expected initially.

13. Electricity space heating is of no interest.

    Direct electricity for space heating seems to be of no interest because of the high running cost. For small buildings though, where the demand is very low, electricity might compete.

14. Exhaust air heat pumps will rarely be selected.

    Because of the low running cost heating system, almost always found optimal, exhaust air heat pumps, due to their high initial outlay, will seldom be part of the optimal retrofit strategy.

15. Costs for environmental pollution can be considered.

    Implementing higher energy prices or higher costs for insulation etc makes it possible to include costs for environmental pollution. Note however the effect on the optimal heating equipment as well as on the thickness of extra insulation.

16. Implementing optimal retrofits can considerably decrease the remaining LCC for a building.

    If bigger buildings are retrofitted in an optimal way a decrease in the LCC with 40 % has been calculated. Implementing LCC optimization makes it possible, both for a private landlord and for the society, to save considerable amount of money.

6. FUTURE WORK

In the now presented thesis, the superiority of life-cycle cost analysis and optimization is shown. The results from such considerations often differ from those achieved from other methods. However, these LCC methods are not in common use, mostly because of the tedious calculation work needed. Modern computers simplify this drudgery. The OPERA - model is run in about thirty seconds for the base case alternative, and thus it can be used extensively.

However, at present the model is implemented in a big computer, which is not in common use. No manual or tutorial exists to help the interested reader with implementing a building of his own.

A big effort will be made to implement the model in smaller computers, like IBM PC and others. If that is successful the LCC concept can be widely spread.

Enhancements will also be made on the model itself. The bivalent system which was found very competitive is at present using a fixed rate for electricity. Time-of-use, or differential rates will be more common in the future and thus it is important to optimize such a system as well. Maybe the model has to be equipped with a linear programming routine in order to solve this problem.

This routine might also make it possible to optimize the retrofit combination situation without using the more complicated iterative process, necessary in OPERA today.

Other types of buildings can also be possible to examine by OPERA. For example industrial buildings which often have a much higher degree of ventilation than is common in residences. Then OPERA must be provided with heat exchanger retrofits which are excluded today.

It is also important to elaborate mathematical expressions for the LCC field, where heating system changes are included. Up to now only one heating system is considered in the LCC expressions. If this is possible the precise LCC field could be depicted and the breaking points in it can be revealed. Now this has to be examined from a number of OPERA runnings.

Another interesting issue is to examine how energy conservation measures will influence the running of district heating cogeneration plants. If the utility is used only for electricity production a marginal use of heat from the condensor will be very cheap, in fact at no cost at all, as the plant must get rid of the heat in some way as long as electricity production is utilized. District heating however, cannot use the low temperature of the cooling water from an ordinary electricity plant. The temperature in the condensor must be increased which leads to loss of electricity, and the price for the heat must reflect this. Optimal energy retrofits in buildings heated with district heating will subsequently be influenced by the needed electricity production at the utility.

The lack of proper input data is also emphasized in this thesis. There is thus a need for extensive research about retrofit costs etc. In the future, information from data bases might be used as default values in OPERA runnings. If the effort at finding suitable input data severely could be reduced, the method would come into common use.

A thorough study of the Swedish subsidiary system will also be elaborated. This is very important in order to encourage desireable behavior concerning energy conservation and retrofits, from the societal point of view. Using the subsidiary system must lead toward the optimal solution found by society. If this could be the situation the nation could use its limitid resources in a better way than today.