Differential rates for district heating and the influence on the optimal retrofit strategy for multi-family buildings

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Abstract

When renovating existing multi-family buildings it is very important to implement the best retrofit strategy possible in order to minimize the remaining life-cycle cost for the building. If the building is heated with district heating this strategy of course changes due to the energy rate used by the utility. It is also very important for the utility that the consumer is encouraged to save energy when there is a need for it i.e. during peak load conditions. Our paper shows that a cost accurate differential rate provides all these facilities.

Introduction

Since 1985 a research project is running concerning retrofitting of multi-family residences. The project is financed by the Swedish Council for Building Research and the community of Malmö, Sweden. The scope of the project is to find out how each unique building shall be retrofitted in order to minimize its life-cycle cost, i.e. to search for the optimal retrofit strategy. This paper however, deals only with district heated buildings and how the retrofit strategy changes if the the district heating utility implements a differential rate for the energy delivered.

When district heating systems were introduced in Sweden the heat was produced by burning heavy oil. This kind of oil was cheaper then the quality that could be used in smaller oil boilers, installed in ordinary multi-family buildings. The cheaper oil made the district heating plants profitable in spite of the higher investment costs. The consumers paid for the energy according to a rate consisting of four parts:

- Connection fee
- Fixed fee
- Power related fee

- Energy fee

The district heating plant only used oil for heating and thus the cost for producing a new unit of energy was the same whether it was winter or summer. After the oil crises the situation became different. Many systems are now heated with refuse, electricity, coal, wood chips etc. The cost for producing one more unit of energy thus differs a lot due to the season of the year as the mix of energy input changes. In the summer the plant can produce almost all of the energy by burning refuse. The cost for producing an extra unit of energy is in such cases of the magnitude 0.01 SEK/kWh. During the winter however, the plant has to burn oil and the cost for producing one more unit of energy is thus about 0.20 SEK/kWh.

The consumer who wants to save energy can choose between a variety of energy retrofits, e.g. insulation measures, caulking windows and doors, installing an exhaust air heat pump, and can also use sun collectors to produce his own energy in the building. It is obvious that if the district heating company is using ordinary rates it is not important to the consumer if he saves energy during the summer or in the winter. The money saved is identical. The district heating utility however wants the consumer to save energy during the winter because then they are burning oil in the plant, which is expensive. During the summer the company must get rid of the refuse and if they can not burn it they have to bury it in the ground. One means to achieve such a behaviour from the consumer is to implement differential rates.

Marginal cost theory

Using the cost for the last unit of energy, produced in the utility, as the price for the total amount of energy delivered, is called marginal cost pricing. The fee is thus the same for all the energy produced in the plant. This without any respect to the fact that almost all of the energy has been produced with a cheaper fuel than is used at the top, at this special occasion. Thus, if any of the heat is produced from expensive oil, all the heat delivered at that moment shall have the oil marginal cost. The utility will therefore earn money, because a lot of the energy is produced with refuse and wooden chips. If the consumers find this oil marginal cost to high they want to use less energy and will thus turn off the heating equipment or at least diminute the use of it. This also means that, according to the national economic theory, the plant will operate in the most efficient way.

The marginal cost pricing shall be used when the facilities are produced in a system which requires large capital investments and if the producing utilities only with a great difficulty can be used for other production. This is the precise situation for district heating plants. For those readers that want a more elaborate discussion about the marginal cost theories, Ref. [1] can be recommended.

A rate that is constructed in the way discussed above is called a cost differential rate, or CDR. However, it is very hard to make the consumer aware of the marginal cost at each moment. New meters have been constructed but they are not in common use. The second best solution is thus to implement a time-of-use rate, TOU. The price for the energy then varies during the year. In the winter the energy price can correspond to the oil price and during the summer to some cheaper fuel. In Malmö, Sweden the utility has introduced a rate according to such a concept, but it is of course possible to have several price levels.

Duration curves

One means to depict the situation both for the energy producing plant and the consumer is to use load duration curves. In Fig. 1 the curve is shown for a district heating plant.

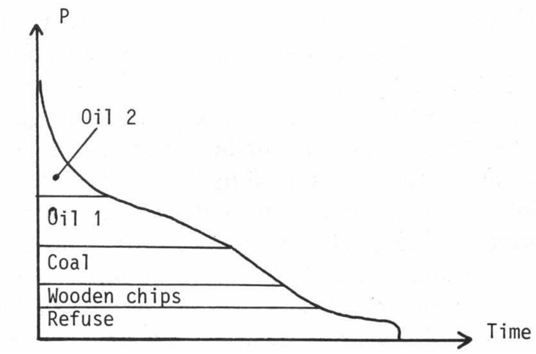

Figure 1: Load duration curve for a district heating plant, [1]

The plant in Fig. 1 is burning refuse all over the year. This is so because the fuel is almost free of cost. It is also hard to save the refuse for the winter because of hygienic reasons. The second cheapest fuel is wooden chips which are used almost during all the year. The most expensive fuel, oil type 2, is used only during peak load conditions. It is also important to note the installation cost for different boilers used in the plant, see Fig. 2.

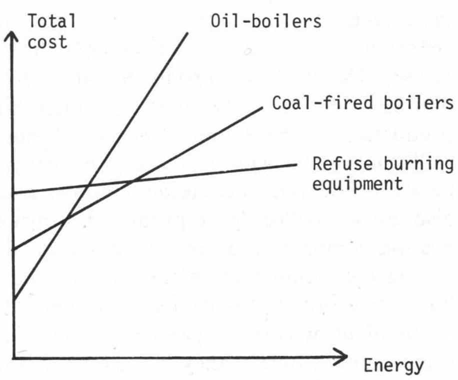

Figure 2: Total cost for district heating boilers.

The cheapest equipment is the oil boiler while the most expensive is the refuse burning facility. Having only a small amount of energy to deliver, the oil boiler should be used. As the amount of energy increases it is more profitable to invest in a coal-fired boiler and so on. However, it is not possible to use only refuse in the plant because the amount of refuse is limited. A mix of different fuels therefore have to be used.

It is also important to examine how different retrofits on a building effect the duration curve, see Fig. 3.

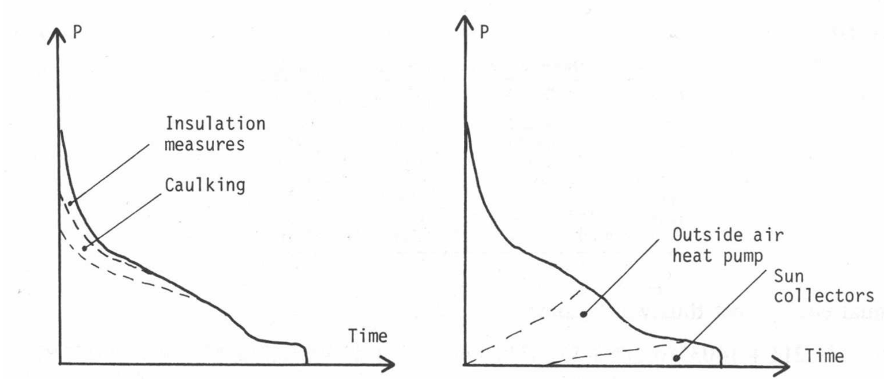

Figure 3: Duration curves for different retrofits, [2]

Of great importance are also the duration curves for competing energy producing facilities that can be installed in the building. It is obvious that if a lot of landlords will invest in sun collectors and outside air heat pumps this can result in negative consequences for the district heating utility.

Comparing rates - normalization

Comparing different types of rates makes it important to ascertain that it is only the differences in the rate construction that shall be compared. The price level of course must be the same. This can be provided in two different ways. The first one considers the fact that one energy unit consumed uniformly during the year shall cost the same independent of the rate. One example is the consuming of hot water. The annual cost must be the same either the fixed rate or the differential type are used. However, this type of normalization gives a higher income to the power company for the true heating load. Much more energy is used during the winter with a high price per unit of energy. Thus this is not a recommendable solution. The other kind of normalization achieves that the district heating company will get the same income for identical heat consumers independent of the construction of the rate.

We will give an example of the two types of normalization. In Malmö, the marginal costs for 1985 are shown in Tab. 1.

In this case we have the differential rate and have to transform it to a fixed one. The first type of normalization is shown using the heating of hot water. Assuming that a building consumes 288 GJ (= 80 000 kWh) each year for this, the annual cost will become:

$$\frac{80000(0.211 \times 744 + 0.211 \times 678 + 0.198 \times 744 + \ldots + 0.211 \times 744)}{8766} = 11840 SEK$$

Month	Rate (SEK/kWh)	Month	Rate (SEK/kWh)
Jan.	0.211	July	0.116
Feb.	0.211	Aug.	0.116
March	0.198	Sept.	0.116
April	0.116	Oct.	0.116
May	0.116	Nov.	0.140
June	0.116	Dec.	0.211

Table 1: Marginal energy cost in Malmö, Sweden 1985. District heating, [2].

The figures 744, 678 ... are the number of hours in each month of the year and 8766 the total number of hours during one year. The annual mean value for the energy is 0.148 SEK/kWh, which gives us the fixed rate.

A normalization of the other type considers the actual heat load due to the climate. The heat load values are taken from [3] were a fictional building is described. The total transmission factor is 3 499 W/K, including 1 267 W/K for the ventilation system. In Malmö the climate can be found in Tab. 2.

Month	Deg.hours	Month	Deg.hours
Jan.	15 252	July	2 083
Feb.	14 035	Aug.	2 455
March	13 838	Sept.	4 680
April	10 080	Oct.	8 258
May	6 696	Nov.	10 872
June	3 600	Dec.	13 392
		Total	105 241

Table 2: Number of degree hours in Malmö, Sweden, [3]

The annual energy cost thus will become:

$$(15252\times0.211+14035\times0.211+13838\times0.198+\ldots+13392\times0.211)3.499 = 61777 SEK$$

The mean value for the energy price is thus 0.168 SEK/kWh.

The combination of climate load and a uniform load (hot water), will make the mean value slightly lower or:

$$\frac{0.168 \times 3.499 \times 105241 + 80000 \times 0.148}{3.499 \times 105241 + 80000} = 0.164 SEK/kWh.$$

A fixed rate of 0.164 SEK/kWh thus will give the heating utility exactly the same income as if the differential rate was used.

Retrofit measures

Retrofit measures done to the climate envelope affect the total transmission factor, 3 499 W/K. In [3] the optimal extra insulation thickness for the attic floor in our fictional building has been calculated to 0.17 m, however not with exactly the same district heating rate. Making such an insulation retrofit decreases the transmission factor above to 2 880 W/K. The cost for energy with a fixed rate of 0.164 SEK/kWh reduces from 73 645 to 62 942 SEK or with 10 702 SEK.

Using the differential rate in table I the energy cost will become:

$$\frac{61777}{3.499} \times 2.880 + 80000 \times 0.148 = 62699 SEK$$

The money saved is 10 946 SEK or a little more than using the fixed rate. The fact is that one will save only about 3 % more with this differential rate . It does not matter how extensive the insulation retrofit strategy is. This is so because the difference between the high price and the low price is to small. However, as is shown in [2], it is not possible to encourage top peak saving, e.g. insulation, only by implementing a differential rate. In such a case the level of the rate has to be increased, i.e. the energy has to be more expensive.

Another retrofit in order to save energy is the exhaust air heat pump. If the heat pump is installed to produce hot water the profitability is lower if a differential rate is implemented. In our fictional case from [2] the heat pump can deliver 374 GJ (= 104 000 kWh) of heat. However there is only a need for 288 GJ and thus the money saved with a fixed rate is:

$$80000 \times 0.168 = 13440 SEK$$

With the differential rate the amount is:

$$80000 \times 0.148 = 11840 SEK$$

The exhaust air heat pump thus has a disadvantage from differential rates.

One more heat producing facility has been examined , i.e. solar collectors. Of course these work best in the summer and concludingly will have disadvantages from a differential rate. In [2] an example is shown using a collector that saves 36 % of the hot water energy, mostly during the summer. The savings were only about 70 % with the differential rate compared to the fixed one.

From this example it is obvious that implementing a differential rate encourages insulation measures and gives disadvantages to competing heat producing facilities. Using a rate which has larger differences between the high and the low prices will emphasize this. In [2] we have shown an example from the district heating company in Linköping, Sweden. The fuels in the plant are:

Refuse	0.01 SEK/kWh
Wood chips	0.10 SEK/kWh
Coal	0.11 SEK/kWh
Electricity	0.10 -0.15 SEK/kWh
Oil	0.23 SEK/kWh

These prices were valid in 1985, and we have constructed a rate as found in Tab. 3.

The insulation alternatives will with this rate be slightly more profitable. The most important thing is though that exhaust air heat pumps only save about 70 % and sun collectors only about 25 % of the money compared to the fixed rate.

Month	SEK/kWh	Month	SEK/kWh
Jan.	0.23	July	0.01
Feb.	0.23	Aug.	0.01
March	0.125	Sept.	0.10
April	0.110	Oct.	0.115
May	0.10	Nov.	0.125
June	0.01	Dec	0.23

Table 3: Constructed rate for district heating in Linköping, [2].

As mentioned above the level of the rate has to be increased if top peak savings shall be encouraged. Assuming a rate with the price 0.25 SEK/kWh during November to March and 0.06 SEK/kWh else, the insulation measures get about 40 % better profitability with this new differential rate. Unfortunately the competing heat producing equipment also get a better profitability but they still have a disadvantage compared to a fixed rate.

Conclusions

Using a differential rate for the energy delivered from a district heating plant gives advantages to the district heating system. Competing energy producing equipment e.g. sun collectors will have less profitability. If the rate level is constant the design of the rate has only a little importance to top peak energy saving measures. If the rate is increased insulation measures will be much more profitable but this also means that e.g. exhaust air heat pumps get a shorter pay back period.

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