The Economy of Heat Cost Allocation and Temperature Control in Multiple Unit Dwellings

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SUMMARY

Heat cost allocation is primarily not a method to save energy. It is a way to give the households the temperature they are willing to pay for. The condition that gives the highest reduction of costs from heat cost allocation is at a high marginal cost of temperature. At a high marginal cost there will not be any reduction of the average indoor temperature at the introduction of heat cost allocation. The reduction of costs comes when the households who prefer a high indoor temperature gets the temperature they are willing to pay for. The reduced costs 114 SEK/yr dwelling in buildings built after 1980 and 262 SEK/yr dw in buildings from before 1975 in Sweden should be compared with the cost for meters, reading and administration 334 SEK/yr dw. (8 SEK = 1 USD)

INTRODUCTION

This is a theoretical analyse based on microeconomics. It compares MU-dwellings with heat cost allocation and temperature control that gives a collective indoor temperature, the same temperature in all dwellings, with systems that gives individual temperatures.

Heat cost allocation in homes with individual control and individual heat metering, individual temperature metering and collective allocation was described in [1] and [2]. The use of a fixed part and a variable part for heat cost allocation after heat quantity was not included. This gives a to low indoor temperature. A fixed part (grundkosten) and a variable part (verbrauchskosten) are used in Germany [3]. The fixed part there is between 30 –50 % of the sum of all costs for heating including cleaning and maintenance of the heating system. A paper about the fixed and the variable part is presented at this conference.

METHODS

The systems with individual temperatures are assumed to have the marginal cost of temperature that corresponds to the heat loss to the outdoor air and a cost for indoor temperature that is close to the cost for the heat loss to the outdoor air. This gives the same cost for an increase of the indoor temperature for both owner and household.

In figure 1 the supply water temperature, t_s is controlled after the outdoor temperature, and the heaters are chosen to give the same temperature in all dwellings. The cost of heat is distributed to the households after their share of the buildings dwelling area. Since all households get the same temperature the cost of cold will be high for the households who want a high indoor temperature. This normally gives a higher indoor temperature than if the households could chose individual indoor temperatures.

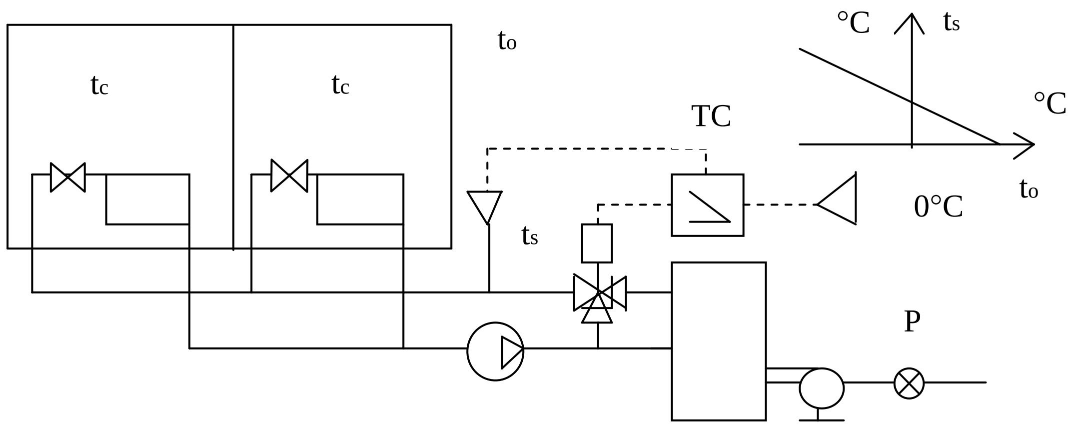

Figure 1. Heating system with a collective temperature, t_c.

The households in a building have different demand curves according to figure 2. The t* is normally distributed with t^*_m = 21.65°C, k = 0.004 (1/°C^2). DI' (SEK/h hh) (8 SEK = 1 USD) is the disposable income per hour and household [4] and [5]. The standard deviation s* = 1.3°C. s* is based on measurements from Swedish SU-dwellings in [6].

To get the demand curve for a collective temperature the individual demand curves in figure 2 are added vertically and divided by the number of households. This gives figure 3.

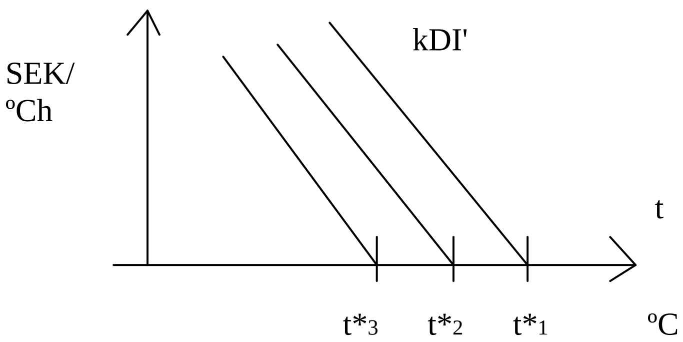

Figure 2. Demand curves for indoor temperature for different households.

The demand curve for a collective temperature in figure 3 goes up to the highest preferred indoor temperature among the households. At a low price of temperature the highest temperature demand will be satisfied. The horizontally marked area is the cost of heat and the diagonally marked area CC(t_c) is the average cost of cold for the households.

If individual heat cost allocation is introduced with the heating system in figure 1 then the indoor temperature is controlled with the valves on the heaters.

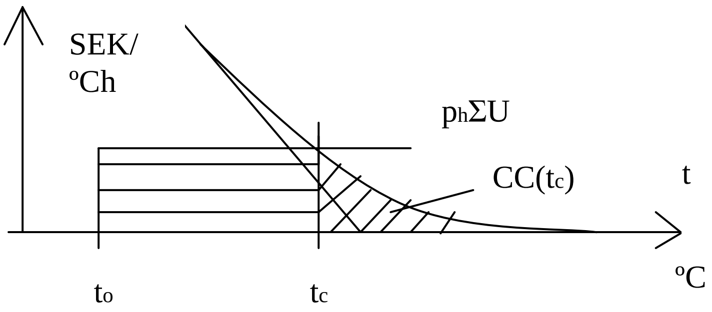

Figure 3. Demand and supply curve for a collective temperature, t_c.

Heat cost allocation systems that gives the marginal cost of temperature that corresponds to the heat loss to the outdoor air is heat metering with a suitable fixed and variable part and indoor temperature metering with the specific heat demand (W/°C) for the heat loss to the outdoor air.

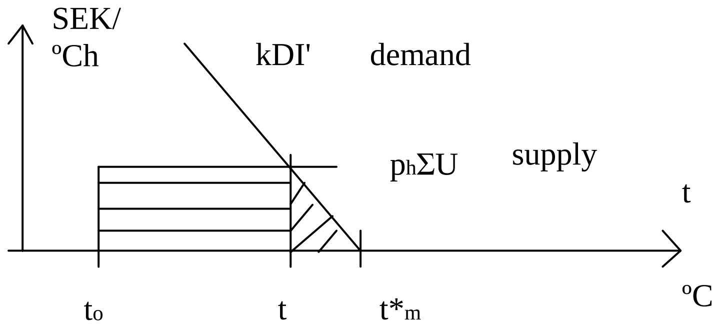

Figure 4. Demand and supply curve for the average of individual temperatures, t.

The supply curve in figure 3 and 4 is $p_h\Sigma U$ where p_h is the price of heat to the dwellings (SEK/kWh) and ΣU is the specific heat loss for a dwelling to the outdoor air (W/°C). t^*_m is the average of the highest demanded temperatures. The horizontally marked area is the average cost of heat and the diagonally marked area is the cost of cold for a household.

Before individual temperatures are introduced a collective temperature in figure 3 is used and after the average indoor temperature in figure 4 is used. The reduced costs RC are figure 4 subtracted from figure 3. The resulting area is shown in figure 5.

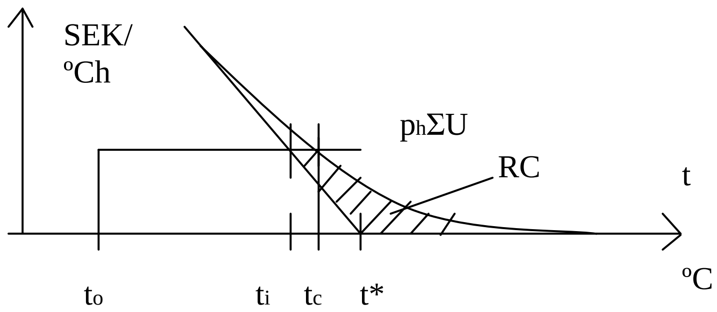

Figure 5. Area, RC representing both the reduced cost of cold and reduced cost of heat when individual temperatures, t_i are introduced. The collective temperature before is, t_c.

$$RC = CC(t_c) + p_h \Sigma U (t_c - t_i) - \frac{k \cdot DI'}{2}(t^* - t_i)^2 \qquad (1)$$

The diagonally marked area in figure 5 or equation 1 represents the reduced cost when the heat cost allocation system is changed from a collective temperature to individual temperatures. The average of the individual temperatures t_i is lower than the collective temperature t_c. The cost reduction is both reduced heat cost and reduced cost of cold. The area RC represents a change from a perfect collective indoor temperature to perfect individual temperatures meaning that they follow the theory. In reality the temperatures are slightly higher than both t_i and t_c. In order to find the perfect collective temperature the owner must know the demand curves of the households. If individual temperature control is used then some households will not control their indoor temperature witch will increase the average.

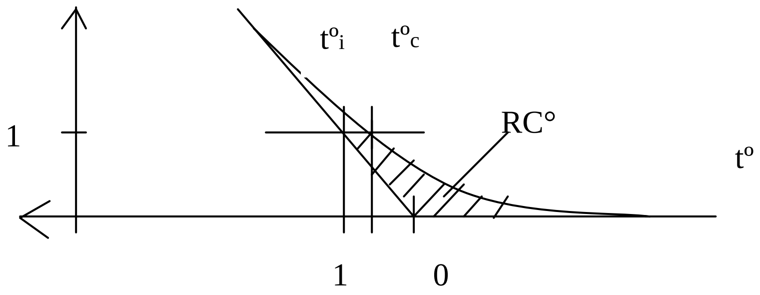

Figure 6. Dimensionless reduced costs, RC° when individual temperatures are introduced in a building with a collective temperature.

Dimensionless area RC° representing reduced costs when heat metering is introduced equation 2. The area CC in figure 3 must be calculated numerically so in order to make the calculations universally valid the axis are normalised. The dimensionless cost of cold for a collective temperature $CC(t_c)$ was shown in [7]. Dimensionless indoor temperature equation 3, individual indoor temperature $t°_i$ equation 4 and standard deviation s equation 5. The dimensionless indoor temperature and corresponding collective temperature, marginal cost, marginal cost of cold and the area that gives the cost reduction are given in table 1.

$$RC° = CC°(t°_c) + t°_i \cdot (t°_c - t°_i) - \frac{t{°_i}^2}{2} \qquad (2)$$

$$t° = \frac{t^* - t}{s} \qquad (3)$$

$$t°_i = \frac{p_h \cdot \Sigma U}{k \cdot DI' \cdot s} \qquad (4)$$

$$s = \sqrt{s^{*2} + s_b^{\,2}} \qquad (5)$$

The temperature in the dwellings in a building with the heating system in figure 1 follows a normal distribution with $s_b = 0.8°C$ according to an estimate from measurements in [8]. s_b depends on the accuracy of the design and balancing of the heating system.

Reduced costs with heat metering equation 6 (SEK/h). To get the cost per year multiplie with the length of the heating season τ (h/year).

$$RC = RC^{\circ}\left(t^{\circ}_{i}\right) \cdot p_{h} \Sigma U \cdot s \qquad (6)$$

Table 1 Dimensionless average of individual, t^{o}_{i} and collective temperature, t^{o}_{c} marginal cost of cold, MC° cost of cold, CC° and cost reduction, RC° at the introduction if individual temperatures.

t^{o}_{i}	t^{o}_{c}	$MC^{o}(t^{o}_{i})$	$CC^{o}(t^{o}_{i})$	$RC^{o}(t^{o}_{i})$
2.0	1.99	2.01	2.50	0.50
1.8	1.79	1.82	2.12	0.50
1.6	1.58	1.62	1.78	0.50
1.4	1.36	1.44	1.47	0.49
1.2	1.15	1.26	1.20	0.48
1.0	0.90	1.08	0.97	0.47
0.8	0.65	0.92	0.77	0.43
0.6	0.35	0.77	0.60	0.39
0.4	0.00	0.63	0.46	0.33
0.2	-0.50	0.51	0.35	0.23
0.0	-2.00	0.40	0.25	0

The highest cost reduction from individual heat cost allocation is at high t°_{i} or when the marginal cost of temperature is high in relation to the disposable income. These economic conditions means that the indoor temperature with collective temperature is low and that the indoor temperature will not be reduced at the introduction of individual heat cost allocation. The reduced costs is from the reduced cost of cold for those who want a high indoor temperature.

At low t°_{i} or at a low price of energy and a high disposable income the indoor temperature will be high with collective heat cost allocation and the temperature reduction at the introduction of individual heat cost allocation will be high. The value of the temperature reduction will be low since the heat has a low price.

RESULTS

The economic evaluation is for one building with MU-dwellings built before 1975 and for one built after 1980 in Sweden. The U-values and the ventilation were reduced after the energy crisis. The dwelling area is 70 m^2/dw.

The economic data for the household refers to 1992. The average disposable income for a house-hold in a multiple unit dwelling were 135.000 SEK/yr hh. The disposable income per hour is DI' = DI/8760 = 15 SEK/h, hh. The length of the heating season 6000 h/yr. The price of heat p_h = 0.5 SEK/kWh (including tax).

The standard deviation $s = (1.3^2 + 0.8^2)^{0.5} = 1.6$°C

The investment in equipment for temperature registration and heat metering is 1500 SEK/dw. It can be used for 10 years and the interest rate is 4 %. The factor of annuity is 0.123 /yr and the cost 184 SEK/yr. To read the heat meters costs 75 SEK/yr dw. The heat cost should be calculated and added to the rent. This is an additional 75 SEK/yr dw. The total cost for heat metering and cost allocation is 334 SEK/yr dw.

Table 2. Heat loss from MU-dwelling to outdoor air.

		Built after 1980		Built bef 1975	
	Area m^2	U $W/m^{2o}C$	ΣUA W/ºC	U $W/m^{2o}C$	ΣUA W/ºC
Wall	31	0.3	10	0.8	25
Roof	70	0.2	14	0.6	42
Window	10	2.0	20	3.0	30
Ventilation		25 l/s	30	30 l/s	36
Sum		ΣU W/ºC	74	ΣU W/ºC	133

Table 3. The average temperature with individual heat cost allocation, t_i and the collective temperature t_c with collective allocation in a MU-dwelling.

Built	t^o_i	t_i ºC	t_c ºC	RCº	RC SEK/yr
Before 1975	0.69	20.54	20.85	0.41	262
After 1980	0.38	21.03	21.73	0.32	114

The reduced costs 262 SEK/yr dw in buildings before 1975 and 114 SEK/yr dw in buildings after 1980 should be compared with the cost for meters, reading and administration 334 SEK/yr dw. Metering cost more than the cost reduction from metering. The cost of the control work from the households is not included.

DISCUSSION

A high marginal cost of temperature makes the households reduce their indoor temperature due to the cost. The reduction will be high at low disposable incomes. If a collective indoor temperature is used, the same temperature for all households, then the indoor temperature is highly reduced for those who preferes a high indoor temperature. Then the value of individual heat cost allocation will be high since everybody can have the temperature they are willing to pay for. The marginal cost of temperature is high if the price of heat is high and if the buildings are poorly insulated. Poorly insulated buildings are used in warm and mild climates. Individual temperatures can be expected were there are long mild winters.

Individual heat cost allocation benefits from badly designed and badly balanced heating systems that don't give the same temperature in all dwellings and from different indoor temperature preferences among the households.

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