# Electricity savings from heat pumps:
# The Norwegian Household Subsidy Programme 2003, 2006->

## 1 Summary of the program.

### 1..1 Short description of the program.

#### 1..1.1 Purpose / goal of the program.

Energy use in Norway is characterized by an, in a European context, unusually high dependence on direct electrical heating. For households this translates into a situation where on average more than 60 % of the electricity consumption is for heating purposes. Many households have no real alternative to electrical heating, and in periods with cold weather and high electricity priced this implies high costs for the households. In addition to these household-level risks, this situation is challenging at the system level, both in terms of total energy supply and grid capacity (power)

The purpose of the Household Subsidy Programme (HSP) is to stimulate the deployment of alternatives to direct electrical heating in households. Main technologies have been wood pellet based systems and air-to-air heat pumps. The latter turned out to be the most successful of these technologies in terms of market penetration, and is thus focused in this case description. In the first period of the programme (2003), 18.000 heat pumps were supported before the subsidy programme was terminated (Bjornstad et al, 2005). Subsequently the heat pump market has developed rapidly, and by 2009 approximately 400.000 units have been installed in homes and buildings. In this case presentation we aim at describing how to calculate the energy savings resulting from this programme.

#### 1..1.2 What type of instruments is used?

The main instrument of the HSP was an investment subsidy, supported by various communication measures, such as media campaigns, a toll-free phone advice service, and a web based information and application portal.

The subsidy was set at 20 % of the total investment cost, or a maximum of NOK 5.000. (≈EUR 625).

### 1..2 General and specific user category (economic sector and subgroups).

The target group for the programme was private households. No segments of households were excluded, but it was recommended that the household had an annual electricity consumption (use) in excess of 20.000 kWh. This recommendation was to ensure a minimum level of profitability potential of the investment for the household.

### 1..3 Technologie(s) involved.

Air-to-air heat pumps with the following technical characteristics were supported:

- Refrigerant: HFC or natural medium
- Inverter technology (variable compressor speed)
- CE-mark (officially tested) or Eurovent-classification
- Adapted to a Nordic climate to prevent ice build-up.

1..4 Relevant as a Demand Response measure?

No

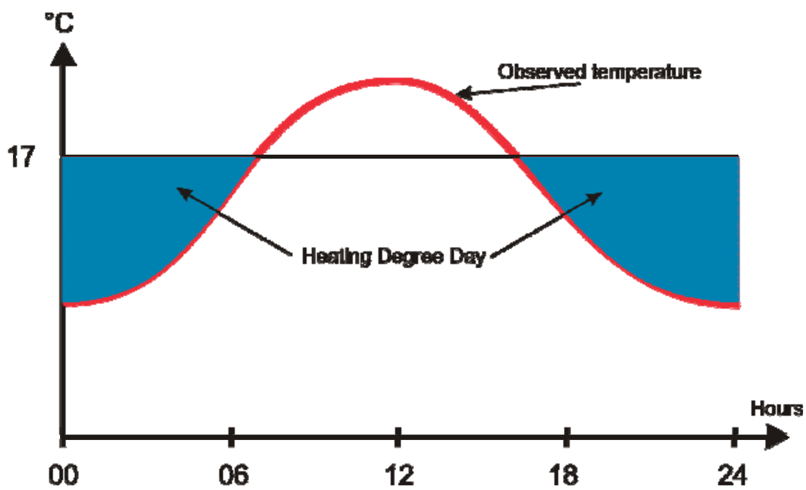
## 2 Formula for calculation of Annual Net Energy Savings

The aim of the calculation is to determine the annual savings in kWh per household of the households participating in the programme. Fundamental in this calculation is the measurement of the actual annual electricity consumption of the household before and after installation of the heat pump. The measured consumption data need to be normalised with regard to heating need, with either the base (ex-ante) year, the after (ex-post) year, or some normal year as reference. In addition we need data on the electricity end use distribution of the household, to determine the share of electricity used for heating. The method applied calculates energy savings only between the metered base year and the metered reference year. By standardising the heating need, however, a normalised annual electricity savings number can be calculated. This number, possibly discounted, can be used to estimate lifetime savings for the heat pumps.

2..1 Formulas used for the calculation of annual net energy savings

2..1.1 Heating Degree Days (HDD)

The concept of "Heating Degree Days" is summarised in the following figure. The basic idea is that homes do not require active heating when the outdoor temperature is 17 °C or higher. The heating need is proportional to the sum (integral) over time of the difference between 17 °C and the observed outdoor temperature. This is indicated by the coloured (blue) areas in the figure.




The integral is the theoretically correct way of conceptualizing the Heating Degree Days. This is equivalent to the difference between 17 °C and the daily average temperature, when this average temperature is lower than 17 °C. In practice different methods are used, depending on how frequent temperature observations are available on the location in question. Since there are significant regional variations in temperatures in Norway, local temperature observations are necessary to get a reliable value for the Heating Degree Days.

Example: A typical October day with an average outdoor temperature of 5 °C implies a Heating Degree Days value of 17 – 5 = 12.

### 2..1.2 End use distribution

Since it is only the heating part of electricity consumption that is subject to HDD variations, it is necessary to isolate the electric energy spent for space heating from other end uses such as lighting, washing, entertainment, refrigeration, etc., in order to compare energy spent for heating between years.

The actual end use distribution of electricity in Norwegian households is an ongoing debate, and the answer to this problem is still uncertain. Top-down and bottom-up methods differ in results. Some attempts to measure the end-use distribution have been undertaken, but it is difficult to generalise from these findings. A recent reference in this respect is the the Remodece–project (Grinden and Feilberg, 2008). In this work the heating share of electricity consumption is estimated to 64 %. However, when a household invests in new heating technology, such as heat pump, one can not apply this "average percentage approach" to both ex-ante and ex-post distributions. An alternative method is to estimate the electricity used for non-heating purposes and define the residual as electricity for heating. Myhre (2004) uses the following simple formula for this purpose:

Non-heating household energy use = 8000 kWh + 1000 kWh per household member.

This latter approach is used in this case.

### 2..1.3 Consumption data

Annual consumption data have been calculated on the basis of semi-annual data on electricity sales before and after the installation of heat pump. Data for the individual households have been obtained from the respective grid owners. This should imply high reliability, provided that the households read and report data correctly. There are still no automatic meter readings in Norway. Another uncertainty related to the measured data, is effects on energy consumption from changes in energy behaviour other than the installed technology.

## 2..2 Specification of calculation parameters

The following parameters and variables are used in the calculations:

| | | |
|---|---|---|
| TC | = | total consumption of electric energy, kWh |
| HC | = | heating consumption of electric energy, kWh |
| NHC | = | non-heating consumption of electric energy, kWh |
| HDD | = | Heating Degree Days |
| N | = | index referring to a normal year (w.r.t. HDD) |
| t | = | time (years) after installation. |
| | | t = 0: last year before installation, baseline year |
| | | t = 1: first year after installation |
| | | t = T: lifetime of the investment/installation |
| i | = | 1..n = household index/identifier. |
| n | = | number of households participating in the programme |
| K | = | number of members in the household |
| S | = | net (annual) savings, kWh |
| PS | = | programme savings, kWh |
| LS | = | lifetime savings |
| r | = | depreciation factor |

The relevant formulas then follow:

$$NHC_{ti} = 8.000 + K_{ti} \cdot 1.000$$

$$HC_{0i} = (TC_{0i} - NHC_{0i}) \cdot \frac{HDD_{Ni}}{HDD_{0i}}$$

$$HC_{1i} = (TC_{1i} - NHC_{ii}) \cdot \frac{HDD_{Ni}}{HDD_{1i}}$$

$$S_{1i} = HC_{0i} - HC_{1i}$$

$$PS = \sum_{t} \sum_{i} S_{ti}$$

Discounting is not considered. If discounting were to be applied, to account for dynamic changes in the baseline and technological and behavioural risks, it is proposed that a "depreciation" approach is chosen over the "inverse growth"-approach. (See discussion below).

2..3 Specify the unit for the energy saving calculation

The saving (kWh/year) is calculated for individual households who have installed air-to-air heat pumps under this programme.

2..4 Baseline issues

In the baseline year, the electricity used for heating can be calculated either as (i) a given percent of the total electricity consumption, or (ii) as the residual after subtraction from the total of a calculated non-heating consumption. Since a major goal with the programme is to reduce the heating share of end use, we must assume as a principle that the heating share of electricity is changed (reduced) in the ex-post situation. Thus, method (i) cannot be applied on the ex-post consumption. The more robust method for obtaining the energy savings therefore is to estimate the non-heating consumption in the baseline, and use the same value as non-heating consumption also after the installation of the heat pump, provided that no changes in demographics or other variables that affect this consumption has been changed. Or, if such changes have occurred, they need to be controlled for.

2..5 Gross to net corrections

There are several possible sources of gross/net deviations in this programme. Heat pump installation combined with retrofit insulation and/or low energy windows will overstate savings. Fuel substitutions, e.g. reduced use of woodfuel, will seemingly reduce savings. These problems can be corrected in several ways. One approach to these side-effects is (i) to perform a regression analysis, thus estimating and subsequently removing the effects of these additional behaviours. Method (ii) is to base the saving calculations on the households that do not report any rebound, substitution or interaction "behaviours". In this concrete case it has been possible to identify a large sub-sample of households that report no changes in their energy behaviour other than the programme intention of substituting heat pumps for direct electrical heating systems. This subsample is used to estimate savings.

The programme triggered a massive development in the heat pump market. As mentioned above, the subsidy scheme was terminated after the initial batch of 18.000 households had received subsidy and installed the pumps. During the following years, until 2009, approx. 400.000 additional units have been installed (without subsidy). Important parts of this market development are likely due to the HSP.

### 2..6 Normalization

Normalization have been applied, for the individual households, to:

- HDD values
- non-heating consumption

## 3 Input data and calculations

### 3..1 Parameter operationalisation

The evaluation of the HSP was based on an extensive survey among the households participating in the programme. From this survey the following parameters/variables needed for the savings calculations were obtained:

- TC: Total gross consumption of electric energy (kWh). The consumption data for the base year and ex-post year were reported by the household, or permission was given to the "surveyors" to contact the electricity grid owner to obtain consumption data for the household in question directly.
- HDD: Data on heating degree days are estimated and published by The Norwegian Meteorological Institute. The resolution of these is up to several points per municipal unit. Based on the address of the household, the closest or most relevant geographical location with an estimated HDD value is chosen as reference.
- K: Number of members in the household is obtained from the survey.

These are the only three variables that are needed in order to estimate the per household savings. Analyses are performed by a research team.

### 3..2 Calculation of net annual savings as applied

To estimate the savings, a statistical subsample is selected. This sample consists of 239 households who report no major adjustment in energy behaviour in addition to the installation of the heat pump. A point estimate for the average annual savings among these households is 6.121 kWh per household per year.

Estimated programme savings:
6.121 kWh/household * approx. 18.000 households = 110 GWh/year

### 3..3 Total savings over lifetime

#### 3..3.1 Savings lifetime of the measure / technique selected

Life time for an air-to-air heat pump is assumed to be 12 years.

3..3.2 Lifetime savings calculation of the measure / technique

*Discounting* of energy savings is a concept that so far is not widely applied in Norway. Let us perform a very simple reasoning around this concept.

Economists talk about discounting basically because of the time preference of economic actors. This time preference implies that an actor has to be compensated for postponing e.g. a certain consumption. This compensation is interest (r). Due to interest, a financial capital thus has to grow over time (annualy) with a factor of (1+r). Discounting usually implies the *correction* of future monetary values to make them comparable at a certain point in time, usually the present. Discounting a series of payments $A_t$ in the years t = 0,1,2,...,n to year 0 therefore is equivalent to the present value (PV):

$$PV = A_0 + \frac{A_1}{(1+r)} + \frac{A_2}{(1+r)^2} + \cdots + \frac{A_T}{(1+r)^T}$$

*Depreciation* is a different concept. Here the economic entity (asset) loses value over time, e.g. at a rate r per year. The value of $A_t$ in year t then becomes:

$$A_t = A_0 (1-r)^t$$

If we are to adjust the value of achieved energy savings according to such reasoning, we can make the corrections in two ways:

$$1)\ LS = \sum_{t=1}^{T} \frac{S}{(1+r)^t} \qquad \text{(discounting)}$$

or:

$$2)\ LS = \sum_{t=1}^{T} S \cdot (1-r)^t \qquad \text{(depreciation)}$$

As an illustration we calculate the "discount factor" using method 1) and 2). Using the heat pump lifetime T = 12 years and r =0,04 the results become 9,385 and 9,295, respectively. The numerical difference is not very significant, but the principles behind the formulas are. From my point of view, method 2 is the principally correct one.

# 4 GHG savings

There is no calculation of GHG savings.

# References

Bjørnstad, E. et al. (2005): Evaluering av tilskuddsordningen til varmepumper, pelletskaminer og styringssystemer. NTF-rapport 2005:2. Nord-Trøndelagsforskning, Steinkjer.

Grinden, B. and N. Feilberg (2008): Analysis of monitoring campaign in Norway. REMODECE report D-10.

Myhre, L. (2004): Energitiltak i eksisterende boliger. Presentasjon. Oslo: Norges byggforskningsinstitutt.

**No Annex:**

Definitions