



DANISH
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Manual

HP-FAT

Heat Pump First Assessment Tool

Højtryksbeholder

Absorber pumpe

Title:

HP-FAT - Heat Pump First Assessment Tool
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Table of Contents

Preface.....	4
1. Background and motivation	5
2. General description.....	6
3. Energy calculations.....	6
4. Financial calculations	8
5. Briefly about the programme	9

Preface

This document is a short manual for the programme HP FAT (Heat Pump First Assessment Tool), which is a freeware based on EES. It is prohibited to sell the programme on commercial terms.

The document as such is not an explanation and documentation of the programme, and it only covers general use of the programme. By means of the EES platform, the programme contains other functions such as parametric tables and sensitivity analyses, but these functions are not dealt with in this manual.

HP FAT is intended as an auxiliary tool in connection with the first assessment of a possible heat pump application, and we would very much like to hear your ideas for how this tool can be improved and made more useful.

Please send your ideas and comments to the writer:

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1. Background and motivation

In line with the transformation of the Danish energy system from fossil fuels to sustainable energy, a progressively larger part of the primary energy supply will be based on electricity. Electrical heat pumps are set to play a central role in this conversion in that heat pumps can deliver more heating capacity than added electrical power and they can lead to a larger and more efficient use of excess heat.

The economics of a heat pump solution strongly depend on the efficiency of the added electricity when converted to heat. This is expressed in terms of COP (Coefficient Of Performance), which is the ration of the supplied heat (what you get from it) and the supplied electricity (what you pay for it).

The COP strongly depends on the temperatures, under which the heat pump operates, and the design of the heat pump. Thus, an analysis of a given application is often an iterative process, where several configurations are examined. Today, this usually occurs in terms of heat pump suppliers estimating a possible COP and first cost (cost of construction), which – in addition to the choice of heat pump technology and refrigerant - involve quite a lot of work as a proposal is expected, which can be realised and which has a good accuracy.

The programme HP FAT (Heat Pump First Assessment Tool) make use of the fact that there is a theoretical maximum for COP for a given set of temperatures. This theoretical value is reduced to a realistic expectable value, which makes it possible to assess the production of heat and simple key economic data.

2. General description

In order to use HP FAT, the window "Main Diagram Window" must be open. All other windows must be closed. The selection of open windows is made in the menu "Windows" found at the top of the screen. "Main Diagram Window" is found under "Diagram Window".

When entering values into the programme, press the button "Calculate" to update the values.

When pressing the button "Print", the elements shown in the diagram window are printed.

When pressing the button "Save", a data file with the entered values is saved. It is possible to reload the entered values into the programme by pressing the button "Load" and then choose an already saved data file.

3. Energy calculations

Input and showing of results occur in the same screen display as seen in figure 1.

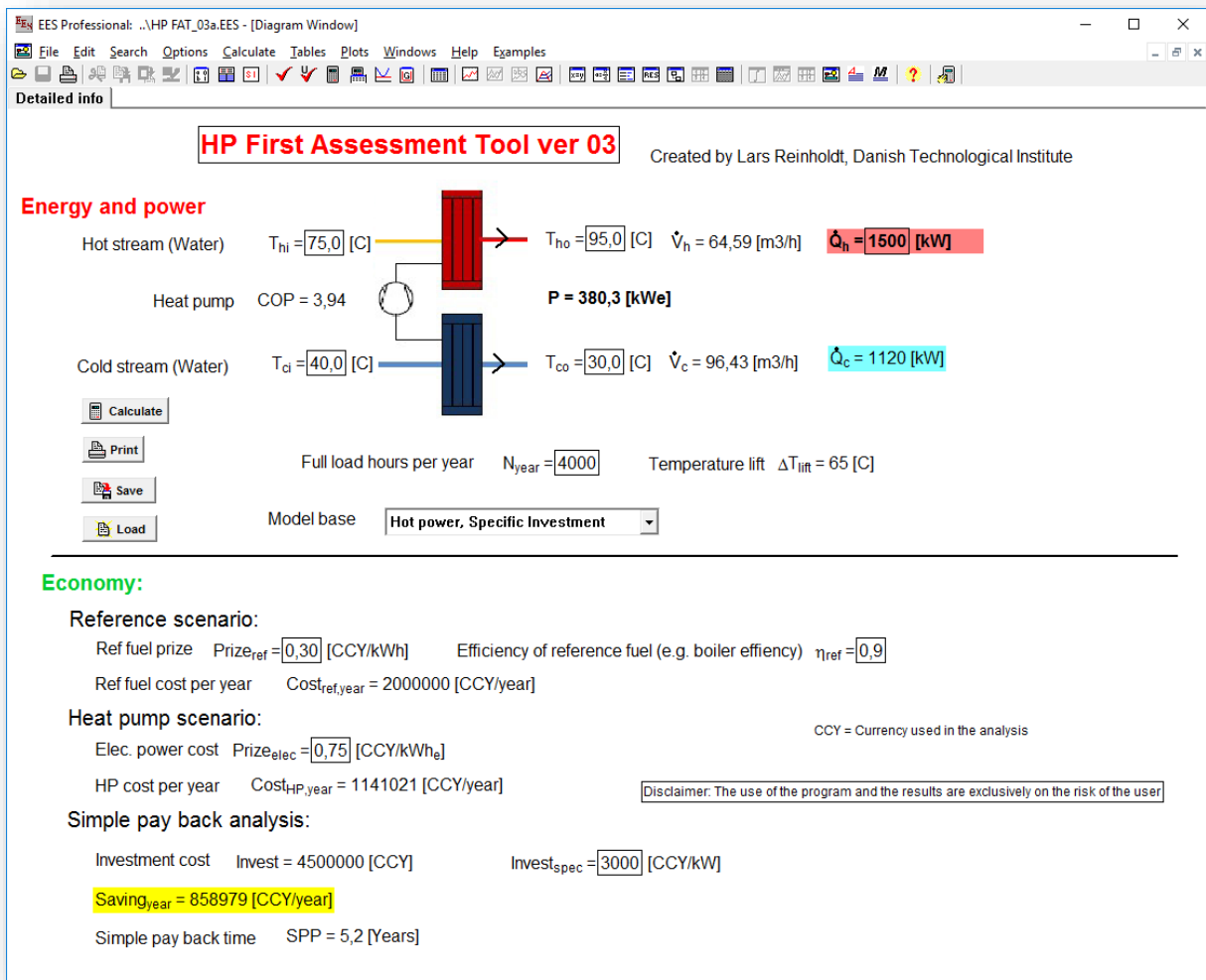


Figure 1: Main diagram window for HP FAT version 3.

The screen display is divided into two:

- A. Energy calculations
- B. Financial calculations

When calculating the COP, specific values must be known/estimated as seen in figure 2. Generally for the programme, the required input data is indicated by a frame around the entry field.

- The temperature before and after it, which is being heated ("Hot Stream").
- The temperature before and after it, which is being cooled ("Cold Stream").

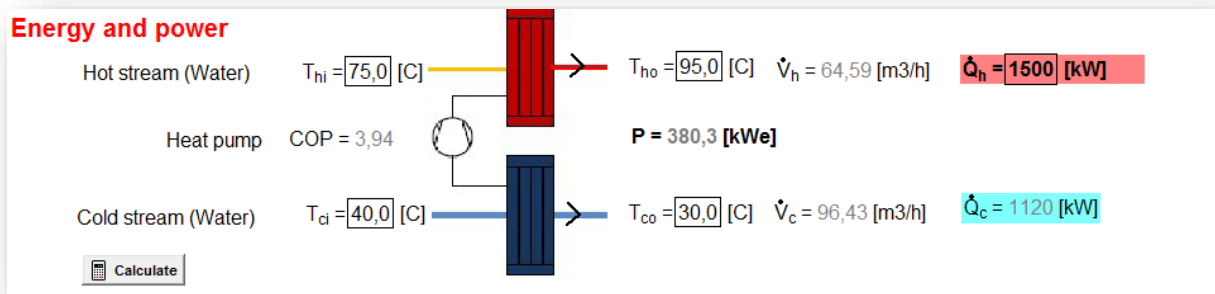


Figure 2: Share of input for the energy and COP calculation.

It is now possible to calculate the COP by pressing the button "Calculate".

Enter the flow temperatures, not the temperature of the refrigerant.

Please note that the further energy calculation is based on water as a medium for the cold and the hot current.

A drop-down menu is found under "Model base", cf. figure 3, where it is possible to choose between different combinations of input.

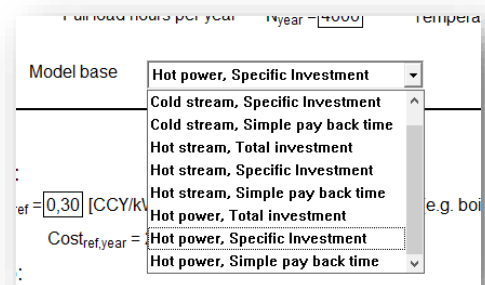


Figure 3: Model base "drop down-menu"

If the flow rate of the heated water is known, select a model, where "Hot Stream" is included in the menu "Model Base". Correspondingly, select a model, where "Cold Stream" is included, if the flow rate of the water being cooled by the heat pump is known. If the wanted amount of produced heat is known, select a model, where "Hot Power" is included.

Depending on the choice of model, the flow rate of one of the following can be indicated:

- The produced hot water (\dot{V}_h , m³/h)
- The water, which is cooled by the heat pump simultaneously (\dot{V}_c , m³/h)
- The wanted amount of produced heat (\dot{Q}_h , kW) (example shown in Figure 3).

The energy streams (cold and hot) and the electricity consumption of the heat pump are hereby calculated.

4. Financial calculations

By including the number of full load hours per year (N_{year}), see Figure 1, the annual amount of energy can be calculated as well.

The financial calculations in HP FAT, as seen in figure 4, are based on a comparison with a reference scenario, where the amount of heat (\dot{Q}_h) is produced with a boiler with the given efficiency (η_{ref}).

Economy:

Reference scenario:
 Ref fuel prize $\text{Prize}_{\text{ref}} = 0,30$ [CCY/kWh] Efficiency of reference fuel (e.g. boiler efficiency) $\eta_{\text{ref}} = 0,9$
 Ref fuel cost per year $\text{Cost}_{\text{ref,year}} = 2000000$ [CCY/year]

Heat pump scenario:
 Elec. power cost $\text{Prize}_{\text{elec}} = 0,75$ [CCY/kWh_e] CCY = Currency used in the analysis
 HP cost per year $\text{Cost}_{\text{HP,year}} = 1141021$ [CCY/year]

Disclaimer: The use of the program and the results are exclusively on the risk of the user

Simple pay back analysis:
 Investment cost $\text{Invest} = 4500000$ [CCY] $\text{Invest}_{\text{spec}} = 3000$ [CCY/kW]
Saving_{year} = 858979 [CCY/year]
 Simple pay back time $\text{SPP} = 5,2$ [Years]

Figure 4 Share of input and results for the financial calculations.

By entering the fuel price ($\text{Prize}_{\text{ref}}$) for the chosen currency (e.g. 0.30 DKK per kWh for natural gas), the annual costs of the reference scenario ($\text{Cost}_{\text{ref,year}}$) is calculated in that currency.

By entering the price of electricity ($\text{Prize}_{\text{elec}}$) as well, the annual operating costs of the heat pump ($\text{Cost}_{\text{HP,year}}$) are calculated.

It is hereby possible to calculate the annual operational savings ($\text{Saving}_{\text{year}}$).

Depending on the choice of "Model base", see figure 3, the key economic data can be calculated based on "simple payback time". In order to do this, one of the following must be known:

- The size of the total investment ("Invest", choose "Total investment" in the "Model base")
- The size of the specific investment (" $\text{Invest}_{\text{spec}}$ ", choose "Specific investment" in the "Model base")
- Wanted period for simple payback time ("SSP", choose "Simple payback time" in the "Model base").

HP FAT now calculates the other two values, which have not been entered the programme.

The following should be noted:

- A. "Total investment" is the total amount of the entire heat pump installation, including the purchase of the heat pump, pipes, and the installation etc.
- B. "Specific Investment" is the total investment per kW heat, which the heat pump produces. A typical value, based on the experiences from large heat pump installations, is 2500-3000 DKK/kW for the heat pump unit itself. To this must the cost of the rest of the heat pump installation (coupling, piping, exchangers, and potentially buildings etc.) be added.

5. Briefly about the programme

In the upper left corner of the window "Main Diagram Window", there is an indexing tab called "Detailed Info". When clicking this tab, a new window opens. This window opens the same kind of window as the one available under "Main Diagram Window", but more values are shown. The values, which can be entered under "Main Diagram Window", cannot be entered under "Detailed Info". Under "Detailed Info", the efficiency of the heat pump is entered (η_{COP}). This value is an expression of how close a real heat pump can get to the theoretical maximum COP. Based on experiences from large heat pump installations, the COP rarely goes beyond 0.6, and the default value is set to 0.55. If the value of a current heat pump is known, this value can be altered, which will improve the comparison between the heat pump and the boiler.

The calculation code is available by pressing "Ctrl." + "E". Basically, the model is based on the Lorenz-COP, which is an enlarged edition of the Carnot-COP. The Carnot-COP considers the possibility of utilizing the change in temperature on both the cold side and the hot side of the heat pump (the temperature "glide"). Expressed in popular terms, the Lorenz-COP is the total COP of an infinite number of series-connected heat pumps, each with a Carnot-COP.