HOW TO GUIDE

Electric heat pumps in energyPRO

About energyPRO

energyPRO is a Windows-based modeling software package for combined techno-economic analysis and optimisation of complex energy projects with a combined supply of electricity and thermal energy from multiple different energy producing units.

The unique programming in energyPRO optimises the operations of the plant including energy storage (heat, fuel, cold and electrical storages) against technical and financial parameters to provide a detailed specification for the provision of the defined energy demands, including heating, cooling and electricity use.

energyPRO also provides the user with a detailed financial plan in a standard format approved by international banks and funding institutions. The software enables the user to calculate and produce a report of the emissions by the proposed project.

energyPRO is very user-friendly and is the most advanced and flexible software package for making a combined technical and economic analysis of multi-dimensional energy projects.

For further information concerning the applications of energyPRO please visit www.emd.dk.

Terms of application

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Contents

In this How To Guide you will learn how to set up an electric heat pump in energyPRO, using the built-in heat pump unit. With this unit, the modelling of a heat pump with a dynamic COP value is a quick and easy task.

In the end of the guide, the formulas behind the built-in heat pump unit are described.

Click the bullets below to jump to the relevant chapter.

Introduction

In energyPRO, an electric heat pump can be modelled in different ways - either by using the built-in heat pump unit or the user defined energy conversion unit. The same results can be achieved with both methods, but the user defined unit requires more from the user regarding the setup. In return, there are almost endless modelling possibilities with the user defined unit, since it's inputs and outputs can be described by user defined formulas.

The ability to enter your own formulas, allows the user to describe for example the correlation between the heat output from a heat pump and external conditions such as the temperature of the heat source. This option makes the modelling very flexible but also rather complex.

As an alternative to the user defined unit, energyPRO offers a built-in heat pump unit, in which all relevant formulas are already incorporated. The necessary inputs are therefore in the form of fixed values or time series and no formulas needs to be entered.

The applied theories behind the heat pump unit are described later in this guide.

Setting up an electric heat pump

To add an electric heat pump to your energyPRO model, start by clicking the blue plus icon in the toolbar as shown in Figure 1. Select "Energy Conversion Unit" in the menu box and then select "Elec. Heat Pump".
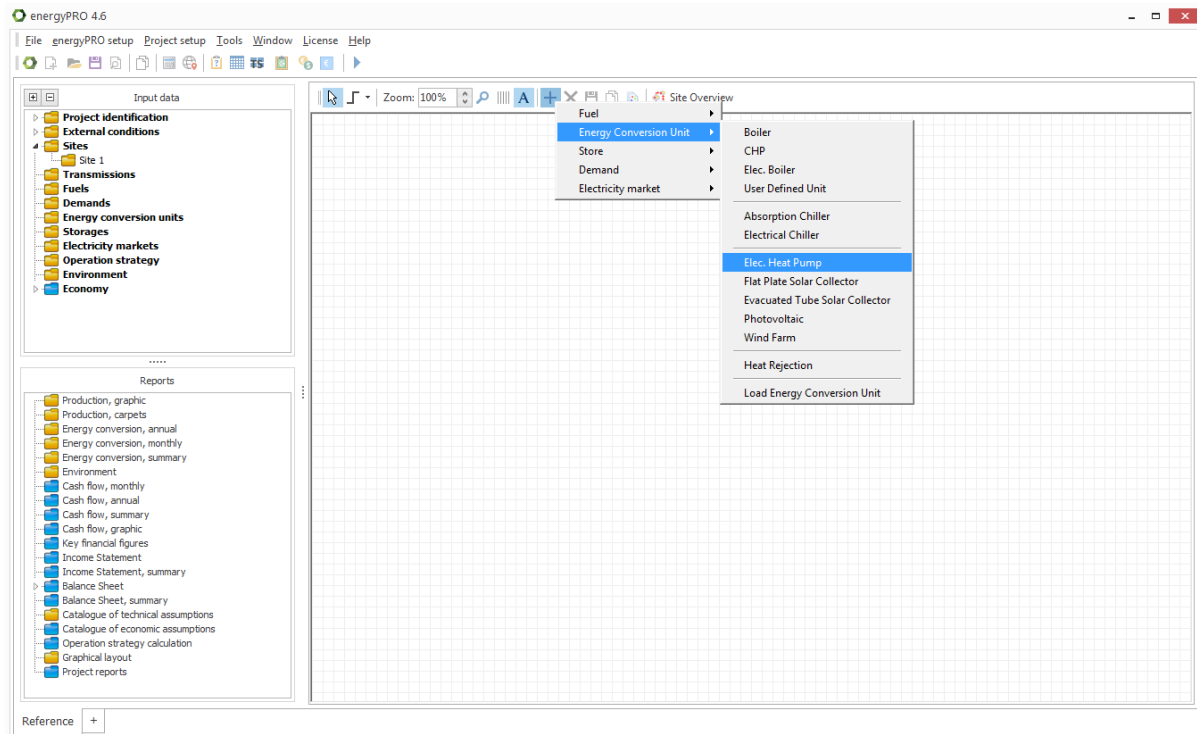

Figure 1. Add an electric heat pump by clicking the blue plus icon in the toolbar

You can also access this menu box by right clicking a random place in the editing window (the checkered paper).

Once the Elec. Heat Pump unit is added, a window with its specifications will open automatically. The window will look like the one in Figure 2.

Figure 2. Type in the specifications of the electric heat pump

The window is divided into two sections: "Heat Pump specification" and "Actual temperatures".

Heat Pump specification

In the Heat Pump specification section, the technical specifications from the data sheet of the unit must be entered and the temperature conditions under which these specifications are valid. The temperature conditions include the inlet and outlet temperatures of both the delivered water from the heat pump and the heat source.

First the following general specifications must be entered:

- Electrical Capacity is the specified electricity load
- Min. electrical load is the electricity load when the heat pump is operated at minimum capacity
- Heat pump COP is the COP stated by the supplier under given temperature conditions.

Next, the related temperature conditions are entered.

Delivered hot water from heat pump is the water entering (Heated from) and the water leaving (Heated to) the heat pump. This could for example be the district heating network's supply and return temperatures.

- <u>Heated from</u> is the water entering the heat pump on the supply side
- <u>Heated to</u> is the water leaving the heat pump on the supply side

The temperatures of the heat source are specified by Cooled from and Cooled down to.

- <u>Cooled from</u> is the initial temperature of the heat source before entering the heat pump
- <u>Cooled to</u> is the temperature of the heat source when leaving the heat pump

Based on the given temperatures a theoretical Lorentz COP can be calculated. This theoretical COP is higher than the stated COP and the ratio between the two is the <u>efficiency of the heat pump</u>, which is fixed in every time step. The efficiency of the heat pump is shown in a grey toned field next to the temperature conditions.

Finally, the maximum heat that can be delivered from the heat pump is specified. With very low temperature differences, the COP value is rather high, resulting in a very high heat capacity. However, this is often not realizable, and it is therefore possible to specify a "Heat output restricted to". In order to make sure that the maximum heat capacity is not exceeded, the electricity capacity is reduced to the "Heat output restricted to" divided with the calculated COP.

- <u>Heat output restricted to</u> is the max achievable heat output capacity. When this value is reached, the electrical load will be reduced.

Actual temperatures

In this section, the actual temperatures of the delivered hot water from the heat pump and the actual temperatures of the heat source are specified. These values may very well vary in every time step of the calculation and it is therefore possible to type in the symbol of a time series rather than entering a fixed value, as shown in Figure 3.

Figure 3. Actual temperatures as time series

The actual temperatures, in Figure 3, are defined by the three timeseries: "ReturnTemp(_)", "SupplyTemp(_)" and "SourceTemp(_)". In this case the source is cooled down 2 degrees below "SourceTemp(_)". When placing the cursor in the input fields, an f(x)-button will appear in the bottom of the window. By clicking the f(x)-button, you can access a list of the available functions and time series in your model.

The actual temperatures are used to calculate the theoretical COP in the given time step, which is multiplied by the calculated efficiency in order to find the actual COP. This actual COP is multiplied with the Electrical Capacity, resulting in the heat capacity of the heat pump.

Note that you must first create the relevant time series in the "External Conditions" folder in the "Input data"-window as shown in Figure 4.
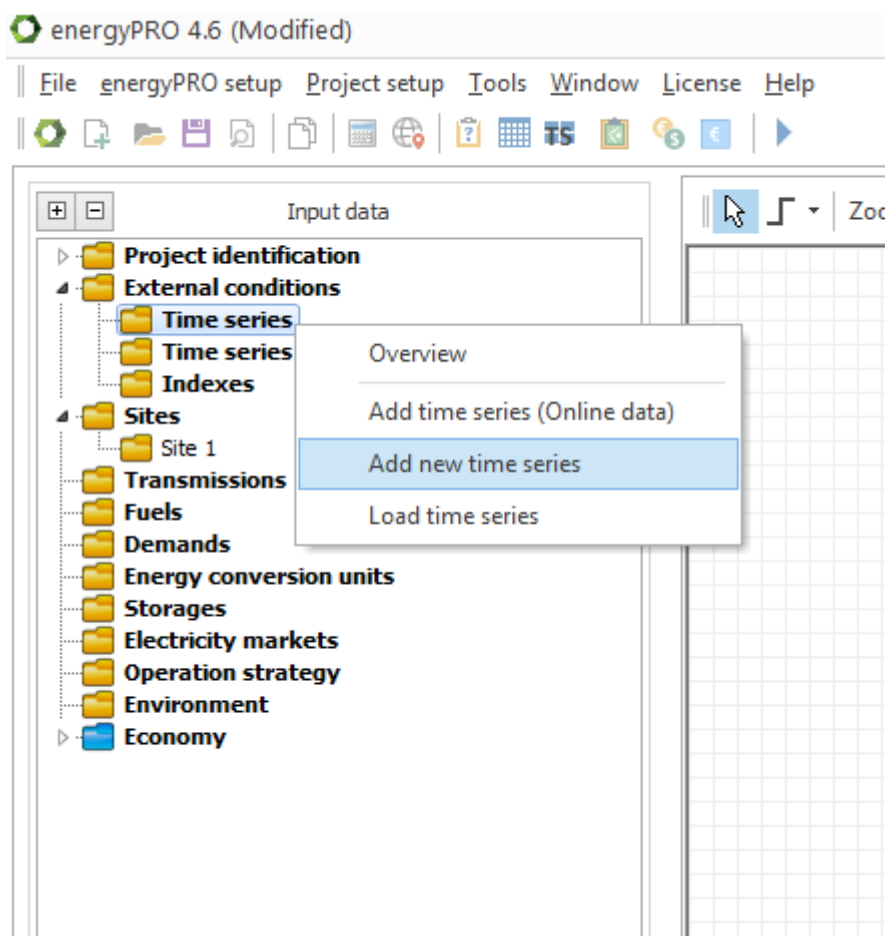

Figure 4. Add relevant time series

The time series can be created manually or by copying data from a spreadsheet. In Figure 5, the district heating forward temperature can be seen as an example of a time series in energyPRO.
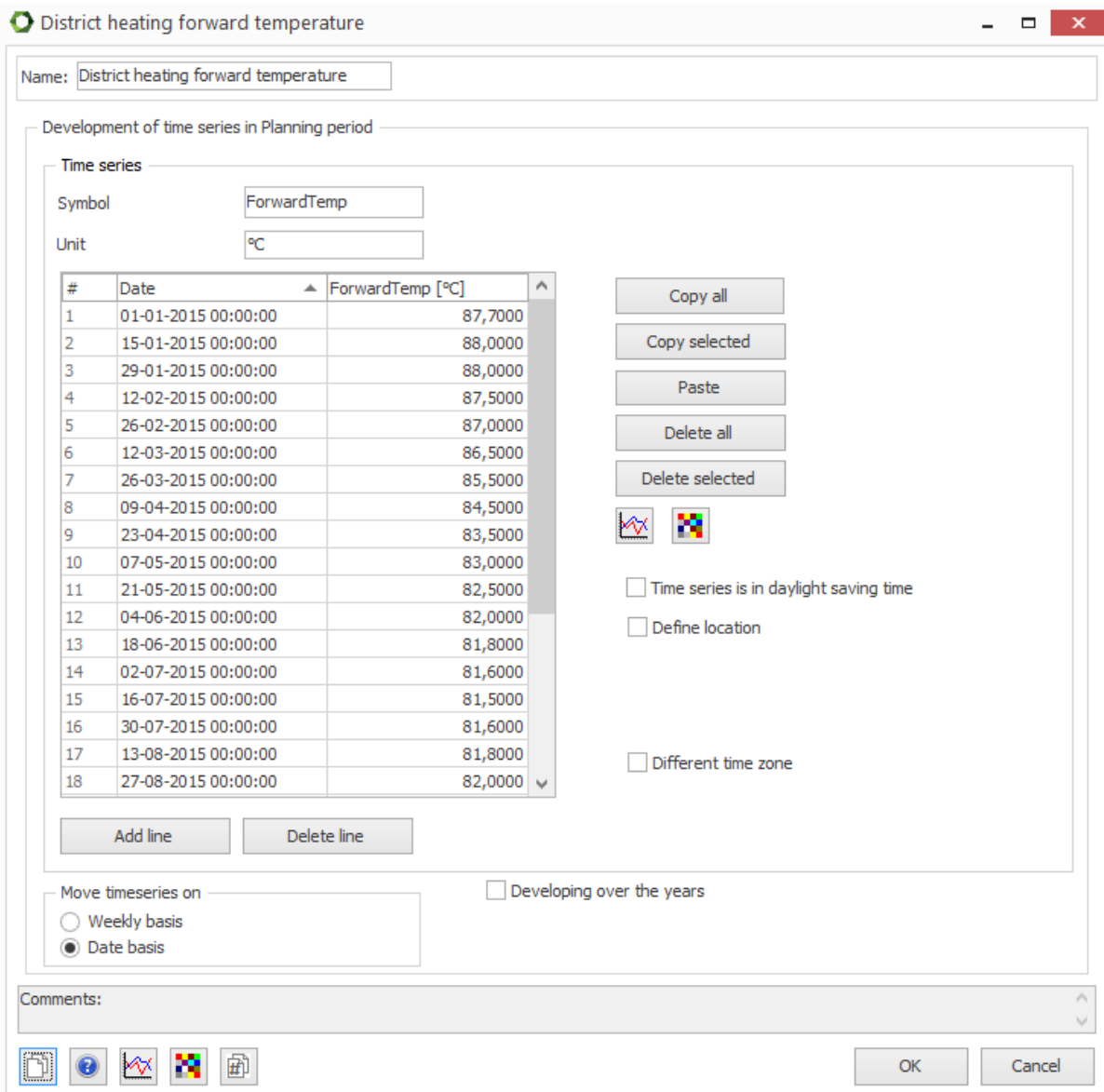
Figure 5. Example of a time series in energyPRO

Graphical representation

The heat pump's input values, calculated capacities and COP factor can be visualized by clicking the "As graphics" button in the bottom of the window, as indicated in Figure 6.

Figure 6. Click the "As graphics" button to see a graphical representation of the heat pump's input values, calculated capacities and COP factor

Clicking this button, will open a window composed of three different graphs as seen in Figure 7. The first graph shows the four actual temperatures: "Heated from", "Heated to", "Cooled from" and "Cooled down to", which are explained in the Heat Pump specification section on page 8.

The second graph shows the COP factor and how it changes during the year. Notice the relation between the COP factor and the actual temperatures in the first graph window.

Finally, the third graph shows the heat and electric capacity of the heat pump at full load and part load. Notice that the heat capacity increases with the increasing COP factor until the "Max heat Capacity" is reached. In this case, the maximum heat capacity is 3.3 MW. Once the maximum heat capacity is reached, the electric capacity is reduced with the increasing COP factor.
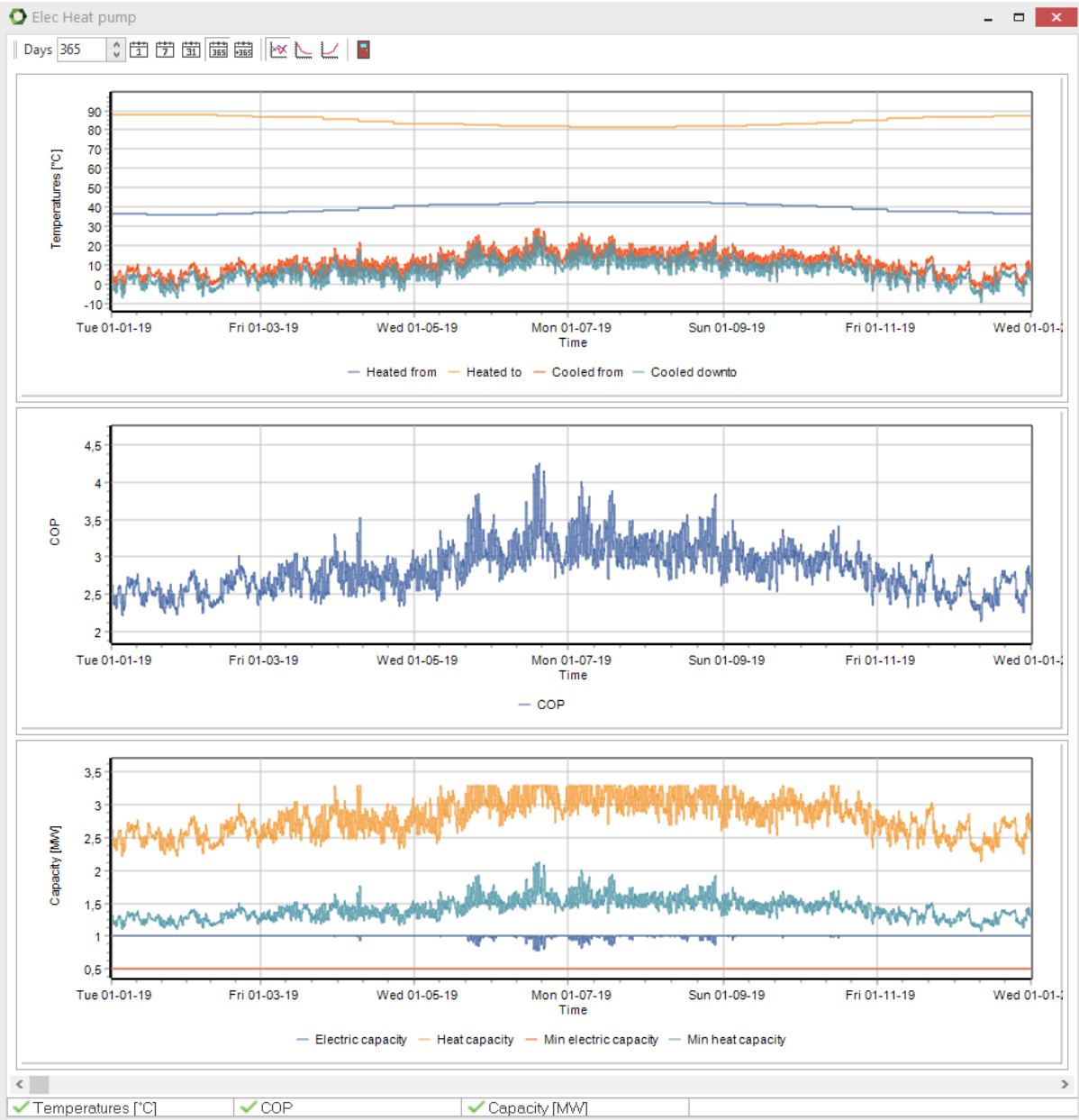
Figure 7. Graphical representation of the heat pump's input values, calculated capacities and COP factor

Calculation methodology

In energyPRO a simple Lorentz heat pump model is implemented for calculating the theoretical COP (coefficient of performance).

The theoretical COP is calculated by:

$$COP = \frac{T_{HighMean}}{T_{HighMean} - T_{LowMean}}$$

Where

$T_{HighMean}$ is the mean temperature (K) of the Delivered hot water

$T_{LowMean}$ is the mean temperature (K) of the Heat source

The mean temperature of the Delivered hot water is calculated as:

$$T_{HighMean} = \frac{T_{HighOutlet} - T_{HighInlet}}{\ln\left(\dfrac{T_{HighOutlet} + 273,15}{T_{HighInlet} + 273,15}\right)}$$

Where

$T_{HighOutlet}$ is the temperature (°C) of the delivered water out of the heat pump

$T_{HighInlet}$ is the temperature (°C) of the delivered water entering the heat pump.

The mean temperature of the Heat source is calculated as:

$$T_{LowMean} = \frac{T_{LowOutlet} - T_{LowInlet}}{\ln\left(\dfrac{T_{LowOutlet} + 273,15}{T_{LowInlet} + 273,15}\right)}$$

Where

$T_{LowOutlet}$ is the temperature (°C) from which heat source is cooled from

$T_{LowInlet}$ is the temperature (°C) that the heat source is cooled down to

In the Heat pump specification, the specified temperatures are used to calculate the theoretical COP. This COP is divided by the stated COP resulting in the heat pump efficiency, HP_{eff}.

The actual temperatures are used to calculate a theoretical COP for each timestep. This theoretical COP is multiplied with the HP_{eff} giving the actual COP.

Please notice, that you can find more information on how to use energyPRO in the How to Guides, User's Guide and tutorials on EMD's website:

http://www.emd.dk/energypro/