

HOW TO GUIDE

Setting up operation strategies in energyPRO



energyPRO



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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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The Operation Strategy in energyPRO defines how the production units in a given project are prioritized. It is therefore essential for the results of the model that the operation strategy is set up correct.

Depending on the type of project being modelled, different options are available for the user when setting up the operation strategy. This how to guide describes the general principles behind the optimization in energyPRO and how to set up operation strategies for the most commonly used projects.

For the more unusual type of projects, there are separate guides to be found on our website, as explained in the end of this guide.

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Introduction to priorities in energyPRO

In energyPRO you can model complicated energy systems, consisting of an unlimited number of demands, energy conversion units, fuels and energy storages. Based on the model specifications and the operation strategy (user defined or automatic calculated), energyPRO calculates the optimal operation of the units in the model.

The optimal operation is determined by assigning each unit a priority number in every time step. Depending on the type of strategy selected, the priority numbers are either user defined or calculated automatically.

Typically, the priority number represents the production cost of each unit in every time step and the unit with the lowest production cost will be assigned the lowest priority number. When calculating the operation, energyPRO will start by inserting a production from the unit with the lowest priority number, followed by the second lowest priority number and so on.

The productions are chosen in a non-chronological order as explained in the below example.

Hour	351	352	353	354	355
Unit 1	200	150	70	40	120
Unit 2	50	90	140	160	120
Unit 3	80	80	80	80	80

Table 1. Example of three production units and their priority numbers during 5 hours

The three production units in the table have been assigned a priority number in every hour in the 5-hour period. Each number represent the production costs for the different units in the specific hour. In order to minimize the production costs, energyPRO will therefore first select the unit in the hour with the lowest number and place production in the corresponding hour. In this case, the first production to be chosen is Unit 1 in hour 354. The second will be Unit 2 in hour 351, followed by Unit 1 in hour 353. If not in conflict with the already planned production, this process will continue with Unit 3 in hour 351 through to 355 and so on until the demand is met or the production opportunities have been exhausted.

Every time a new production is placed in a given hour, energyPRO will check if it is in accordance with the already scheduled productions in order to avoid conflicts with the system boundaries such as thermal storage capacity, available fuel, etc.

By default, photovoltaic and wind farms are always set to a priority higher than all heat-producing units. Next the heat producing units are calculated, then the cooling producing units. Of the cooling producing units the absorption chillers are calculated first and finally the electric chillers.

More details on how energyPRO calculates the most optimal operation can be found in the User's Guide at <http://emd.dk/energyPRO>.

Operation Strategy window

To set up the operation strategy open the Operation Strategy window by double-clicking the "Operation Strategy" folder in the input data window or click the "Operation Strategy" button in the toolbar.

Depending on the type of energyPRO project, you will see a window similar to the one in Figure 1, where you can select the type operation strategy.

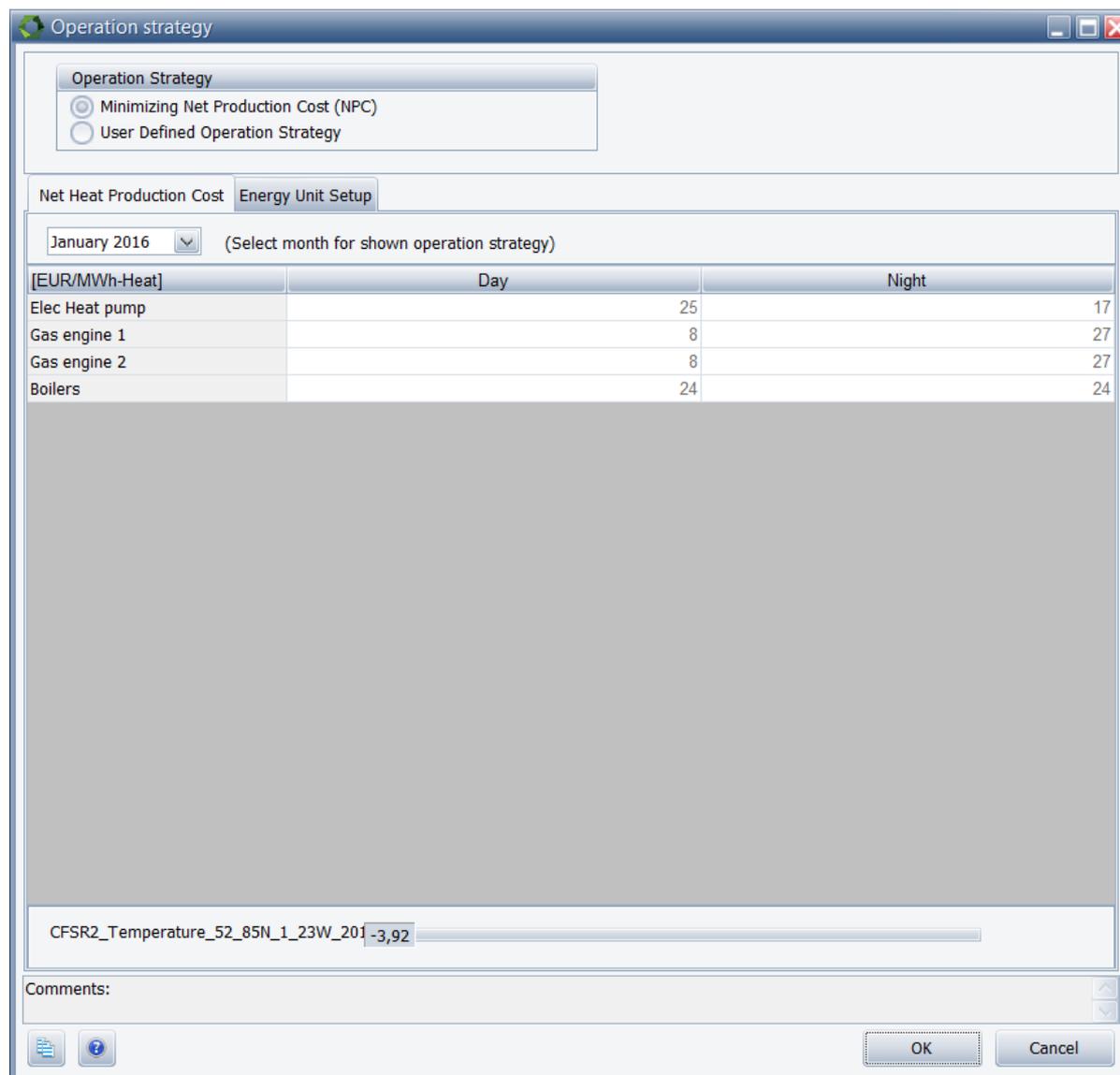


Figure 1. Operation strategy window with fixed tariffs market

In the top of the window you can choose between two types of strategies: "Minimizing Net Production Cost (NPC)" or "User Defined Operation Strategy". The rest of the window appears differently, depending on the type of strategy selected and the type of electricity market present in the model.

Day ahead market

The prices in the Day ahead market (spot market) usually varies in every hour with no systematic recurrence. These changing prices affect the economy of the production units that either consume or produce electricity and thereby also the

priority number for each unit. Since the priority numbers vary in a way that is not systematic and consistent, they cannot be listed in a table. Instead the priorities are either visualized in a graph where the Net Heat Production Costs (NHPC) is a linear function of the electricity price, as shown in Figure 2, or expressed as a formula.

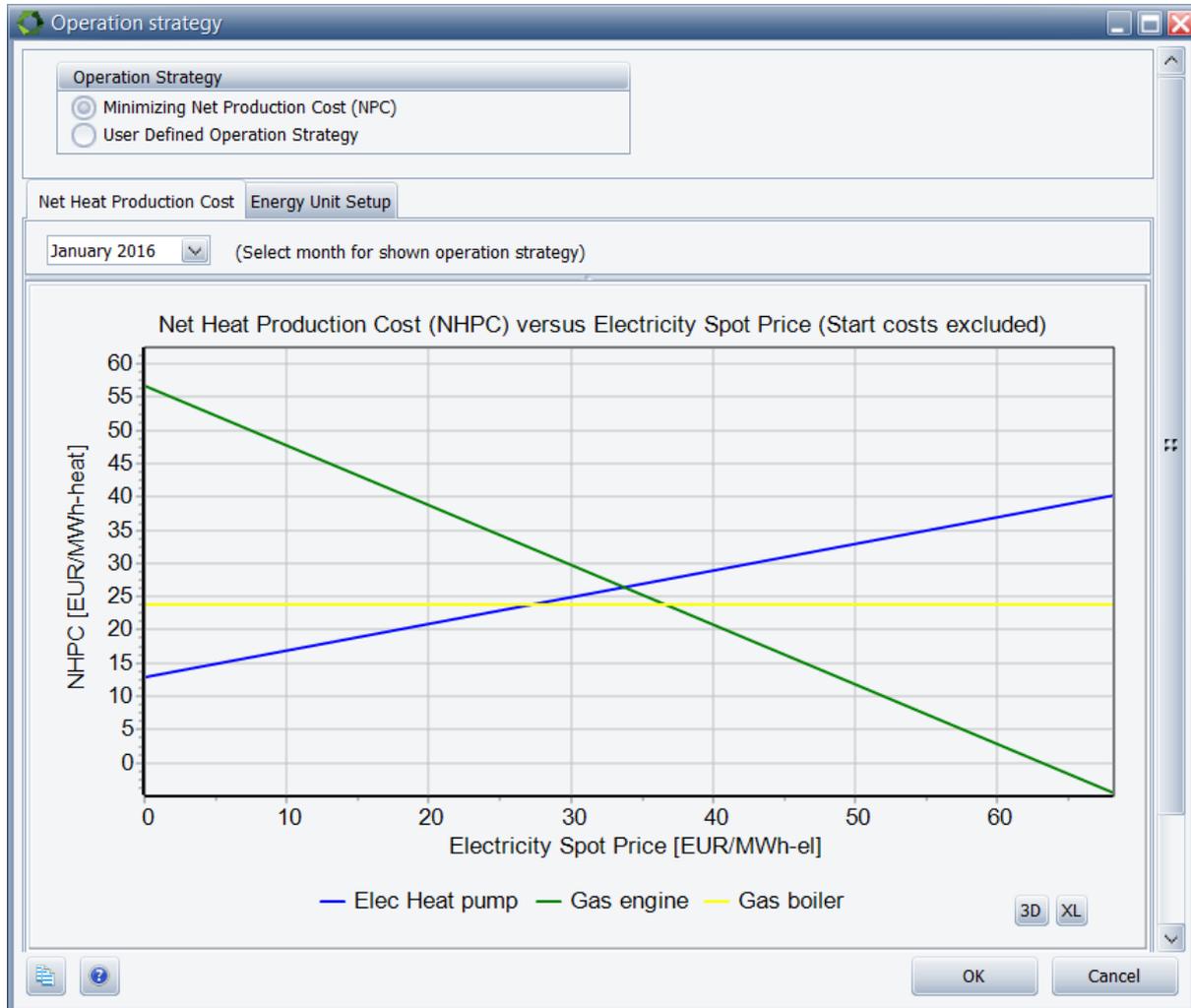


Figure 2. Operation strategy window with day ahead market (spot market)

In the figure the Net Heat Production Cost (NHPC) for an electric heat pump, a gas engine and a gas boiler is shown as a function of the spot price. The NHPC of the gas boiler (yellow) is constant since it is neither producing or consuming electricity. The electric heat pump (blue) is consuming electricity and its NHPC is therefore increasing with the increasing spot price. The gas engine (green) is producing electricity and its NHPC is therefore decreasing with the increasing spot price.

Fixed Tariffs

In a fixed tariffs market, it is possible to define an unlimited number of tariff periods, which is often convenient if electricity prices vary systematically. In Figure 3 below, a fixed tariffs market is defined with three different periods: "Peak Load", "High Load" and "Low Load".

Name: Fixed tariffs

Market Type: Fixed Tariffs

Tariff element name

- Peak Load
- High Load
- Low Load

	From time	To time	From day	To day	Holidays	From date	To date
Peak Load	07:00	09:00	Monday	Friday	Excluding		
High Load	06:00	22:00	Monday	Friday	Excluding		
Peak Load	17:00	19:00	Monday	Friday	Excluding		
High Load	10:00	23:00	Saturday	Sunday	Excluding		

Comments:

OK Cancel

Figure 3. Defining the tariff periods in fixed tariff market

The duration of the different tariff periods is specified in the lower table in the figure. In this example the year will be divided into hundreds of time periods.

Each tariff period can have different payment lines assigned and allowing the user to define different electricity prices in the different tariff periods. In this way, the NHPC of each unit will typically vary from one tariff period to another, as shown in Figure 4. The figure shows, that if there is a fixed tariff market with multiple tariff periods in the model, an operation strategy for each period is defined.

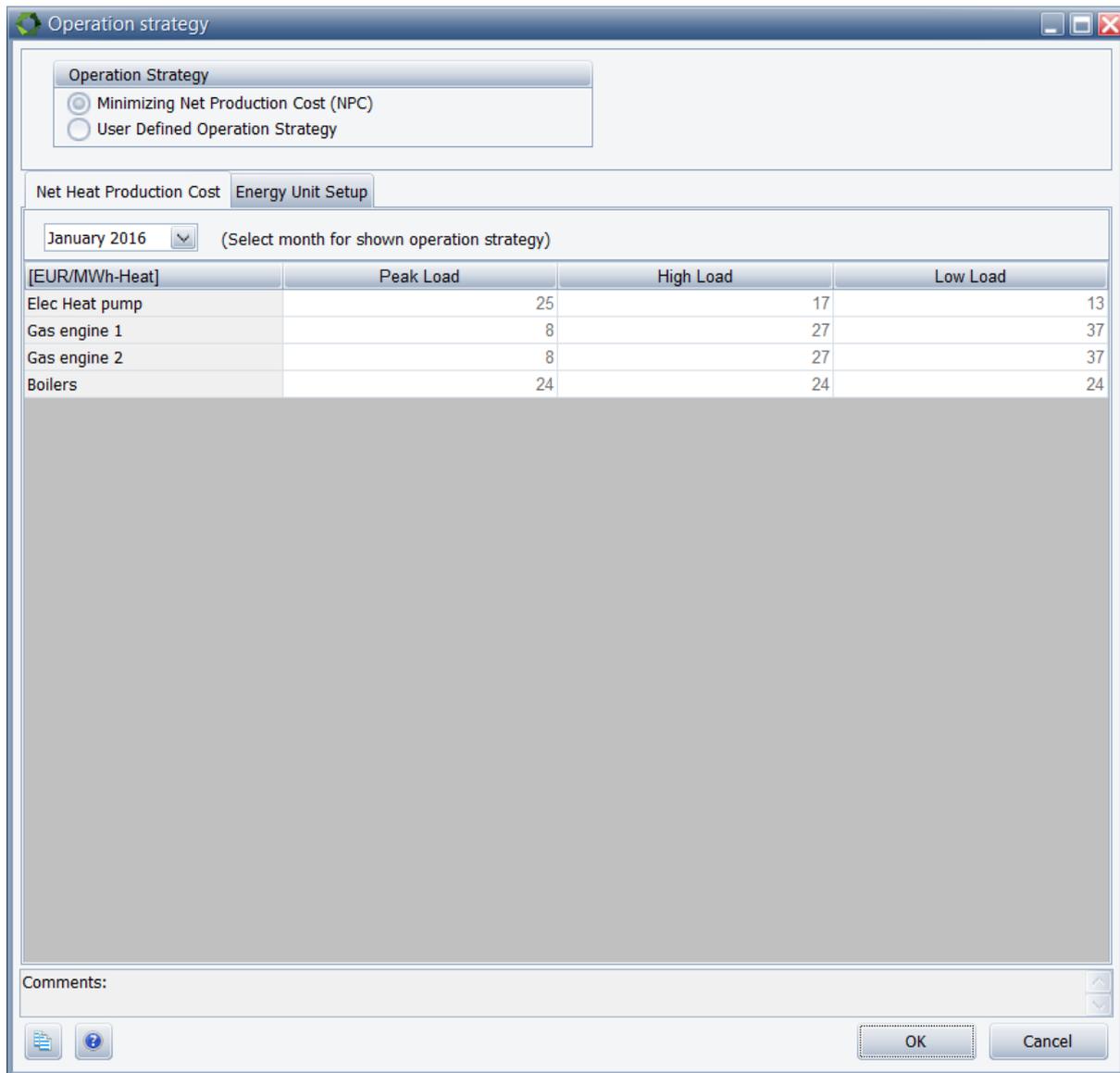


Figure 4. NHPC of the different units in different tariff periods

In the figure it can be seen that gas engine 1 and 2 are the cheapest heat producers in the Peak Load period, while the heat pump is the most expensive unit. Conversely, the heat pump is the cheapest unit in the Low Load period, while the engines are the most expensive units. The NHPC of the boilers is the same in all periods since it is neither producing or consuming electricity.

Regardless of the type of electricity market that is present in the model, the user can choose between a User Defined Operation Strategy and an automatic calculated operation strategy called "Minimizing Net Production Cost (NPC)". The difference between these strategies will be described in more details in the following chapter.

Minimizing Net Production Cost

The strategy, Minimizing the Net Production Cost (NPC), is based on the idea that many local energy plants have an obligation to cover local energy demands e.g. demands for heat, process heat or cooling. The obligation means that all energy demands should be covered – no matter the cost. The goal of the operation strategy “Minimizing Net Production Cost” is therefore to cover these local demands at the lowest possible net production cost.

The “net” indicates that profits from other outputs (e.g. electricity) is also taken into account in the strategy. If a unit is required to cover a certain demand, it might also be producing other outputs, which represent a certain value that thereby reduces the overall net production cost.

An example could be a gas fired engine that is required to cover a heat demand. While producing heat the engine is also producing electricity, which is sold on the electricity spot market. The net production cost of supplying heat is reduced when running the engine in hours with high electricity prices instead of hours with low electricity prices. This is also clear from the graph in Figure 5, where the Net Heat Production Cost (NHPC) is plotted as a function of the electricity spot price for the three units in the model; heat pump, gas engine and gas boiler.

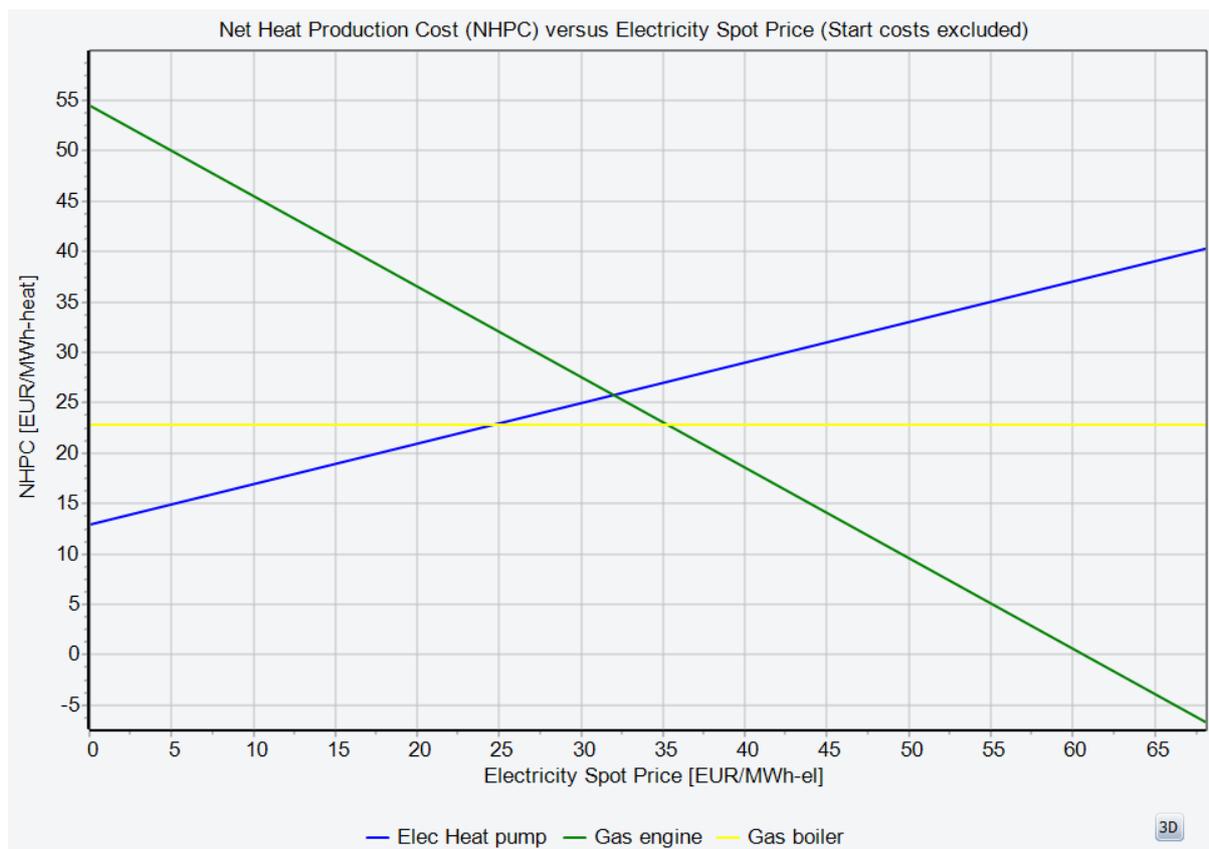


Figure 5. Graphical presentation of the strategy, Minimizing Net Production Cost

As can be seen in the figure, the engine has the lowest heat production cost when electricity prices are high. Conversely, the heat pump has the lowest heat production cost when electricity prices are low. The cost of heat from the gas boiler is constant since it is not affected by the price of electricity.

The calculation of the operation strategy, Minimizing NPC, is entirely based on the payments in "Revenues" and "Operation expenditures" set up by the user to describe the Operation income¹. The economy is in this way tied together with the operation of the units in the model. Therefore, it is important that these payments are set up properly before running the calculation.

In Figure 6 it is clear how changes in the electricity price affects the priority of the units in the example from before. In the figure the electricity price is shown in the top graph and the priorities of the different units are shown in the bottom graph.

Electricity produced by the engine is sold on the spot market, which is modelled as a revenue. Electricity consumed by the heat pump is purchased on the spot market, which is modelled as an operation expenditure. Due to these payments, the priority of the engine and the heat pump varies with the changing electricity price.

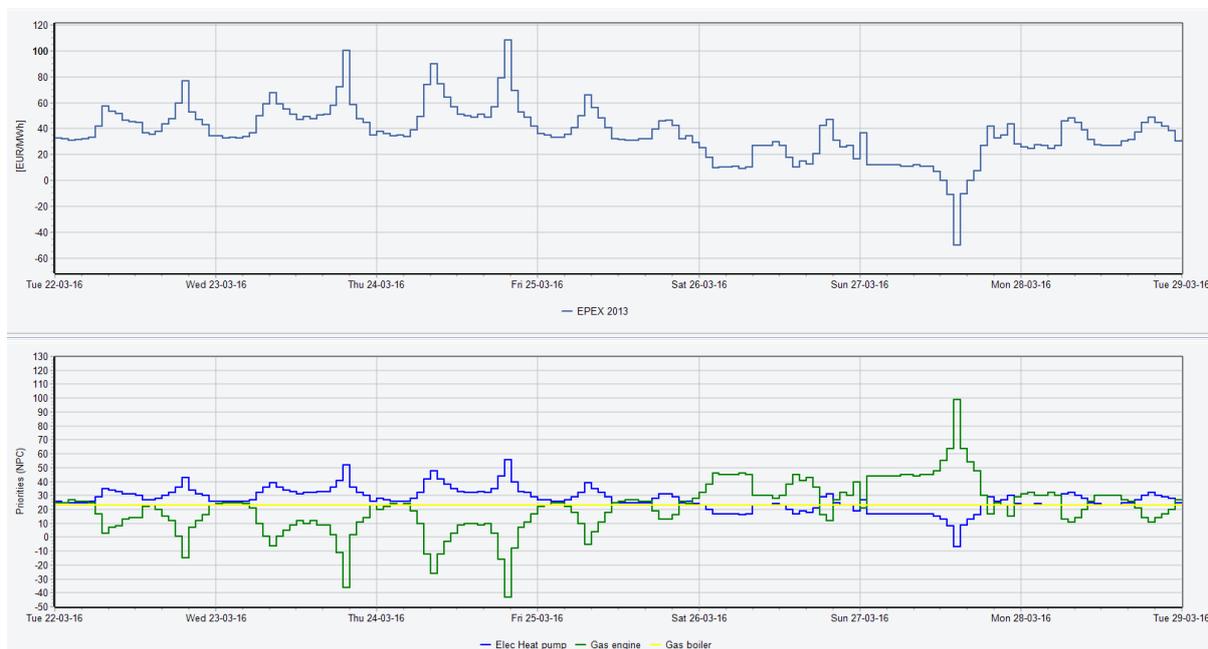


Figure 6. Example of how varying spot prices affects the priority of some production units

In figure it can be seen that when electricity prices are high, the priority number of the heat pump (blue curve) is high while the priority number of the engine (green curve) is low. Note that energyPRO places productions on the units with the lowest priority number first, followed by the second lowest and so on.

The priority of the gas boiler (yellow curve) is constant because the payments regarding the operation of the boiler is not affected by the varying spot price.

Limitations to Minimizing Net Production Cost strategy

In some projects, the automatic calculated operation strategy, "Minimizing Net Production Cost", is not available. This is the case when the option, "Delivery of both heat and process heat" is enabled in the "Project identification"-folder as

¹ See the energyPRO User's Guide for how to set up economy

shown in Figure 7. The same is the case when there are fuel producing energy units in the project. In these cases, the automatic calculation for the operation strategy is not supported.

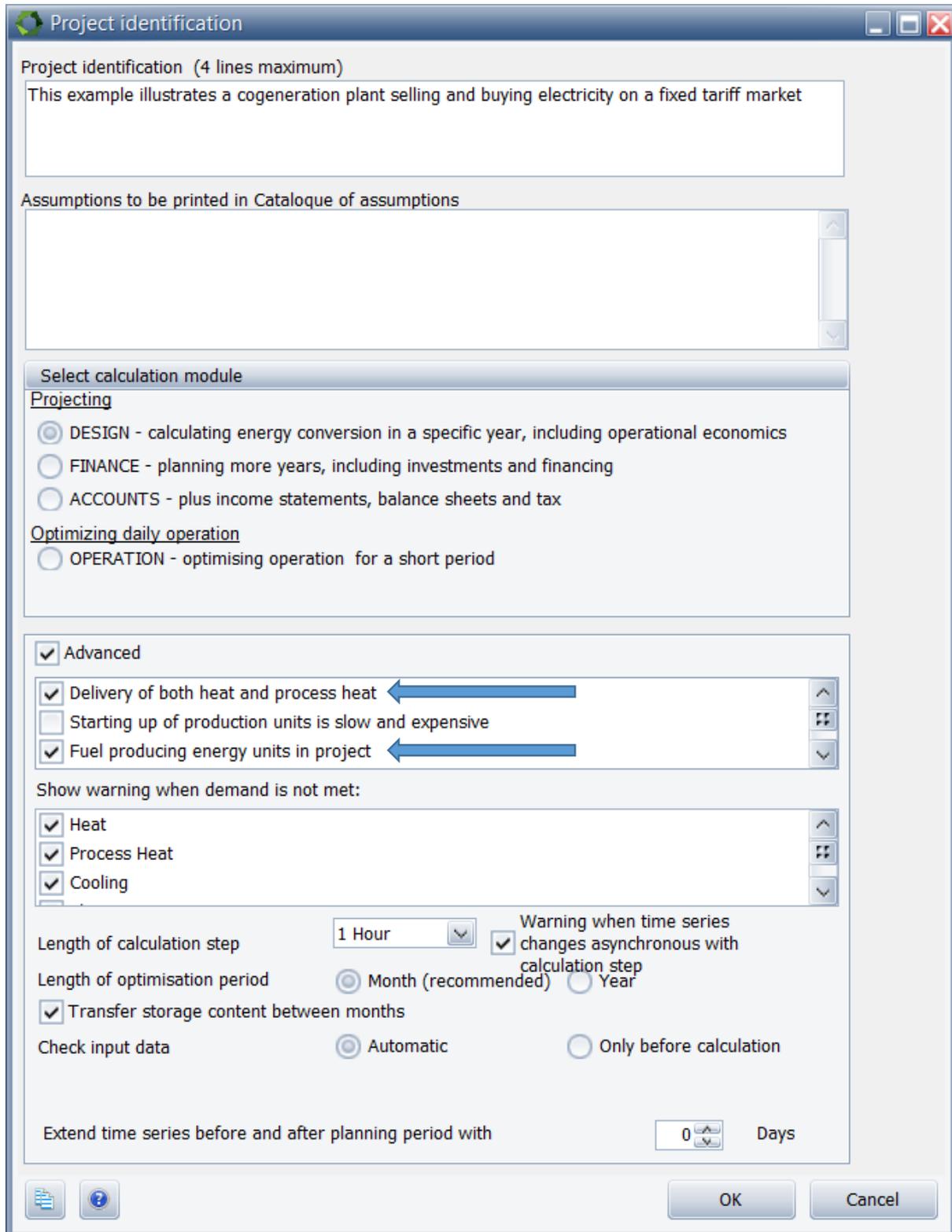


Figure 7. Automatic calculations are not possible if delivery of process heat is enabled

User Defined Operation Strategy

In the User Defined Operation Strategy, the calculation of priorities does not depend on the revenues and operation expenditures in the project. In this type of strategy, the user can specify the desired priorities regardless of the economy.

Figure 8 shows an example of a simple user defined operation strategy. In the example the heat pump, gas engine and gas boiler are given the priority numbers 1, 2 and 3, respectively.

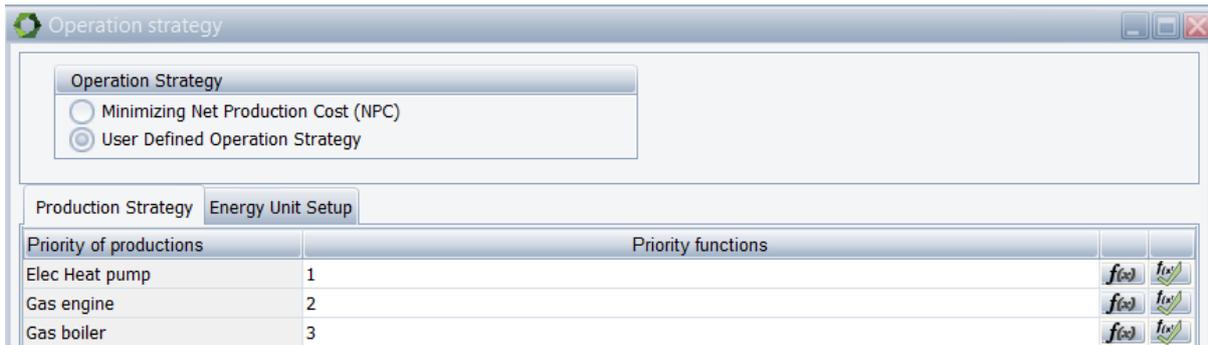


Figure 8. An example of a simple user defined strategy

In this strategy the heat pump is always preferred over the other units. The gas engine will only run if the heat pump cannot cover the heat demand alone and the gas boiler is the least preferable production unit, which will only run if the heat pump and gas engine cannot cover the demand.

It is also possible to define a user defined operation strategy using functions. You can see a list of the available functions by clicking the f(x)-button in the right-hand side of the window.

In the example below, the priorities of the heat pump and the gas engine are functions of the electricity spot price ("SpotPrice(_)"). The priority of the gas boiler is constant in this example.

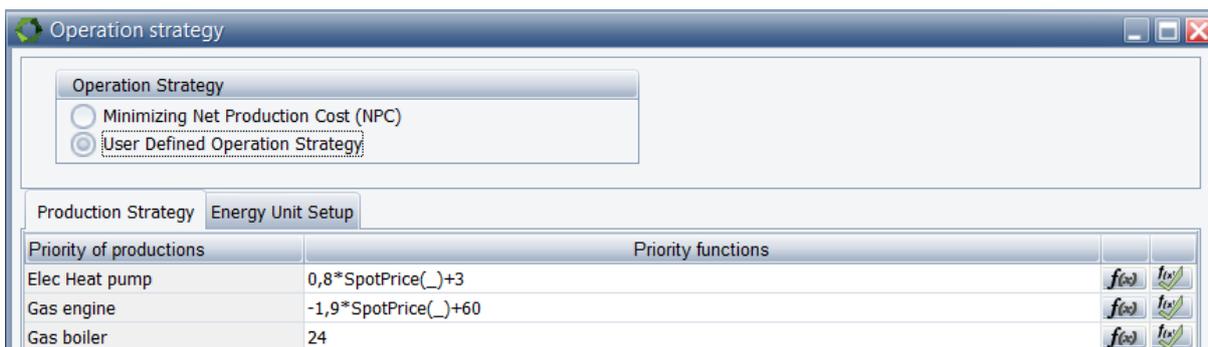


Figure 9. An example of a formula based user defined operation strategy

Energy Unit Setup

In the “Energy Unit Setup”-tab, it is possible to specify miscellaneous settings for each of the units in the project. When clicking the tab, a window similar to the one in Figure 10 will be shown.

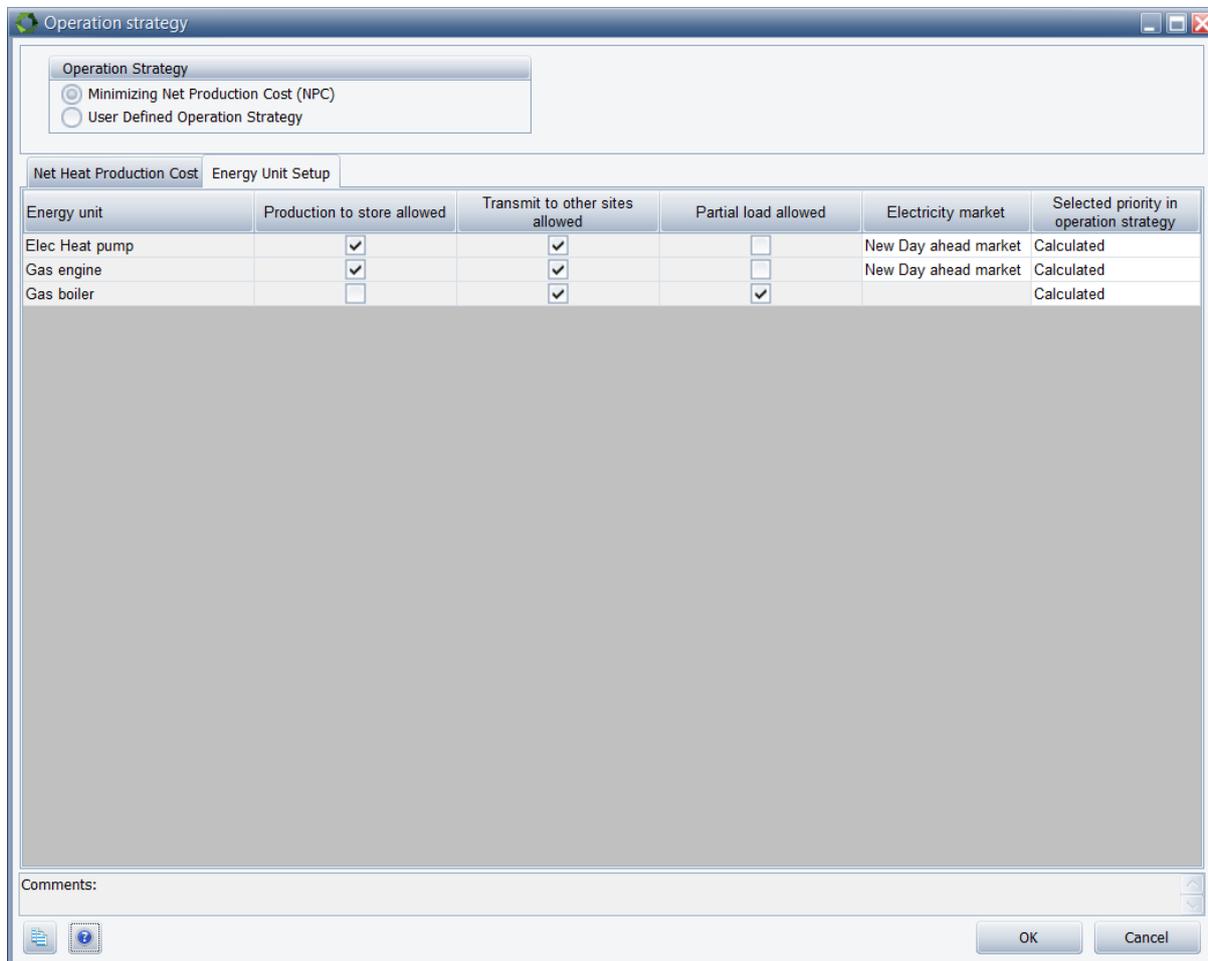


Figure 10. Window for setting up miscellaneous options for each unit

As it can be seen in the figure, there are up to five columns in the table:

1. Production to thermal store allowed (only visible if a thermal store is present in the model)
2. Transmit to other sites allowed (only visible if there is more than one site in the project)
3. Partial load allowed
4. Selection of electricity market
5. Selected priority in operation strategy (only visible if the operation strategy is automatic calculated)

In the first column, state whether the production units have access to thermal storages.

In the second column, state whether the production units are allowed to transmit energy to other sites.

In the third column, state whether the production units are allowed to run on partial load.

In the fourth column, select from a drop-down menu which of the available electricity markets that the specific unit is trading on (It is only possible to have more than one electricity market if MARKETS module is activated). This is done for each production unit that are producing and/or consuming electricity.

In the fifth column, it is possible to overrule the predefined standard settings of the automatic calculated strategy. The standard settings are:

- Boiler: calculated
- CHP: calculated
- Elec. Heat pump: calculated
- Elec. boiler: calculated
- User defined unit: calculated
- Absorption cooler: calculated
- Electric cooler: calculated
- Wind farm: High
- Solar collector: High
- Photovoltaic: High

“Operation Strategy Calculation”-report

The report “Operation Strategy Calculation” shows the calculation of the operation strategy in details. The report is invoked by clicking the “Operation Strategy Calculation”-folder in the Reports tree view shown on Figure 11.

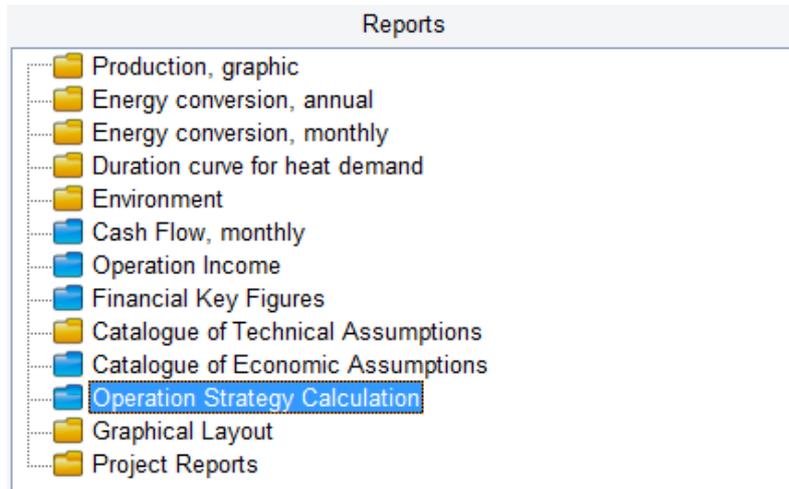


Figure 11. “Operation Strategy Calculation”-report

The report first presents a table containing the calculated operation strategy. The values in this table are identical to the values found in the “Operation Strategy”-window. In the following pages, the details behind the calculation of the strategy for each production unit are shown. Each table contains the calculation of the net heat production costs in all tariff periods.

Note that payments that are identical for all production units in all tariff periods are removed. This could for instance be a fixed payment not related to the energy conversion.

Example of how the net heat production cost is calculated

In the following, the calculation of the net heat production costs for a gas engine in the Day tariff, is described.

The gas engine has the following power curve:

Power curves			
Operation	Fuel	Heat	Elec. power
Performance	kW	kW	kW
Linear	5267,0	2114,0	2000,0

Figure 12. Power curve, Gas engine.

When producing 1 MWh-heat the use of fuel will amount to:

$$1MWh_{heat} * \frac{5267kWh_{fuel}}{2114kWh_{heat}} = 2.5MWh_{fuel}$$

The corresponding electricity production will be

$$1MWh_{heat} * \frac{2000kWh_{elec}}{2114kWh_{heat}} = 0.95MWh_{electricity}$$

With these figures in place we can move on to the economy section.

The production on 0.95 MWh-electricity will generate a revenue depending on the price per unit for export of electricity as shown on Figure 13.

The screenshot shows a software interface for configuring electricity sale parameters. The window title is "Day". It contains several sections:

- Name:** A text box containing "Day".
- Unit Selection:**
 - Payment concerns:** A dropdown menu set to "Exported electricity".
 - Payment concerns priority period:** A dropdown menu set to "Day".
- Formula selecting monthly amounts:** A text box containing the formula "ExportedElectricity(Fixed tariffs;Day)".
- Price per Unit:**
 - A checked checkbox.
 - A text box containing "55,000".
 - The unit "EUR/MWh".
 - The text "(in January 2016)".
 - A dropdown menu set to "Fixed monthly price".
- Include in operation strategy:**
 - A checked checkbox.
 - The text "Payment included in operation strategy calculation".

Figure 13. Screenshot, Sale of electricity revenue

The revenue will amount to:

$$0.95MWh_{elec} * 55GEUR / MWh_{elec} = 52.3EUR$$

The operation expenditures are divided into Fuel costs and Operation and Maintenance costs.

The screenshot shows a software window titled "Natural gas" with the following configuration options:

- Name:** Natural gas
- Unit Selection:**
 - Payment concerns: Imported fuel
 - Fuel: Natural gas
- Formula selecting monthly amounts:** ImportedFuel(Natural gas)/HeatValue(Natural gas)
- Price per Unit:**
 - 0,2420 EUR/Nm3 (in January 2016) Fixed monthly price
- Include in operation strategy:**
 - Payment included in operation strategy calculation

Figure 14. Fuel cost payment

We also need to specify the heat value of the fuel Natural gas:

The screenshot shows the "Natural gas" configuration window with the following settings:

- Name:** Natural gas
- Unit:** Nm3
- Heat value:** 11,0000 kWh/Nm3
- Restrictions and storage

Figure 15. Natural gas heat value

The Natural gas payment amount to:

$$2.5MWh_{fuel} * \frac{1000kWh / MWh}{11kWh / Nm3} * 0.242EUR / Nm3 = 55EUR$$

The last payment regards the operation and maintenance costs.

The screenshot shows a software window titled "Gas Engine". At the top, there is a text box labeled "Name:" containing "Gas Engine". Below this is a section titled "Unit Selection" which contains several dropdown menus: "Production unit" (set to "Gas engine"), "Type" (set to "Electricity production"), "Production Unit" (set to "Gas engine"), and "Payment concerns priority period" (set to "All Periods"). Below these is a text box for the formula "EP(Gas engine;All Periods)". A section titled "Price per Unit" has a checked checkbox, a text box with "6,0000", the unit "EUR/MWh", a note "(in January 2016)", and a dropdown menu set to "Fixed monthly price". At the bottom, there is a section titled "Include in operation strategy" with a checked checkbox for "Payment included in operation strategy calculation".

Figure 16. Operation and Maintenance costs for the gas engine

The operation and maintenance costs are related to the electricity production:

$$0.95MWh_{elec} * 6.00EUR / MWh_{elec} = 5.7EUR$$

The total operation expenditures are thus:

$$55EUR + 5.7EUR = 60.7EUR$$

and subtracted the revenue, the net heat production costs of 1 MWh-heat is

$$60,7EUR - 52,3EUR = 8,4EUR$$

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/download/tutorials-and-how-to-guides/>



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