



energyPRO version 3.3

(Introduction to automatic calculation of operation strategy)

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1. Introduction - What is new?

This version update of energyPRO encompasses the options for automatic calculation of operation strategies. The update enables automatic calculation based on fixed electricity tariffs and automatic calculation of operation strategies on Spot Market conditions (time series data). By introducing automatic calculation of operation strategies we fulfil one of the most requested extensions to energyPRO.

The immediate visible changes on the energyPRO desktop are:

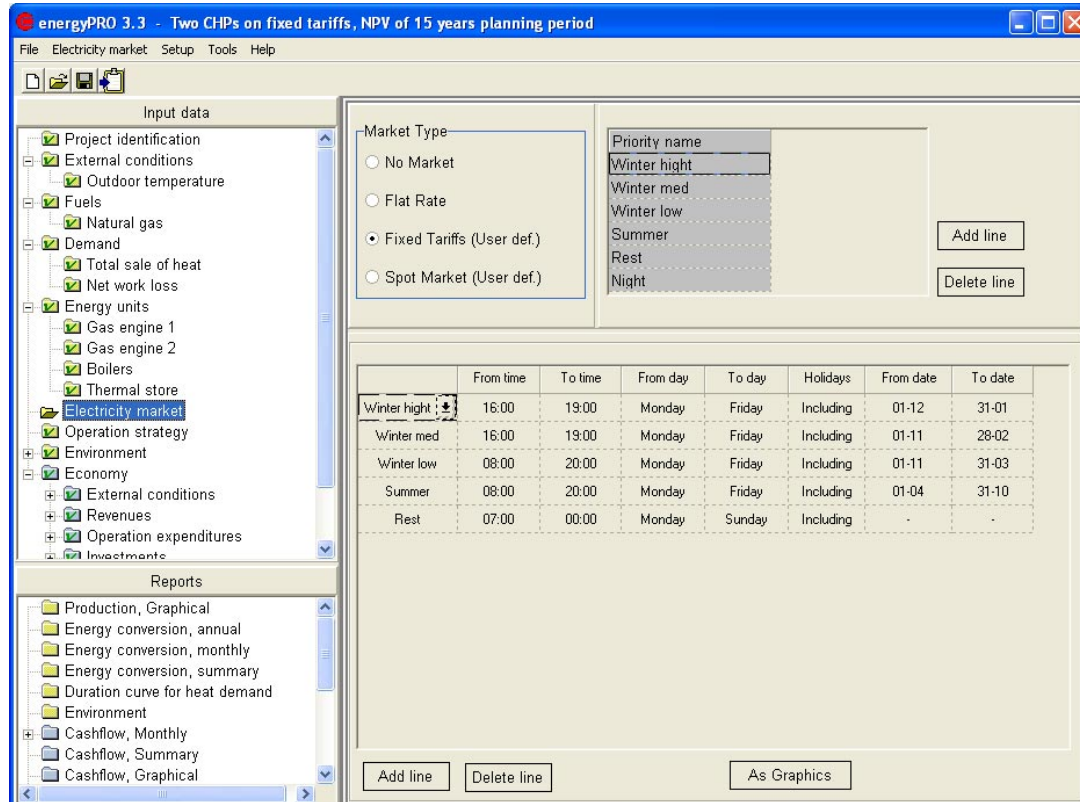
1. Electricity Market window substitutes the Periods of priority window.
2. Operation Strategy – new option for auto calculation of operation strategy.
3. Operation strategy calculation report.

Hereto comes a change that is not visible for the user is that the optimizing period is changed from annually to monthly. Hence there might occur small differences in results when calculating with version 3.3 compared with version 3.2.

1.1 Electricity Market window

The new Electricity market window is shown in Figure 1.

Figure 1: Electricity market substitutes old Periods of priority window.



In this window is introduced a new term “Market Type”. Four types of markets are introduced, see Figure 2. First “No market”, which indicate the absence of an electricity market, second “Flat rate” indicating that the electricity prices is the same all the time.

Hereto come “Fixed Tariffs” and “Spot Market”. Fixed tariffs are tariffs such as the Danish triple tariff or a UK “Day and Night” tariff. “Spot Market” are electricity spot market prices. The addition (User def.) or (auto) indicates if the actual selected Operation strategy is calculated automatically or it is user defined.

Figure 2: Defining Market Type

Figure 2 shows two side-by-side screenshots of the 'Market Type' selection dialog. Both dialogs have a title bar 'Market Type' and four radio button options: 'No Market', 'Flat Rate', 'Fixed Tariffs (User def.)', and 'Spot Market (User def.)' (left) or 'Spot Market (Auto)' (right). In the left screenshot, 'Spot Market (User def.)' is selected. In the right screenshot, 'Spot Market (Auto)' is selected.

The layout and functionality of the rest of the Electricity Market window depends on the actual choice “Market Type” and choice of “Operation Strategy”. If “No Market” or “Flat Rate” are chosen the rest of the window is empty.

Figure 3: Electricity markets. Fixed tariffs selected as Market Type

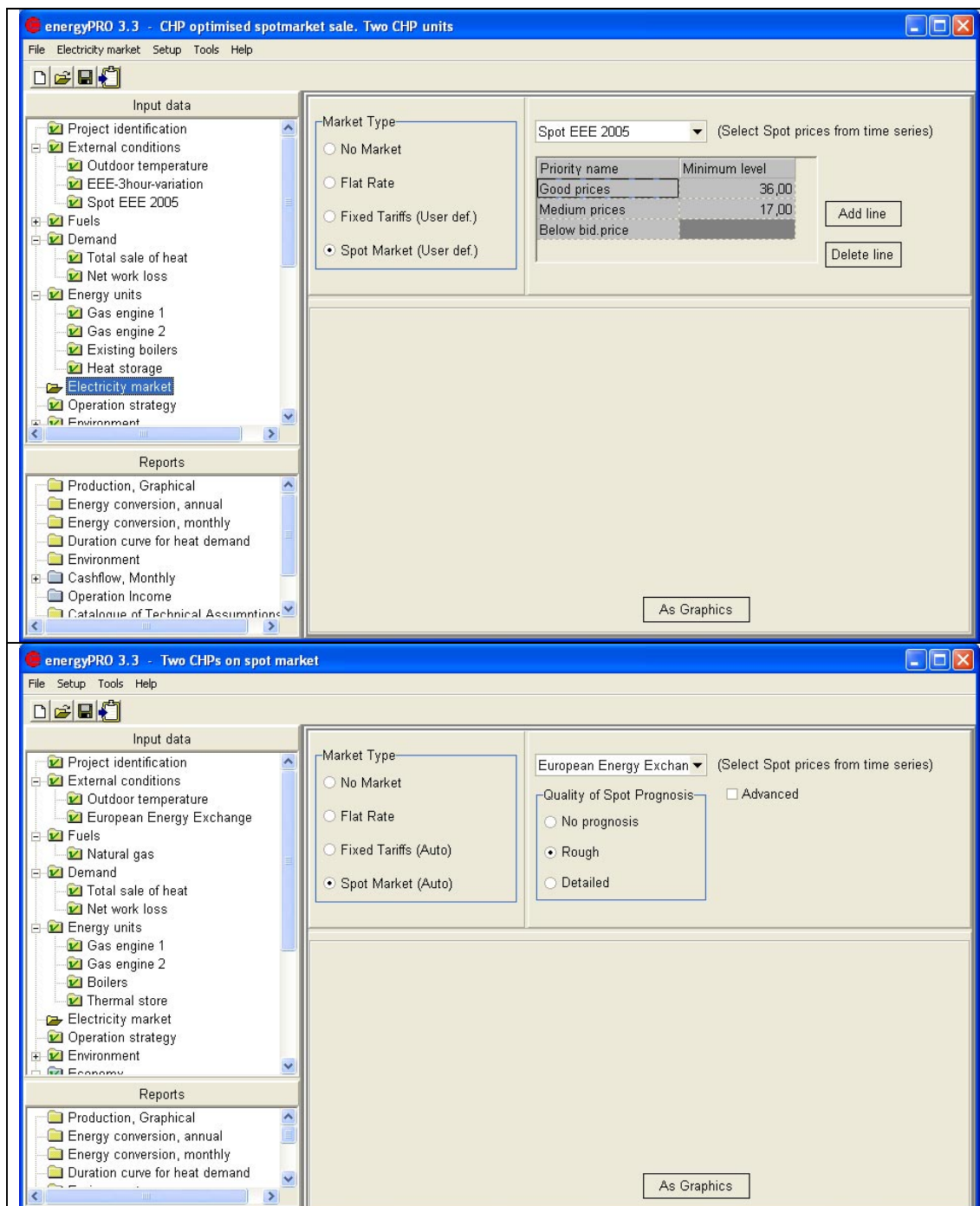
Figure 3 is a screenshot of the energyPRO 3.3 software interface. The title bar reads 'energyPRO 3.3 - Two CHPs on fixed tariffs, NPV of 15 years planning period'. The menu bar includes 'File', 'Electricity market', 'Setup', 'Tools', and 'Help'. The left sidebar shows a tree view of 'Input data' and 'Reports'. The 'Electricity market' window is active, showing 'Market Type' as 'Fixed Tariffs (Auto)'. To the right, there is a list of 'Priority name' entries: 'Winter hight', 'Winter med', 'Winter low', 'Summer', 'Rest', and 'Night'. Below this list are 'Add line' and 'Delete line' buttons. At the bottom of the window, there is a table with columns: 'From time', 'To time', 'From day', 'To day', 'Holidays', 'From date', 'To date', and 'Date'. The table contains six rows of data for the different priority periods. At the bottom of the window, there are 'Add line', 'Delete line', and 'As Graphics' buttons.

	From time	To time	From day	To day	Holidays	From date	To date	Date
Winter hight	16:00	19:00	Monday	Friday	Including	01-12	31-01	01-01-0
Winter med	16:00	19:00	Monday	Friday	Including	01-11	28-02	01-01-0
Winter low	08:00	20:00	Monday	Friday	Including	01-11	31-03	01-01-0
Summer	08:00	20:00	Monday	Friday	Including	01-04	31-10	01-01-0
Rest	07:00	00:00	Monday	Sunday	Including	-	-	01-01-0
Night								

If fixed tariffs is selected the rest of the information in the window is identical with the periods of priority in energyPRO 3.2 version. That is a list of the names of the tariff periods (to the right) and a definition of which time periods that belong to the tariff names (lower part of the window). For further information please refer to the energyPRO 3.2 Users Guide.

If “Spot Market” is chosen the rest of the window will change, see Figure 4.

Figure 4: Electricity markets. Spot Market selected as Market Type. Upper: Operation strategy selected as user defined. Lower: Automatic calculation of operation strategy.



In Figure 4 is shown the “Electricity market” window if “Spot Market” is chosen as Market Type. The upper part of the figure show the window as laid out if operation strategy is selected as user defined and the lower part shows window lay out if operation strategy is selected as automatic calculated operation strategy. Common for both is that they have to be based on a selected time series. Note that the time series first must be established as an element in the External conditions folder.

Figure 5: Defining “Spot market”. Left: Operation strategy is user defined. Right: Operation strategy is calculated automatically

The figure consists of two side-by-side screenshots of a software window titled 'Spot Market'.

Left Screenshot (User defined strategy): At the top, there is a dropdown menu set to 'Spot EEE 2005' with the text '(Select Spot prices from time series)'. Below this is a table with two columns: 'Priority name' and 'Minimum level'. The table contains three rows: 'Good prices' with a value of '36,00', 'Medium prices' with a value of '17,00', and 'Below bid price' with an empty cell. To the right of the table are two buttons: 'Add line' and 'Delete line'.

Right Screenshot (Automatic strategy): At the top, there is a dropdown menu set to 'European Energy Exchan' with the text '(Select Spot prices from time series)'. Below this is a section titled 'Quality of Spot Prognosis' with three radio buttons: 'No prognosis', 'Rough' (which is selected), and 'Detailed'. To the right of this section is a checkbox labeled 'Advanced' which is currently unchecked.

If the “User defined” operation strategy is selected a filter has to be set up to divide the selected time series into subgroups, se Figure 5 left. In this example the user has chosen to divide the Spot prices into three price groups. “Good prices”, “Medium prices” and “Below bid. Price”. Good prices are here all spot prices above “36,00”, medium prices are prices above “17,00” and under “36.00”. All prices below “17,00” belong to the group “Below bid. Price”.

On Figure 5 right, is shown how the Spot Market is defined, if the Operation strategy is chosen as auto calculated. Here it is possible to choose the “Quality of Spot Prognosis”, which basically decides how many subgroups the spot prices are divided into. Better quality means more subgroups.

To illustrate this see Figure 6, which shows the default values used for making subgroups. If “No prognosis” is selected, there will be no subdivision. If “Rough” or “Detailed” are chosen, there will be one price group containing the hours with the highest spot prices. In the default setting this is set to 5% (“Hours in peak price hours”). The rest of the hours are divided into a number of subgroups/price intervals. The default setting is 3 intervals in “Rough” prices and 6 intervals in “Detailed” Prognosis.

Figure 6: Defining “Spot market”, advanced setting

The screenshot shows the 'Spot Market' window with the 'Quality of Spot Prognosis' section expanded. The 'Advanced' checkbox is checked. Below the radio buttons, there are three input fields: 'Hours in peak price hours [%]' with a value of '5', 'Intervals in Rough Prognosis' with a value of '3', and 'Intervals in Detailed Prognosis' with a value of '6'.

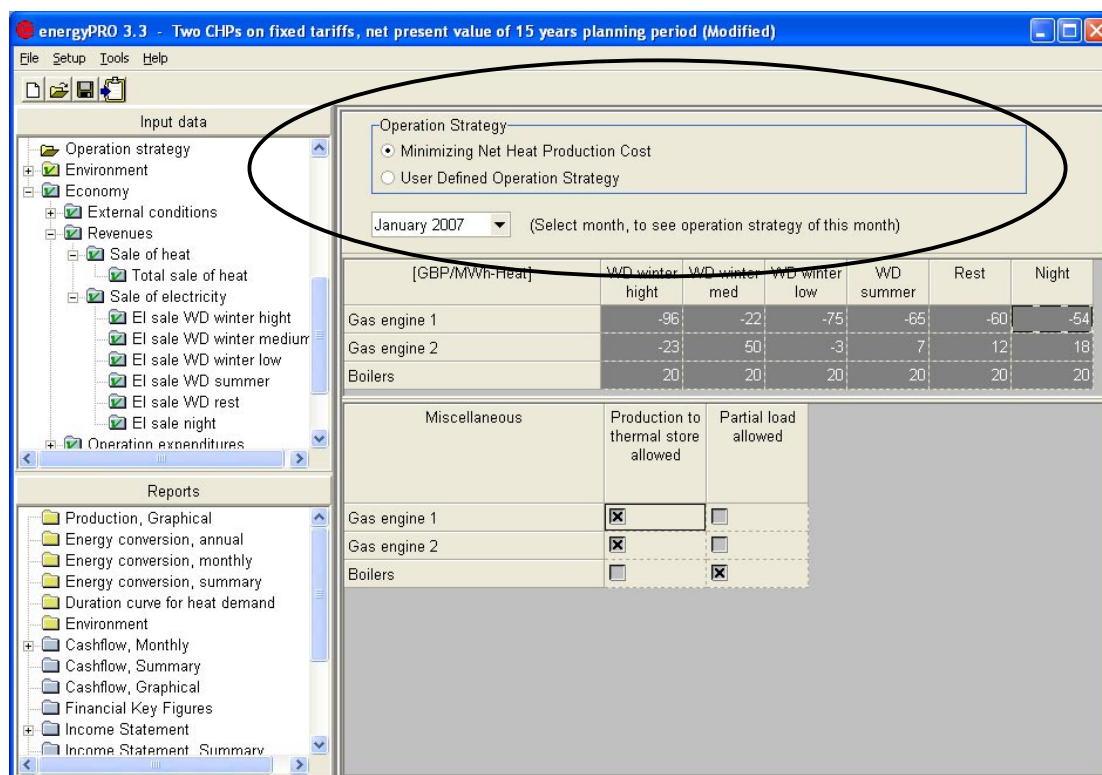
This division in subgroups will furthermore be supplemented with the electricity balance prices between boilers and CHP-units, independent on the quality of the spot prognosis.

1.2 Operation strategy window

The new Operation strategy window is shown in Figure 7. The main change is the new option for choosing between automatic calculation of operation strategy “Minimizing Net Heat Production Cost” and user defined “User defined Operation Strategy”.

The functionality of “User defined Operation Strategy” is identical with the functionality of the original energyPRO operation strategy found in versions prior to version 3.3.

Figure 7: Operation strategy. Selection of Operation strategy mode added



1.2.1 The operation strategy. Fixed tariffs.

Figure 8 shows an example of an operation strategy with auto calculated Net Heat Production Costs, in the matrix consisting of the tariff names and the production units. These values cannot be edited while “Minimizing net Heat Production Cost” is selected. Choosing “User defined operation strategy” hereafter will keep the calculated values and make the table editable.

Figure 8: Operation strategy table. Minimizing the net heat production cost. Fixed tariffs.

[GBP/MWh-Heat]	Winter high	Winter med	Winter low	Summer	Rest	Night
Gas engine 1	-23	-18	-3	7	12	1
Gas engine 2	-23	-18	-3	7	12	1
Boilers	20	20	20	20	20	2

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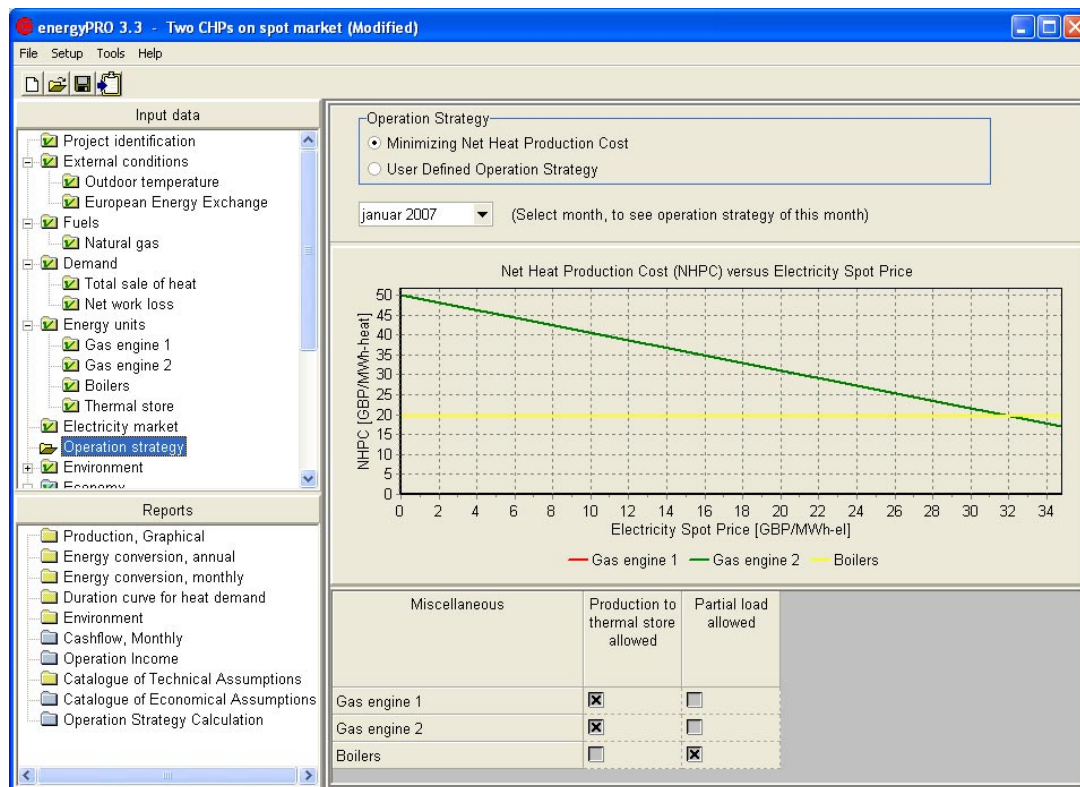
How is the Operation Strategy calculated?

The functionality of “Minimizing Net Heat Production Cost” is described in the next section.

1.2.2 The operation strategy. Spot prices.

If “Minimizing Net Heat Production Cost” is selected the operation strategy table is substituted by an graphic representation of the Net heat production cost for energy production units as function of the electricity spot prices.

Figure 9: The operation strategy window with Net Heat Production Cost shown as function of electricity spot prices



2. How is the Operation Strategy calculated?

The basic idea behind the automatic operation strategy calculations in energyPRO is that the net heat production costs are calculated for each production unit for all tariff periods. For instance, if there are six tariff periods, six prices for the net heat production costs are calculated one for each of the six periods. When afterwards calculating the energy conversion energyPRO first place as much production as possible on the production unit/tariff period combination with the smallest net heat production costs. Hereafter the production unit/tariff period with the second smallest net heat production cost will get as much production as possible, etc. This is done until all demands are met or the production opportunities are exhausted.

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How is the Operation Strategy calculated?

The calculation of the operation strategy is entirely based upon the “Revenues” and the “Operation expenditures” set up by the user to describe the Operation income¹. Therefore it is of crucial importance that these payments are set up properly, prior to the energy conversion calculation. The energy and economy calculation are tied together and will affect each other. The calculation strategy is calculated for each month in the planning period.

The methodology for calculating the operation strategy is an incremental approach where each of the heat-producing units is calculated as stand alone units producing 1 MWh-heat. In this calculation all the payments in “Revenues” and “Operation expenditures” are evaluated and calculated. The calculation is repeated for each production unit in each electricity tariff period.

This is the case for production units with heat production. In Figure 10 is shown the heat-producing units in energyPRO. This is CHP, Boiler, Electrical heat pump and User defined. Note that a “User defined” production unit need a heat production typed into the power curve.

Figure 10: Net Heat production costs are only calculated for Heat producing Production units.

Gas engine 1

Production unit type: User defined

Fuel type: CHP

Powerunit: Boiler

Electrical heat pump

Absorption Cooling

Electrical Cooling

User defined

☒ Annual non availability periods

#	From date	Time	To date	Time
1	09/01	00:00	17/01	00:00
2	01/02	00:00	09/02	00:00

Add line Delete line

Power curves

Operation Performance	Fuel [kW]	Heat [kW]	Elec. power [kW]	Elec. consump. [kW]	Cooling [kW]
Linear	5267.0	2114.0	2000.0	0.0	0.0

Add line Delete line ☐ Enable formulars in power curve

☐ Operation restricted to period

☐ Operation dependent on other unit

Absorption coolers are always set to a priority higher than all heat-producing units. Electrical coolers are always set to a priority lower than heat-producing units.

If a payment is the same in for all productions units in all tariff periods the payment is ignored. By other words fixed payments not related to the operation of production units are eliminated.

¹ See the energyPRO 3.2 manual for how to set up economy

In annex 1 is shown how the formulas, that may occur when describing the payments, are interpreted when being used to calculate the operation strategy.

When optimizing energyPRO calculates new operation strategies for every month. By selecting a month in the project period, the corresponding operation strategy is calculated and shown in the table as shown in Figure 11.

Figure 11: The operation strategy for an arbitrary month of the planning period can be selected

The screenshot shows the 'Operation Strategy' section with two radio buttons: 'Minimizing Net Heat Production Cost' (selected) and 'User Defined Operation Strategy'. Below this is a dropdown menu set to 'January 2007' with the instruction '(Select month, to see operation strategy of this month)'. A table displays the results for January 2007, with columns for '[GBP/MWh-Heat]', 'WD winter hight', 'winter w', 'WD summer', 'Rest', and 'Night'. The rows are 'Gas engine 1', 'Gas engine 2', and 'Boilers'. An arrow points from the 'January 2007' dropdown to the 'WD winter hight' column.

[GBP/MWh-Heat]	WD winter hight	winter w	WD summer	Rest	Night
Gas engine 1	-96	-75	-65	-60	-54
Gas engine 2		-3	7	12	18
Boilers	20	20	20	20	20

2.1.1 Limitations in use of the automatic calculation of Operation Strategy

There are two limitations in the use of the automatic calculation of the operation strategy. The first limitation is that use of formulas describing the power curves of the production units is not allowed. See Figure 12.

Figure 12: Automatic calculations of the operation strategy is not possible if formulas occur in the power curves for production units

Gas engine 1

Production unit type: CHP

Fuel type: Natural gas

Powerunit: kW

☒ Annual non availability periods

#	From date	Time	To date	Time
1	09-01	00:00	17-01	00:00
2	01-02	00:00	09-02	00:00

Add line Delete line

Power curves

Operation Performance	Fuel [kW]	Heat [kW]	Elec. power [kW]
Linear	min(2*HD1(_);	Min(HD1(_);5000)	Min(HD1(_)/0,5*0,4;4000)

Add line Delete line ☒ Enable formulars in power curve

☐ Operation restricted to period

☐ Operation dependent on other unit

The second limitation is if the process production option is enabled, as indicated on Figure 13.

Figure 13: Automatic calculations is not possible if the process production option is enabled

energyPRO 3.3 beta: - Two CHPs on fixed tariffs, net present value of 15 years planning period

File Setup Tools Help

Input data

- Project identification
- External conditions
 - Outdoor temperature
- Fuels
 - Natural gas
- Demand
 - Total sale of heat
 - Net work loss
- Energy units
 - Gas engine 1
 - Gas engine 2

Reports

- Production, Graphical
- Energy conversion, annual
- Energy conversion, monthly
- Energy conversion, summary
- Duration curve for heat demand
- Environment
 - Cashflow, Monthly
 - Cashflow, Summary
 - Cashflow, Graphical
 - Financial Key Figures
 - Income Statement

Project identification (4 lines maximum)

This example illustrates two CHPs operating under fixed tariffs based on British conditions. Planning period is set to 15 years. 1 GBP is approx. equal to 1.5 EUR

Assumptions to be printed in Catalogue of assumptions

Projecting

- DESIGN - calculating energy conversion in a specific year, including operational economics
- FINANCE - planning more years, including investments and financing
- ACCOUNTS - plus income statements, balance sheets and tax

Optimizing Daily operation

- OPERATION - optimizing operation for a short period

Adding supplementary calculation modules

- REGION - regional energy planning

☒ Advanced

- ☒ Transmission of heat from plant through both high and low temperature pipes
- ☐ Starting up of production units are slow and expensive

3. Report Operation Strategy Calculation

There has been added a new report “Operation Strategy Calculation”. This report shows the calculation of the operation strategy in details. The report is invoked by clicking the Operations Strategy Calculation folder in the Reports tree view, shown in Figure 14. Then choose the month to be shown (Figure 15).

Figure 14: Selecting Operation Strategy Calculation

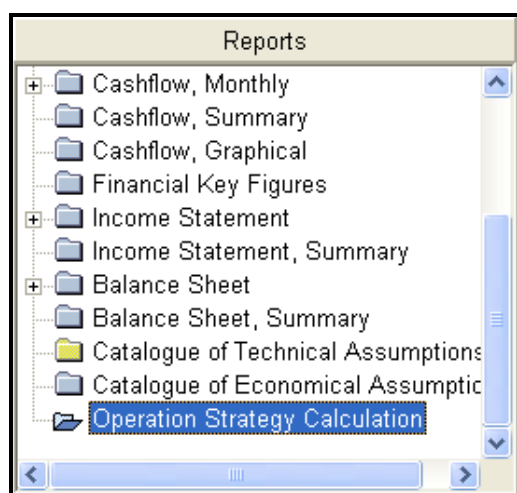
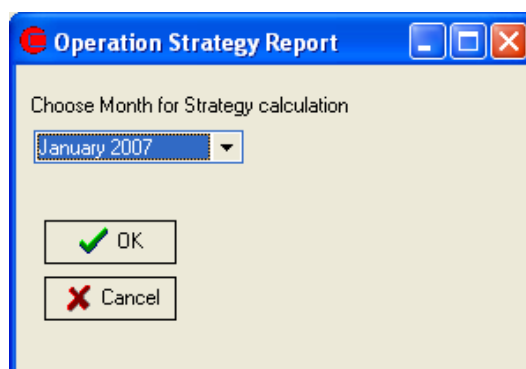


Figure 15: Selecting a month for the Report



Hereafter a report will appear. An example is shown on Figure 16.

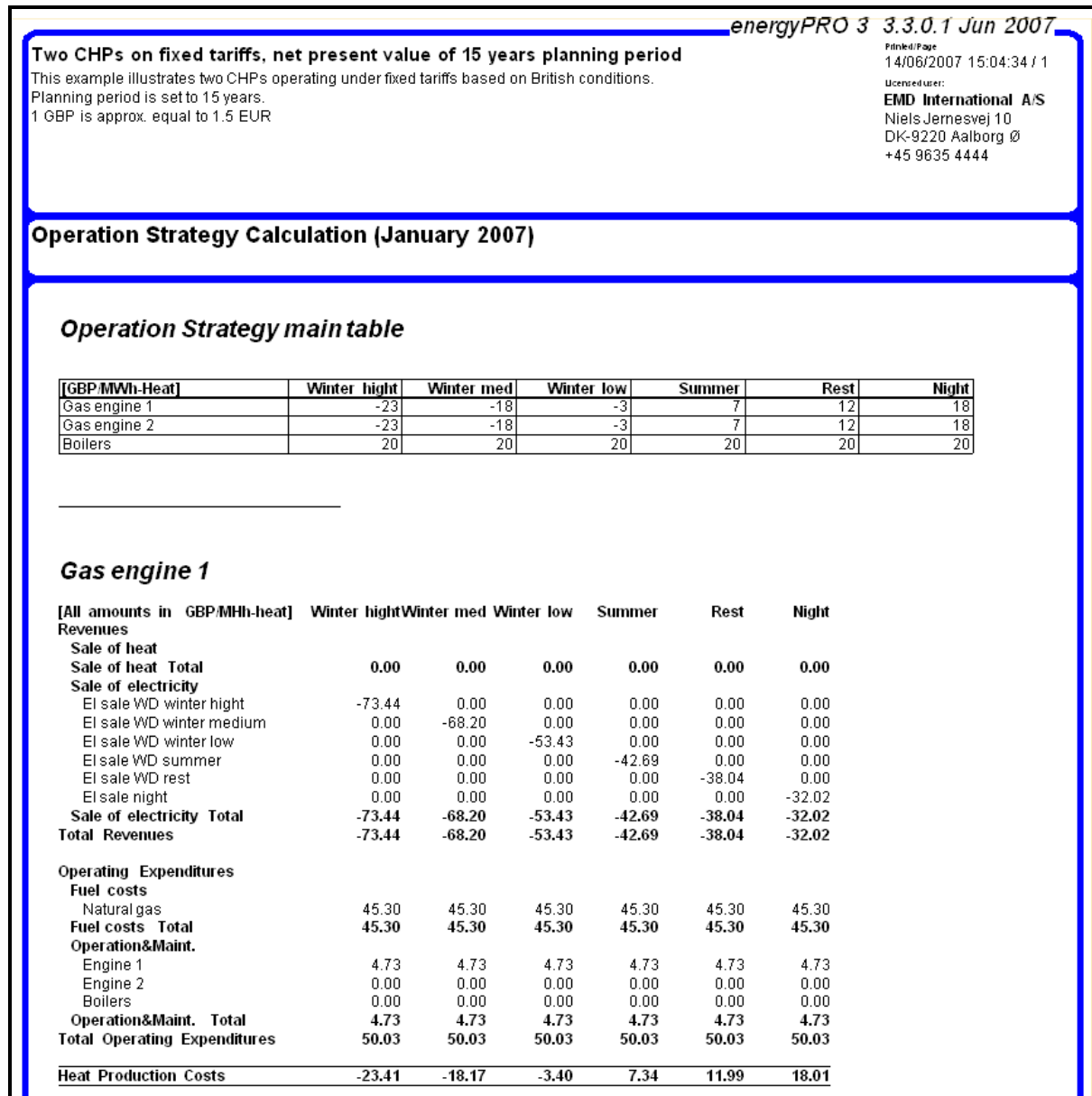
The report starts with a main table containing the calculated Operation Strategy. The value in this table is identical with the values found in the Operation Strategy window.

Hereafter follows tables with detailed calculation results for each production unit. Each table contain the calculation of the net heat production costs in all tariff periods.

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

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Figure 16: Operation strategy calculation an example



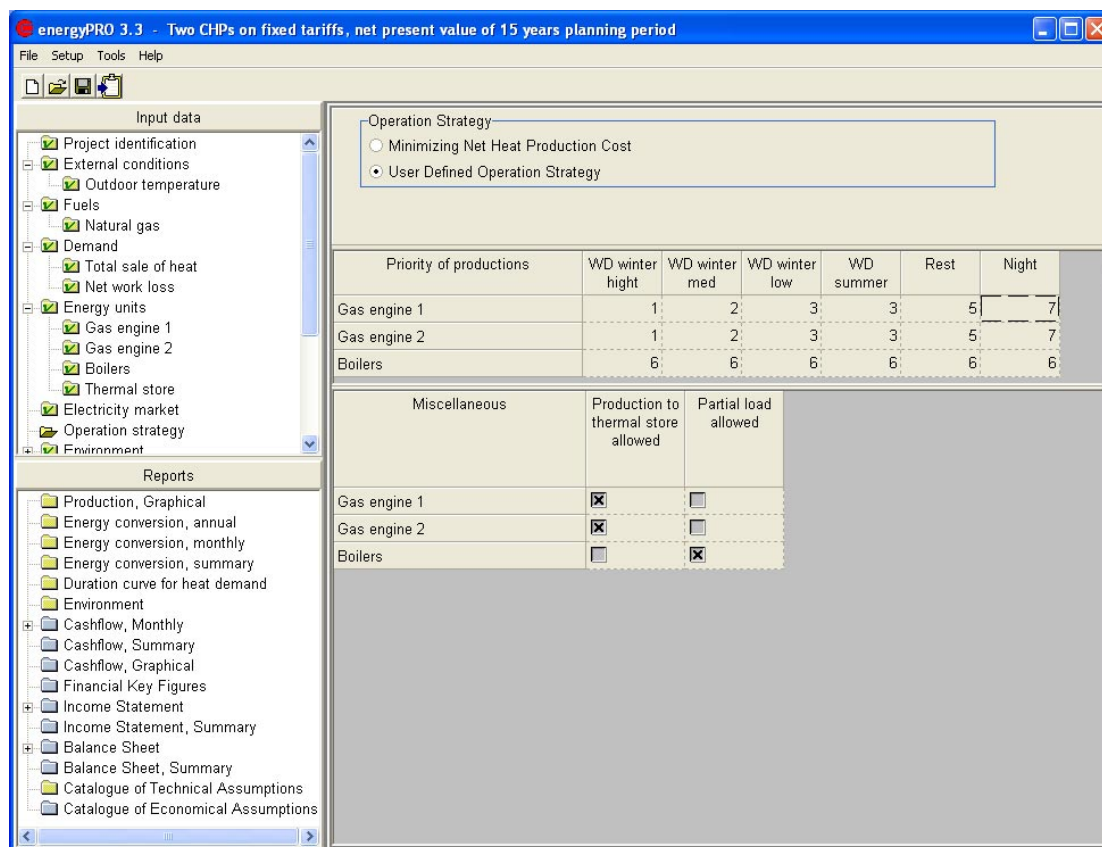
4. New and Existing energyPRO-projects

Existing energyPRO projects are basically unaffected of the changes. There might be small variations in calculation results due to the change from annual to monthly optimization, when comparing results calculated in the old 3.2 version and the present 3.3 version.

4.1 Fixed tariffs or Spot market selected in Electricity Market

Existing energyPRO projects (prior to version 3.3) is automatically set in user-defined mode in the Operation Strategy window. This setting is equivalent to Operations strategy functionality used up till now in energyPRO, shown in Figure 17.

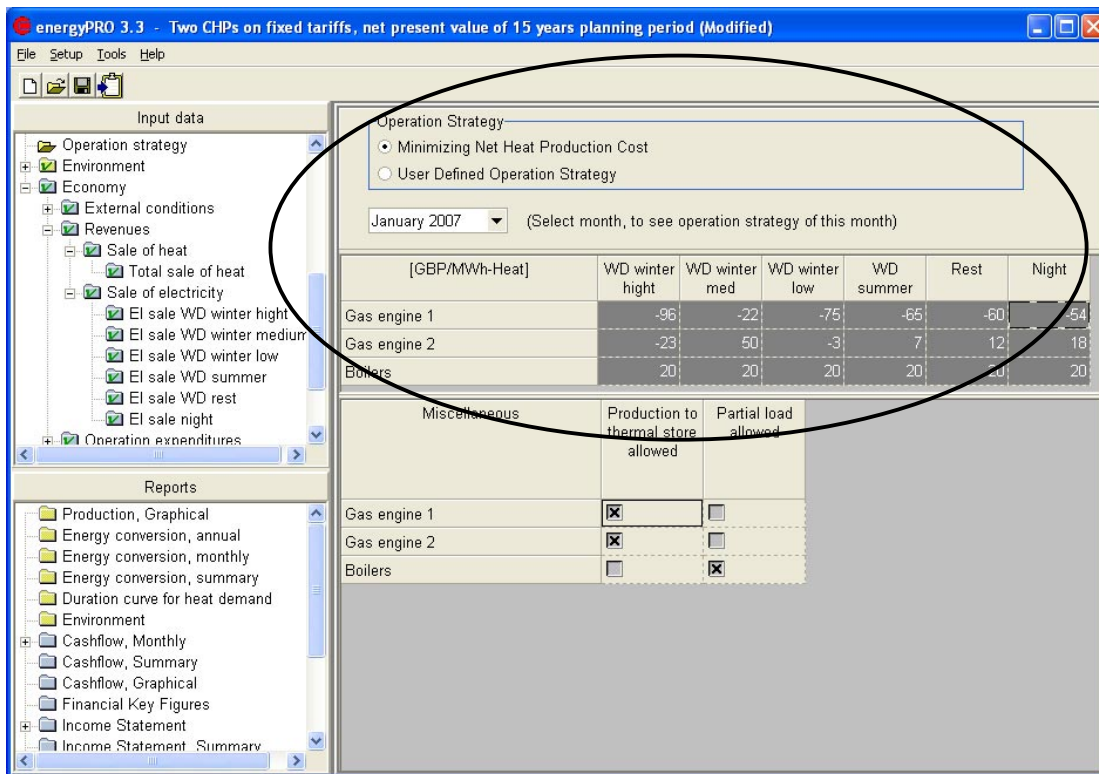
Figure 17: Operations strategy. In existing energyPRO projects the operation strategy is automatically set to User defined



If the Operation Strategy is changed to “Minimizing Net Heat Production” the “Priority of Productions” table is changed. Firstly, the table name is changed to “<Currency>/MWh-heat” (example “£/MWh-heat”). Secondly, the values in this table are substituted by the calculated net heat production cost for the production units in the respective tariff periods (first month in calculation period). Hereafter it is not possible to edit the table values.

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Figure 18: Operations strategy. If “Minimizing Net Heat Production Cost” is selected the Operation strategy is shown for the first month of the year.



4.2 New energyPRO-projects

The Operation Strategy mode is as default set to “Minimizing Net Heat Production Costs”.

Annex 1: Interpretation of formula functions in “Revenues” and “Operations expenditures”, being used calculate the operations strategy

Function (Economy functions)	Formular (Power curve values)	Comments
Systemlevel functions	0	
AccDeliveredElectricity	0	
AccReceivedElectricity	0	
AccReceivedFuel	0	
APeakDeliveredElectricity	0	
APeakReceivedElectricity	0	
DeliveredElectricity	0 $1/\text{HeatProd} \cdot \text{EIProd}$	Electricity demand exists No electricity demand exists
PeakDeliveredElectricity	0	
PeakReceivedElectricity	0	
PeakReceivedFuel	0	
ReceivedElectricity	0 $1/\text{HeatProd} \cdot \text{EIProd}$	Electricity demand exists No electricity demand exists
ReceivedFuel	$1/\text{HeatProd} \cdot \text{FuelCon}$	
Production unit level functions		
AccEP	0	
CD	0	
CoolingProduction	$1/\text{HeatProd} \cdot \text{CoolProd}$	
EC	$1/\text{HeatProd} \cdot \text{EICon}$	
ED	0	
ElectricCapacity	0	
EP	$1/\text{HeatProd} \cdot \text{EIProd}$	
FC	$1/\text{HeatProd} \cdot \text{FuelCon}$	
HC	$1/\text{HeatProd} \cdot \text{HeatCon}$	
HD	0	
HoursOfOperation	$1/\text{HeatProd}$ $1/\text{HeatProd} \cdot 1000$	Powercurve unit in MW Powercurve unit in kW
HP	1	
PeakElecLoadAnnual	0	
PeakElectricDemand	0	
PHD	0	
Turnons	0	
Other		
HeatValue	Unchanged	
UnitOfDemand	Unchanged	
Month	Unchanged	
Index,	Unchanged	
Indeksfaktor	Unchanged	
TSMean,	Unchanged	
Spotpricefunctions		
PeriodsOfPriorityXDeliveredElectricity	0	Old subst. by SpotpricesXDeliv.....
PeriodsOfPriorityXReceivedElectricity	0	Old subst. by SpotpricesXReceiv...
PoPxDE	0	Old subst. By SPxDE
PoPxRE	0	Old subst. By SPxDE
SpotPricesXDeliveredElectricity	0	
SpotPricesXReceivedElectricity	0	
SPxDE	0	
SPxRE	0	

Where:

Heatprod = Heat production capacity
ElPprod = Electricity production capacity
CoolProd = Cooling Production capacity
ElCon = Electricity consumption capacity
FuelCon = Fuel consumption capacity

All in [MWh] or [kWh]

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