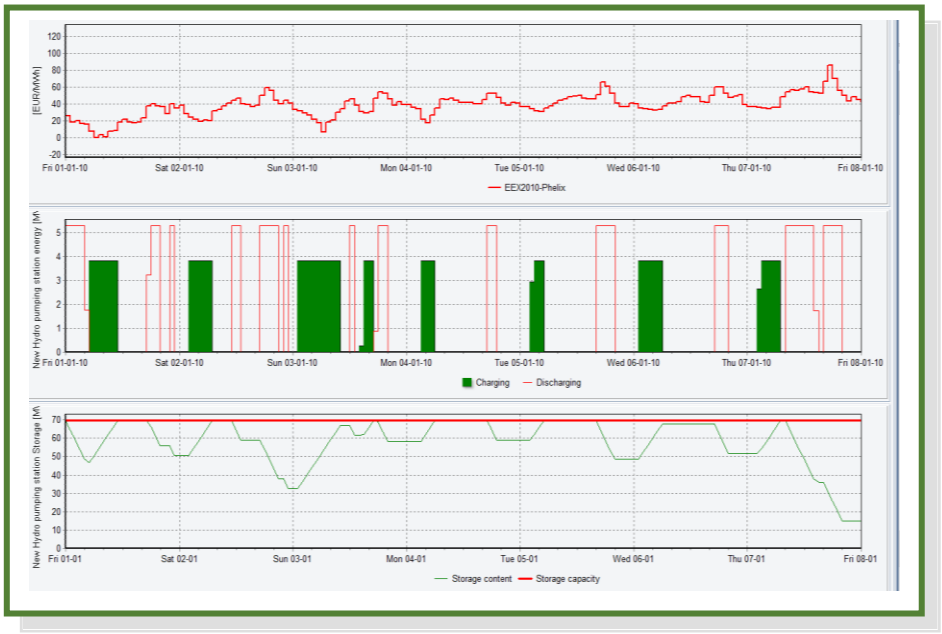
HOW TO GUIDE

Optimisation of an electricity storage in an electricity market



Software for techno-economic analyses of energy projects

EMD
www.emd.dk

Preface

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 accepted by international banks and funding institutions. The software enables the user to calculate and produce a report for 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

EMD International A/S, November 2013

Content

1. Introduction

This 'How to Guide' details how to use energyPRO for optimisation of a pumped-storage hydroelectric station in an electricity spot market, such as the EPEX or Nord Pool Spot market. The descriptions in this guide have been made using the DESIGN module and the guide is for users, who have already a basic understanding of energyPRO.

Through this guide you will learn:

- How to load electricity market prices into energyPRO (Chapter 2. Setting up the electricity market).
- How to add a pumped-storage hydroelectric station (or hydro pumping station) with revenues and expenditures (Chapter 3. Setting up a pumped-storage hydroelectric station).
- How to analyse the results of an energyPRO project (Chapter 4. Analysing the results of the model).

If you are in need of more detailed information regarding the elements described in this 'How to Guide' please refer to the energyPRO User's Guide found here: www.emd.dk/energyPRO/Downloads/

2. Setting up the electricity market

Firstly, it is important to define the period of the modelling. In this guide the year 2010 will be used as the modelling period. To set up the modelling period open "External conditions" as shown on Figure 1.

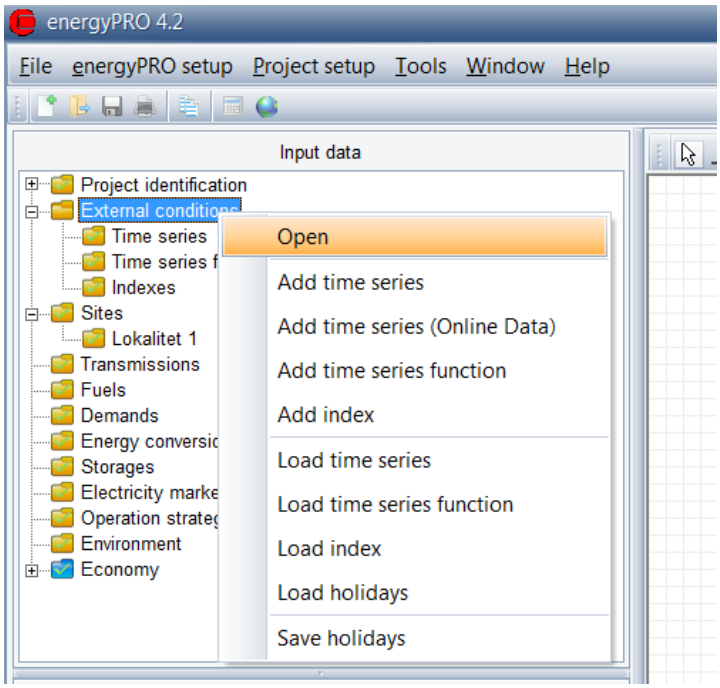


Figure 1. Setting up the modelling period

This brings up a menu where it is possible to set the "Planning period" which is the period modelled in the project. In this guide the used planning period is from "01-01-2010" to "31-12-2010" corresponding to the entire year of 2010.

With the period set it is relevant to define the prices on the electricity market. In this guide the prices on the EPEX Spot in the price area Phelix (Germany/Austria) will be used. EPEX Spot is a spot market for electricity where the price changes on an hourly basis and the price on this market is hereby defined by a time series with hourly values. To add a time series with the prices from an electricity market, the user can ei-

ther browse the folder called “energyPRO data”[1] where price data from several electricity markets are available, or the user can add other price data if needed. See “Annex: Import data from a spreadsheet to a time series” for more on importing other price data into a time series in energyPRO.

In this guide a time series with electricity prices from the “energyPRO data” folder will be used. To add this time series, right-click the folder called “Time series” under “External conditions”, and choose “Load time series”, as shown on Figure 2.

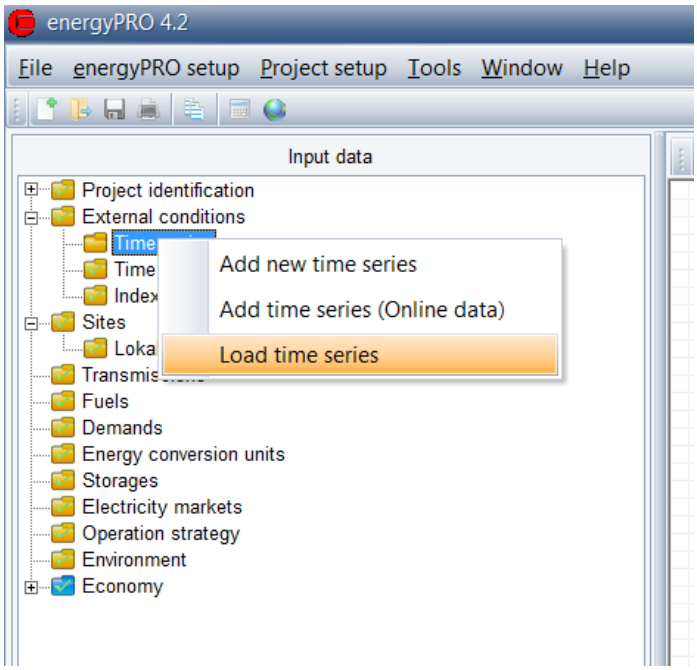


Figure 2. Loading a time series into energyPRO

From here navigate to the file EEX2010-Phelix.epw found in the energyPRO data folder (assumed installed in the C: drive): C:\energyPRO data\English\External conditions\Electricity market prices\ and select the file and press “Open”. This will add the time series to your energyPRO project.

Now that the prices are added to the project it is time to add the electricity market. This is done by right-clicking the “Electricity markets” and choose “Add new electricity market” and “Spot Market” as seen on Figure 3.

[1] By default the folder’s location are C:\energyPRO data.

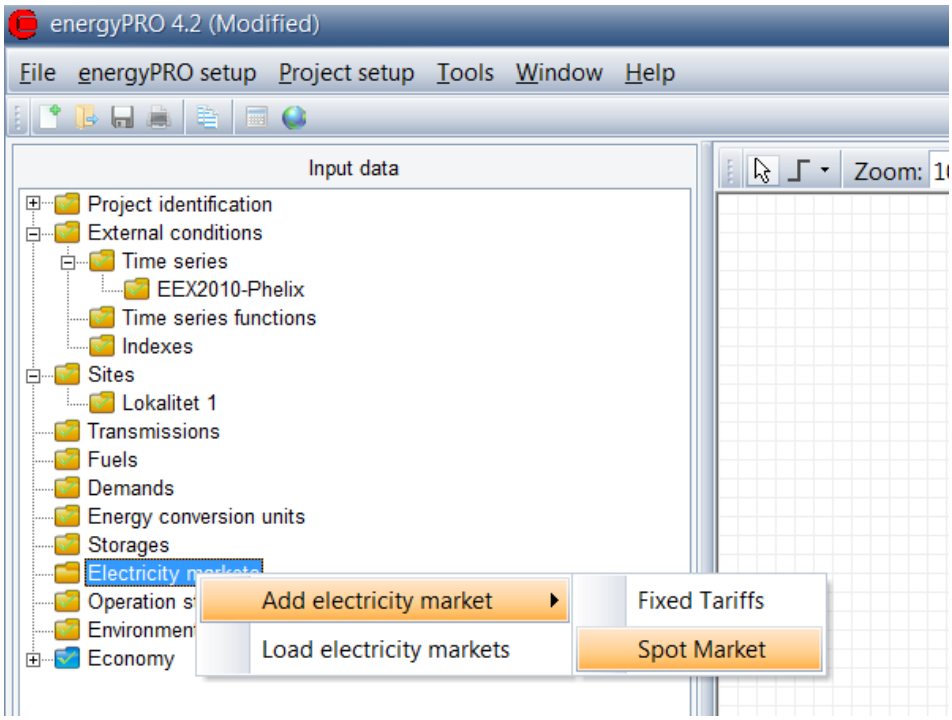


Figure 3. Adding an electricity market in energyPRO

Name the added electricity market an appropriate name, e.g. EEX2010-Phelix by right-clicking on the folder, and open it. Subsequently double-click on the added electricity market-folder. This will make it possible to choose the time series with the spot market prices added earlier. Choose the time series on the left side and, and press “OK”. The time series on the right will automatically adjust according to the chosen one as pictured on Figure 4.

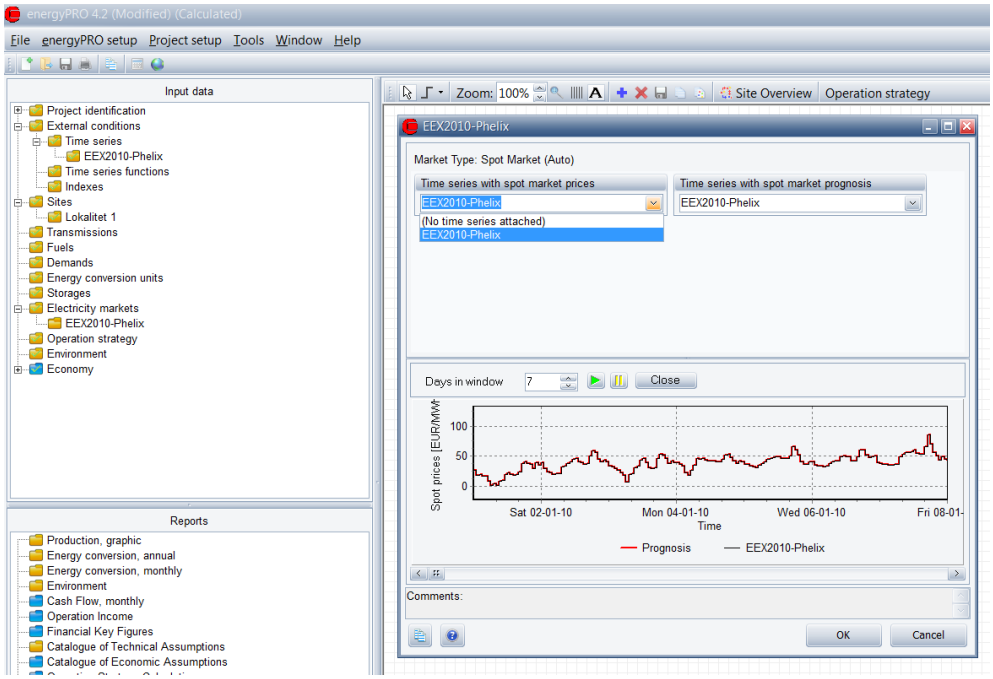


Figure 4. Choosing time series

Now an electricity market is added with the prices from EPEX Spot market for the price area Phelix (Germany/Austria) in 2010.

3. Setting up a pumped-storage hydroelectric station

With the electricity market set up it is time to add the pumped-storage hydroelectric station (or hydro pumping station). To add this right-click “Storages”, choose “Add electrical storage” and “Add hydro pumping station”, as shown below on Figure 5.

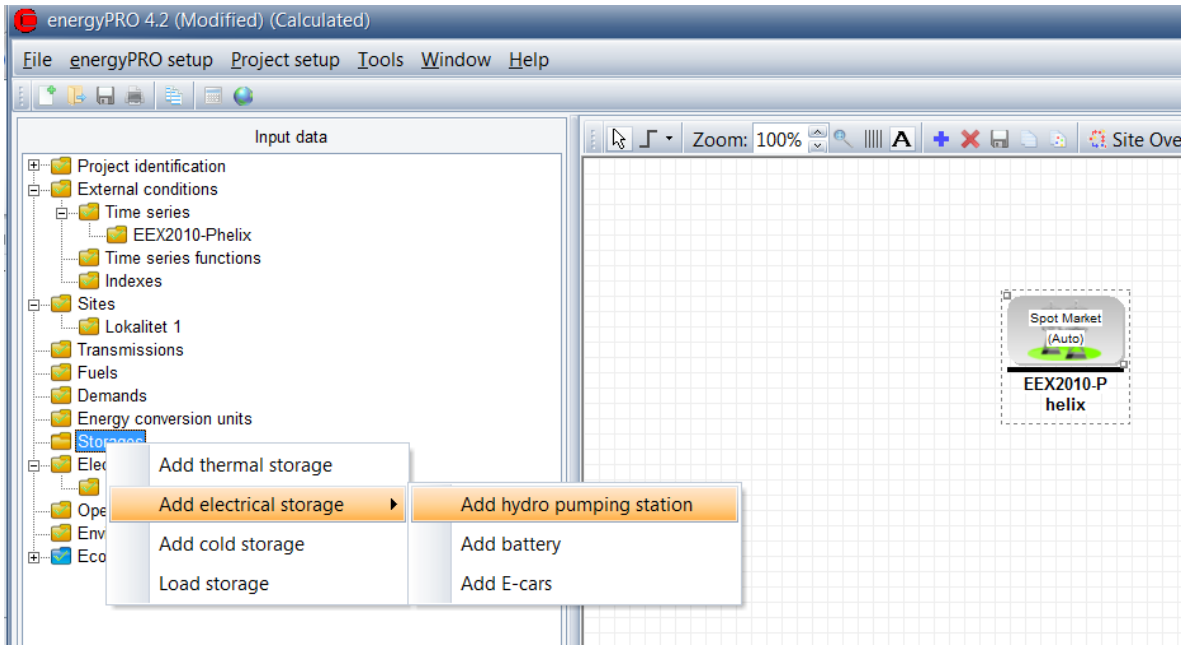


Figure 5. Adding a hydro pumping station in energyPRO

This will add a hydro pumping station to the project.

If in the “Graphical User Mode” you will notice that graphically this storage has been placed on top of the electricity market. To rearrange these icons either move the icons around by clicking them and dragging them with the mouse, or simply click the “Auto Arrange All Items” button as shown on Figure 6.[2]

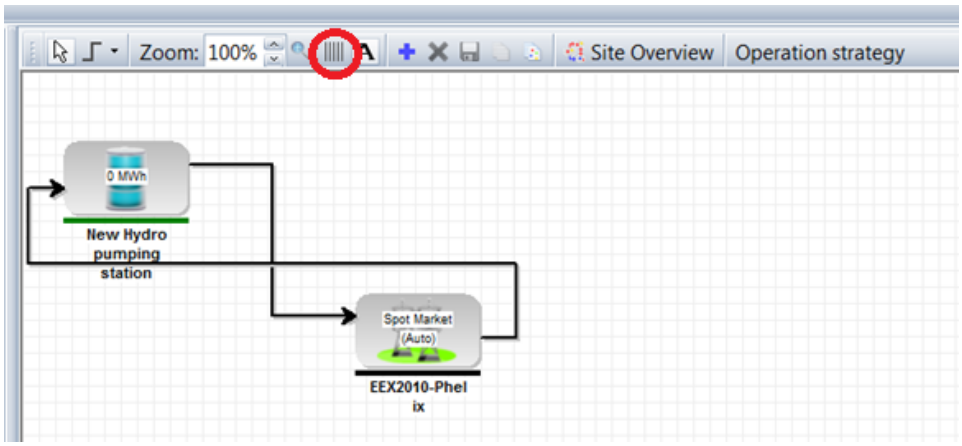


Figure 6. Auto arrangements of items in graphical user mode

By default the hydro pumping station have a capacity of 0. To change this simply open the hydro pumping station by double-clicking on the logo or on the “Hydro pumping station”-folder, and type in the relevant values according to the Figure 7 below.

[2] If the hydro pumping station is added by right-clicking in the graphical user interface, then the hydro pumping station will be placed at that position, and not in the top left corner.

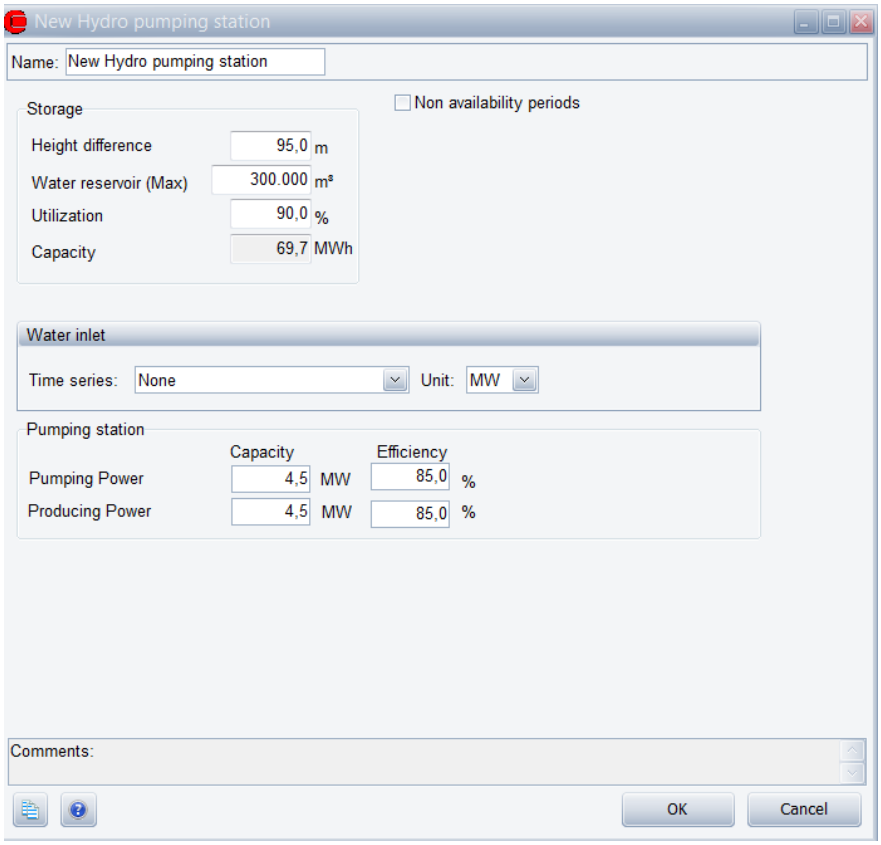


Figure 7. Where to type in the relevant values for the hydro pumping station

Looking at the setup of the hydro pumping station there are two overall parts. These are the storage capacity and the pumping/producing capacity. The storage capacity is defined by the height difference between the two reservoirs, the volume of the upper water reservoir and an utilization percentage. The pumping capacity defines at what rate the storage can be filled up, and the producing capacity defines at what rate it can be discharged. In this guide the hydro pumping station are modelled using the values as shown above and without any water inlet. Water inlet is water flowing to the storage such as a creek and thus not included in the water pumped to the storage.

After the hydro pumping station has been added it is time to add the revenues and expenditures. Firstly the currency has to be defined. This is done by opening the “Economy” folder, as can be seen on Figure 8.

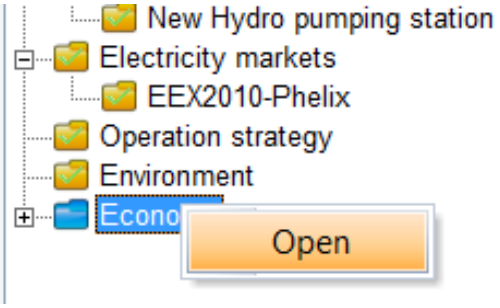


Figure 8. Adding revenues and expenditures to the project

In here write the name of the currency. In this guide EUR is used.

Figure 9. Define currency for the project

Hereafter it is time to add the different revenues and expenditures. First add the revenue from selling electricity to the EPEX Spot market. This is done by right-clicking revenues and pressing “Add payment”, as shown on Figure 10.

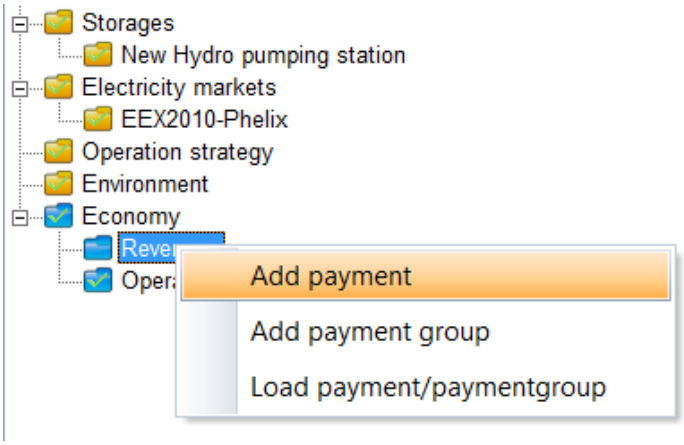


Figure 10. How to add a revenue

Give the added revenue a descriptive name, e.g. Sold electricity, and open it by double-clicking on the folder. Under “Payment concerns” choose “Exported electricity” and mark the checkbox “Spotmarket payment”, as shown on Figure 11 and press “OK”. This revenue line will now register the income from selling electricity to the spot market using the price time series defined in the electricity market.

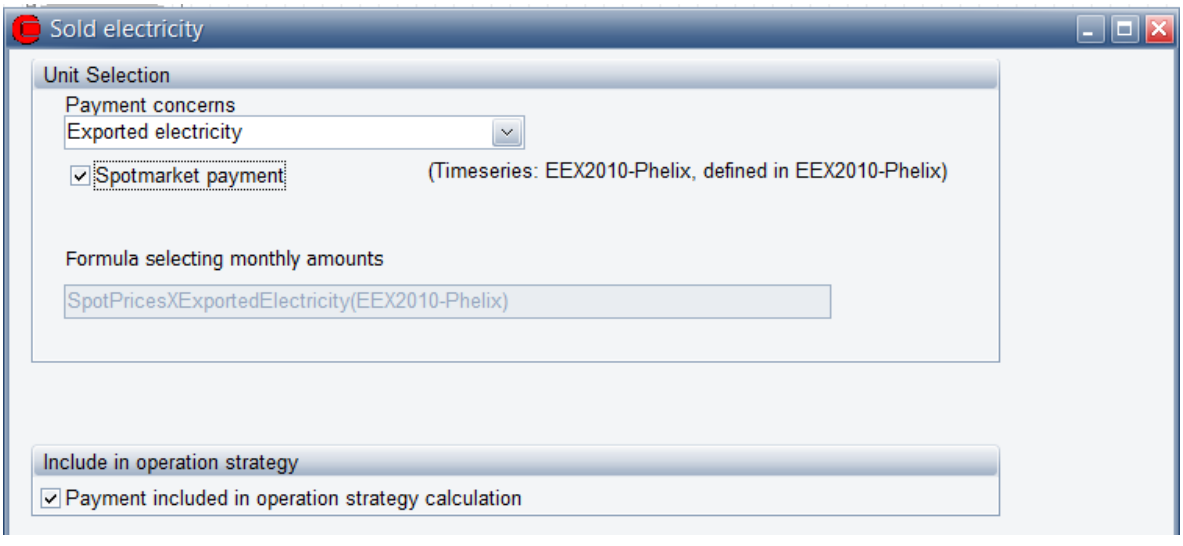


Figure 11. How to register an income from selling of electricity

To add the payment for buying electricity from the spot market, right-click “Operation expenditures” and choose “Add payment” as shown below on Figure 12.

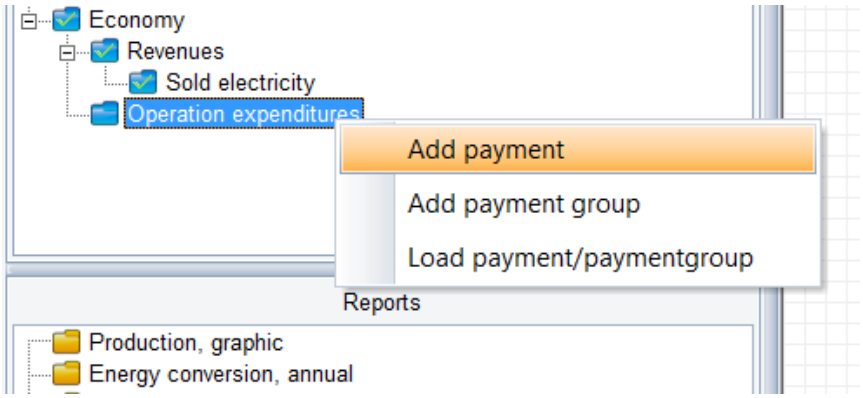


Figure 12. How to add an expenditure

Again, give the payment a descriptive name and open it. Under “Payment concerns” choose “Imported electricity” and mark the checkbox for “Spotmarket payment”.

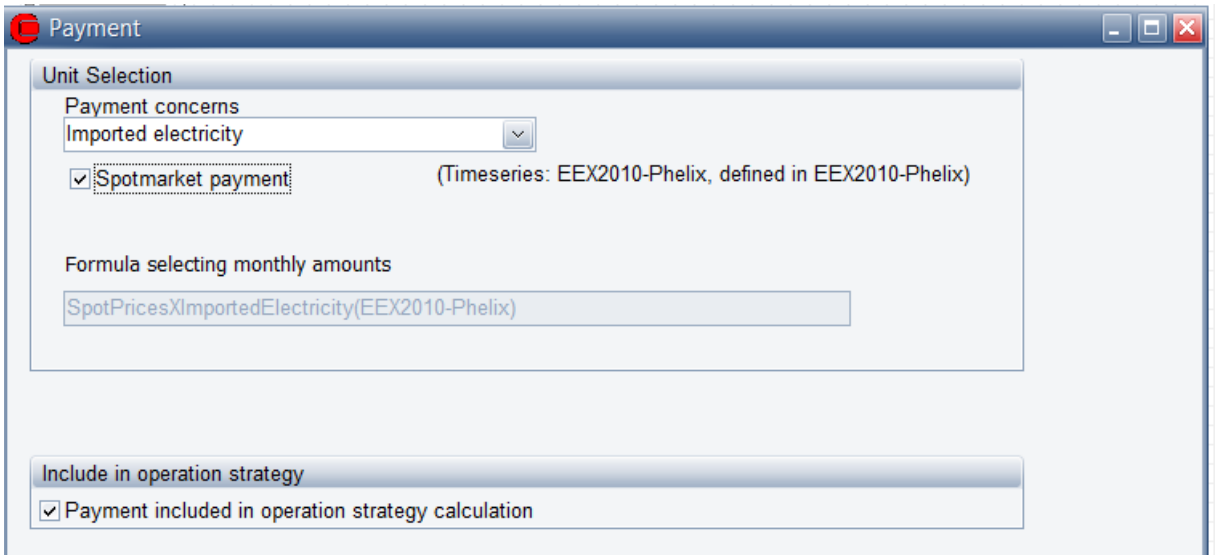


Figure 13. How to register a cost of selling electricity

Now the payment for buying and selling electricity from the electricity market has been modelled.

Besides payments concerning the electricity market it is also relevant to model a production dependent operation and maintenance (O&M) cost for using the hydro pumping station. In order to define this, add a new payment under “Operation expenditures”. In this model the O&M cost will be added when exporting the electricity from the storage. Therefore under “Payment concerns” choose “Exported electricity” and set a “Price per Unit”, e.g. 2 EUR/MWh as shown on Figure 14.

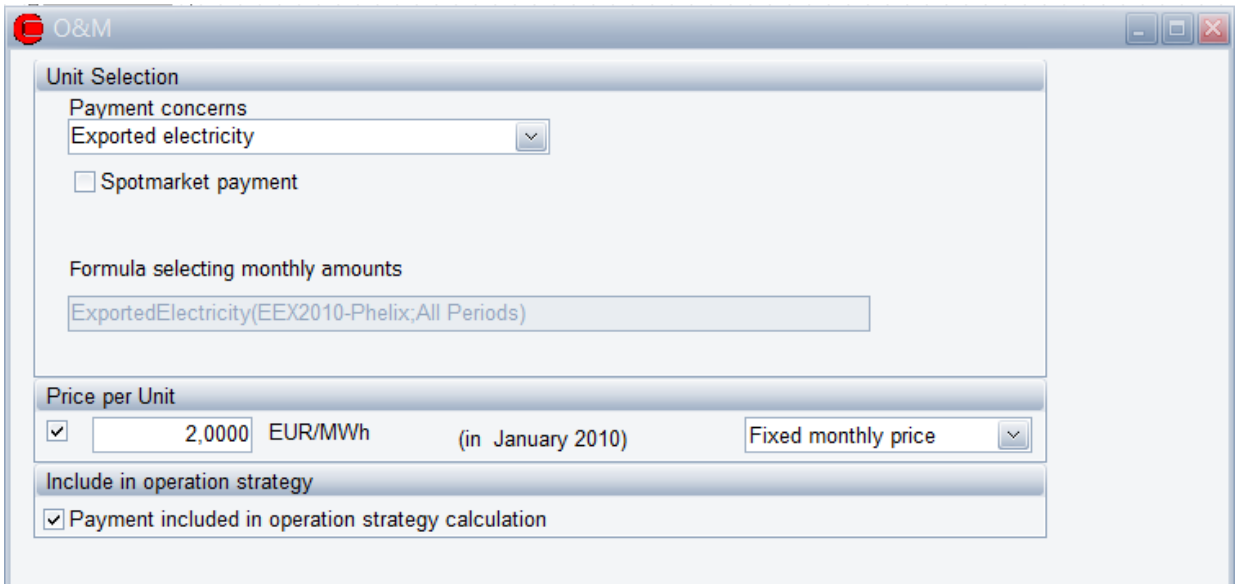


Figure 14. Adding operation and maintenance costs

More payments could be added if needed, but in order to keep the guide simple these are sufficient. So now that both the electricity market and the hydro pumping station are clearly defined it is time to let energyPRO do the optimisation.

4. Analysing the results of the model

There are several ways of examining and analysing the results of an energyPRO calculation. In this guide only the reports “Production, graphic”, “Energy conversion, annual” and “Operation Income” will be shown. To run an energyPRO calculation, simply click any of the desired reports.

The report “Production, graphic” shows the detailed hour-by-hour usage of the hydro pumping station, where the storage content is shown for all hours in period, alongside the price on the electricity market, as shown below on Figure 15.

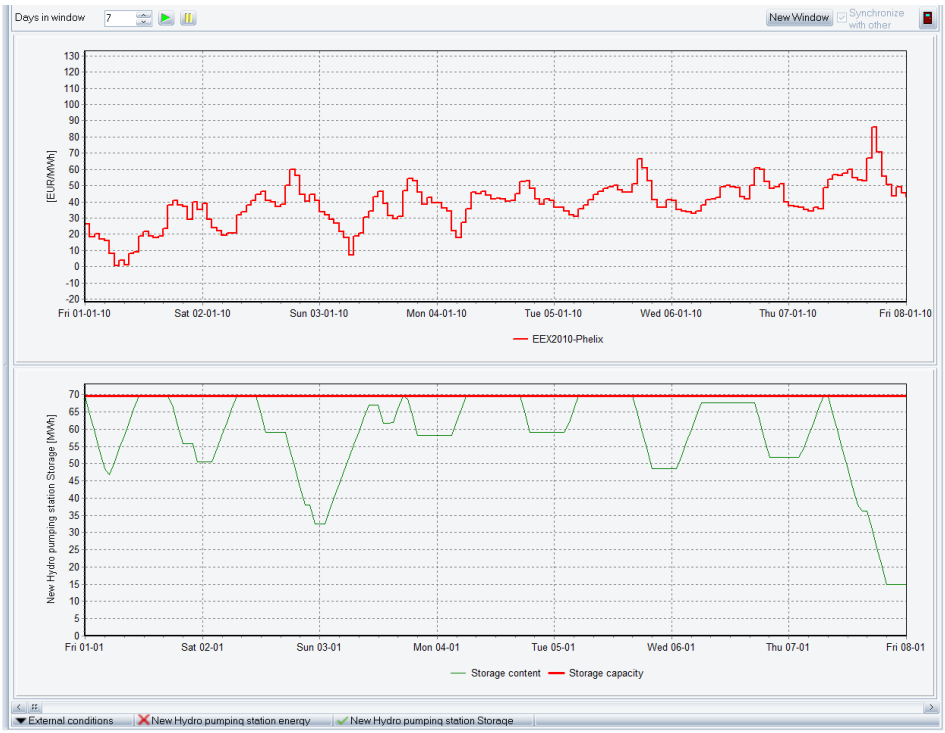
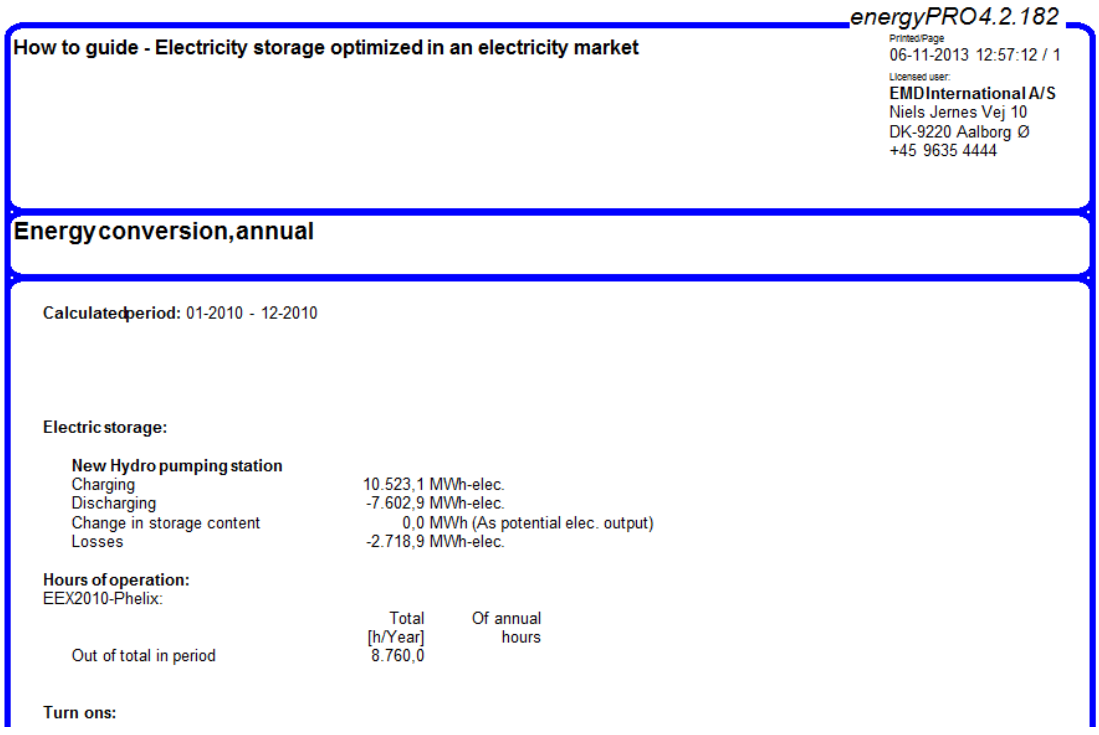


Figure 15. Graphic illustration of the production

This report makes it possible to make detailed assessments of an energyPRO calculation. In this example the report shows that the hydro pumping station fills up the storage in hours with low electricity prices and sells it again when the price is high.

The yearly energy charging and discharging of the hydro pumping station can be seen in the report "Energy conversion, annual" as can be seen on Figure 16.



energyPRO4.2.182

How to guide - Electricity storage optimized in an electricity market

Printed/Page
06-11-2013 12:57:12 / 1

Licensed user:
EMD International A/S
Niels Jernes Vej 10
DK-9220 Aalborg Ø
+45 9635 4444

Energy conversion, annual

Calculated period: 01-2010 - 12-2010

Electric storage:

New Hydro pumping station

Charging	10.523,1 MWh-elec.
Discharging	-7.602,9 MWh-elec.
Change in storage content	0,0 MWh (As potential elec. output)
Losses	-2.718,9 MWh-elec.

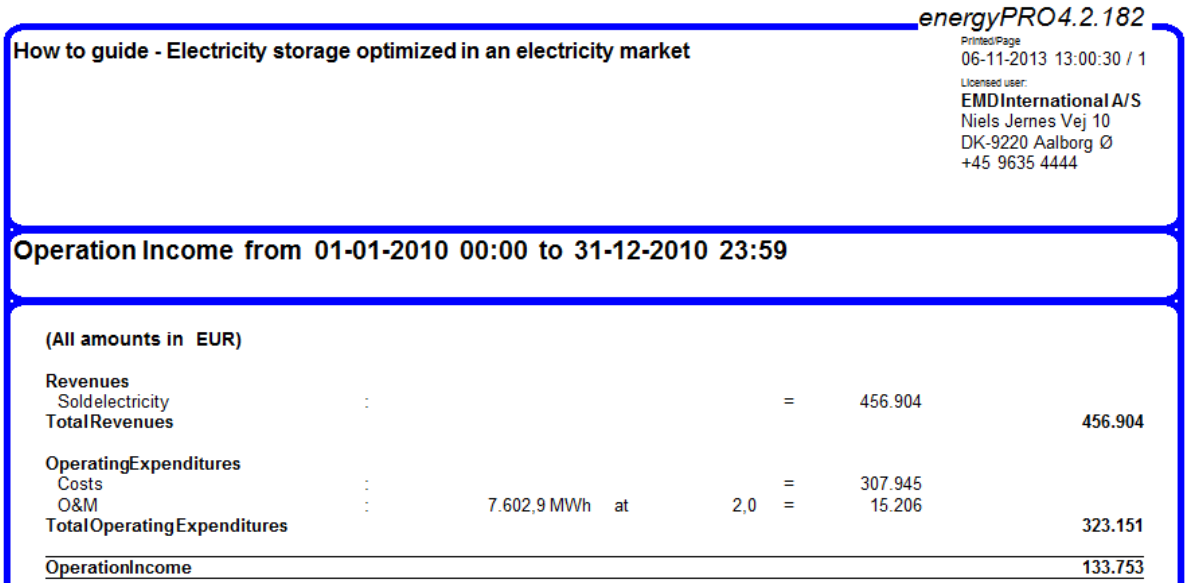
Hours of operation:
EEX2010-Phelix:

	Total [h/Year]	Of annual hours
Out of total in period	8.760,0	

Turn ons:

Figure 16. Report showing the annual energy conversion

In order to see the economic result of the optimization in the spot market, the report “Operation income” is useful. This report shows all the revenues and operation expenditures throughout the modelled period and calculates the total operation income. On Figure 17 is shown the “Operation income” report for the energyPRO project described in this ‘How to guide’. Here it is found that the operation income of optimized use of the hydro pumping station in the EPEX Spot marked in 2010 is 133,753 EUR with the used costs.



energyPRO 4.2.182

Printed/Page
06-11-2013 13:00:30 / 1

Licensed user:
EMD International A/S
Niels Jernes Vej 10
DK-9220 Aalborg Ø
+45 9635 4444

How to guide - Electricity storage optimized in an electricity market

Operation Income from 01-01-2010 00:00 to 31-12-2010 23:59

(All amounts in EUR)

Revenues							
Sold electricity	:				=	456.904	
Total Revenues							**456.904**
Operating Expenditures							
Costs	:				=	307.945	
O&M	:	7.602,9 MWh	at	2,0	=	15.206	
Total Operating Expenditures							**323.151**
Operation Income							**133.753**

Figure 17.Report showing the annual energy conversion

5. Annex: Import data from a spreadsheet to a time series

To import data from a spreadsheet into a time series in energyPRO it is very important to use a format for date and time that can be recognized by energyPRO. The format will depend on the settings on the particular computer. The simplest way of doing so is to start from the time series in energyPRO and copy the format from here. In this annex it is shown how a time series of the ambient temperature can be added, however the method is similar for electricity market prices.

First create a time series for e.g. the ambient temperature under ‘External conditions’. Type in the date and time of the first instance in line #1 as shown on Figure 18.

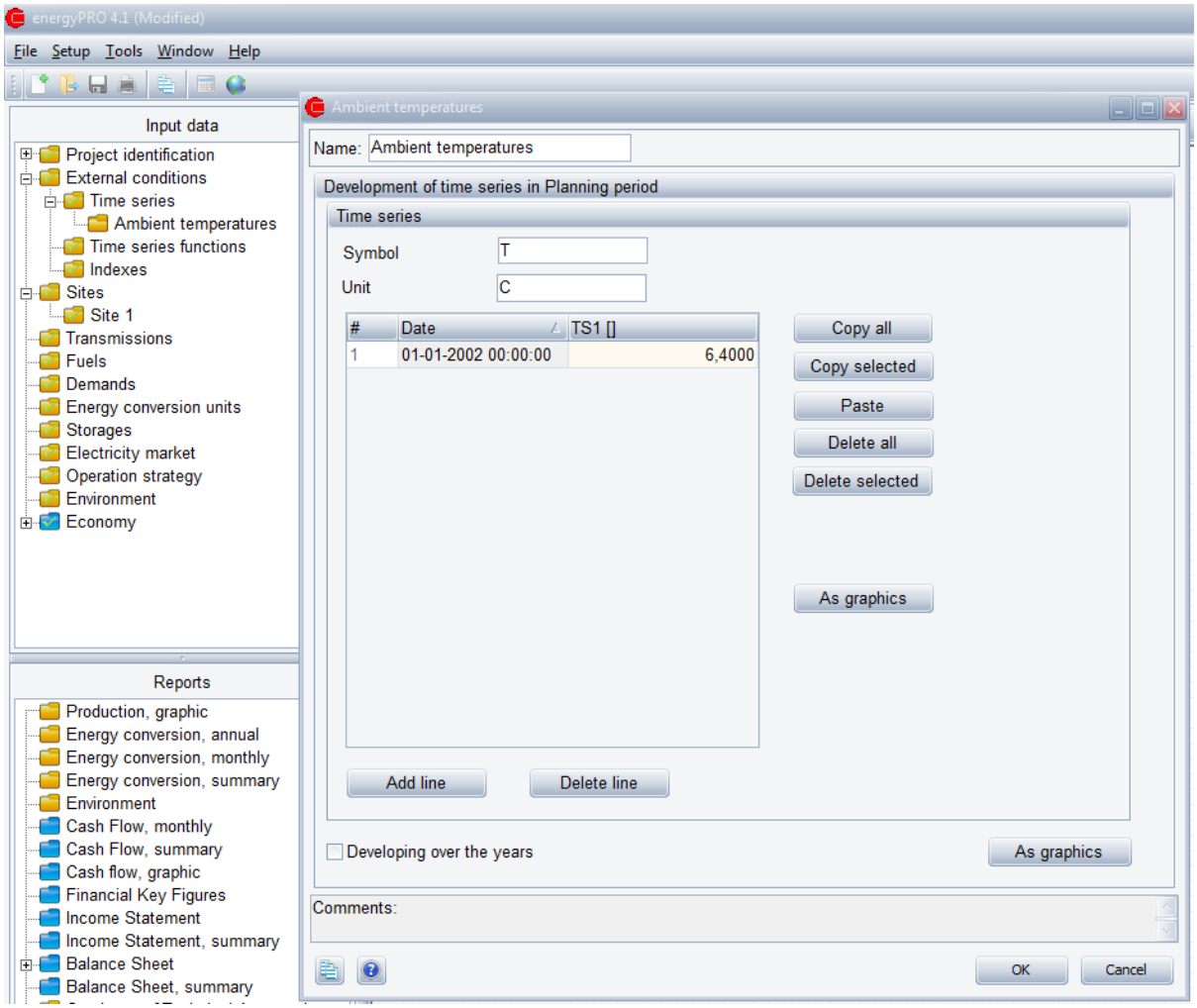
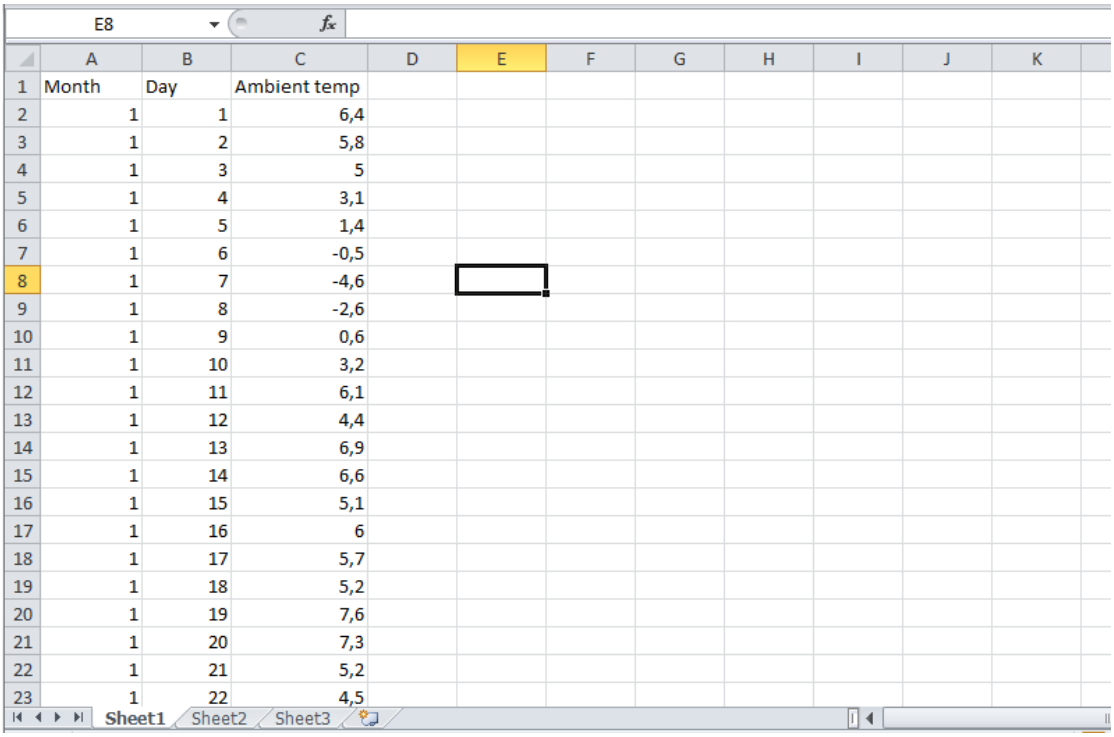


Figure 18. Import of a time series into energyPRO

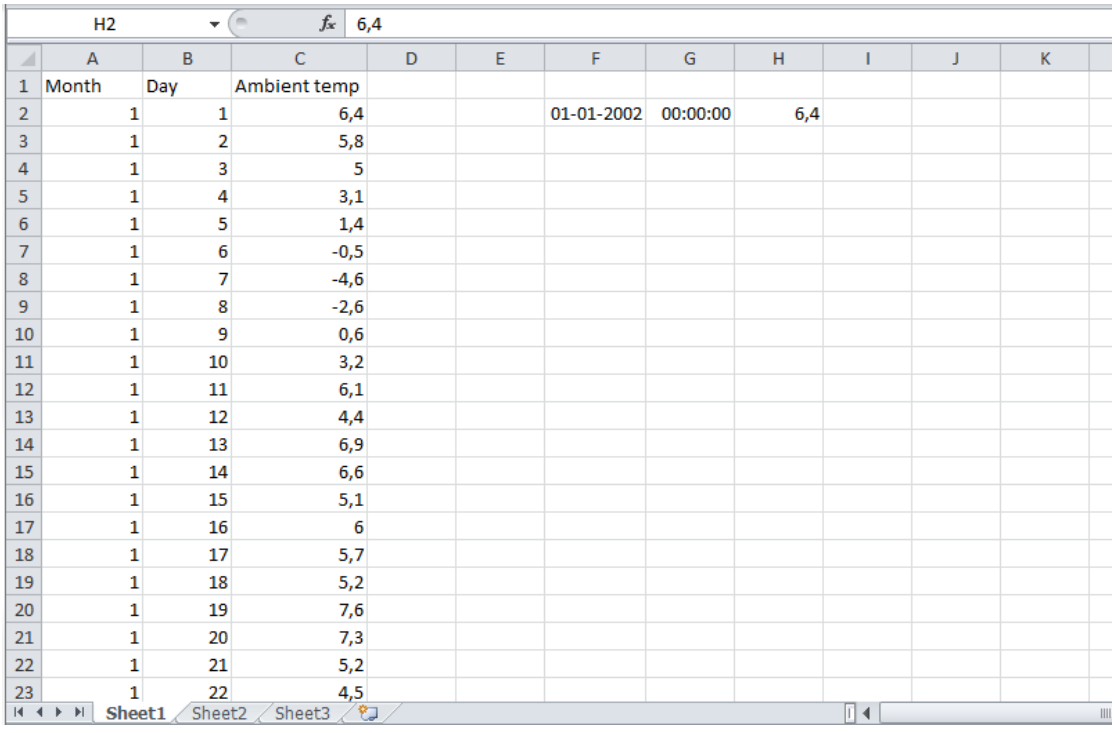
Open the spreadsheet to be used. In this example is used a spreadsheet with the month, day and ambient temperature specified.



	A	B	C	D	E	F	G	H	I	J	K
1	Month	Day	Ambient temp								
2	1	1	6,4								
3	1	2	5,8								
4	1	3	5								
5	1	4	3,1								
6	1	5	1,4								
7	1	6	-0,5								
8	1	7	-4,6								
9	1	8	-2,6								
10	1	9	0,6								
11	1	10	3,2								
12	1	11	6,1								
13	1	12	4,4								
14	1	13	6,9								
15	1	14	6,6								
16	1	15	5,1								
17	1	16	6								
18	1	17	5,7								
19	1	18	5,2								
20	1	19	7,6								
21	1	20	7,3								
22	1	21	5,2								
23	1	22	4,5								

Figure 19. Month, day and ambient temperature to be converted into a time series

Use the buttons for copying and pasting the date and time from energyPRO into the spreadsheet as shown below on Figure 20.

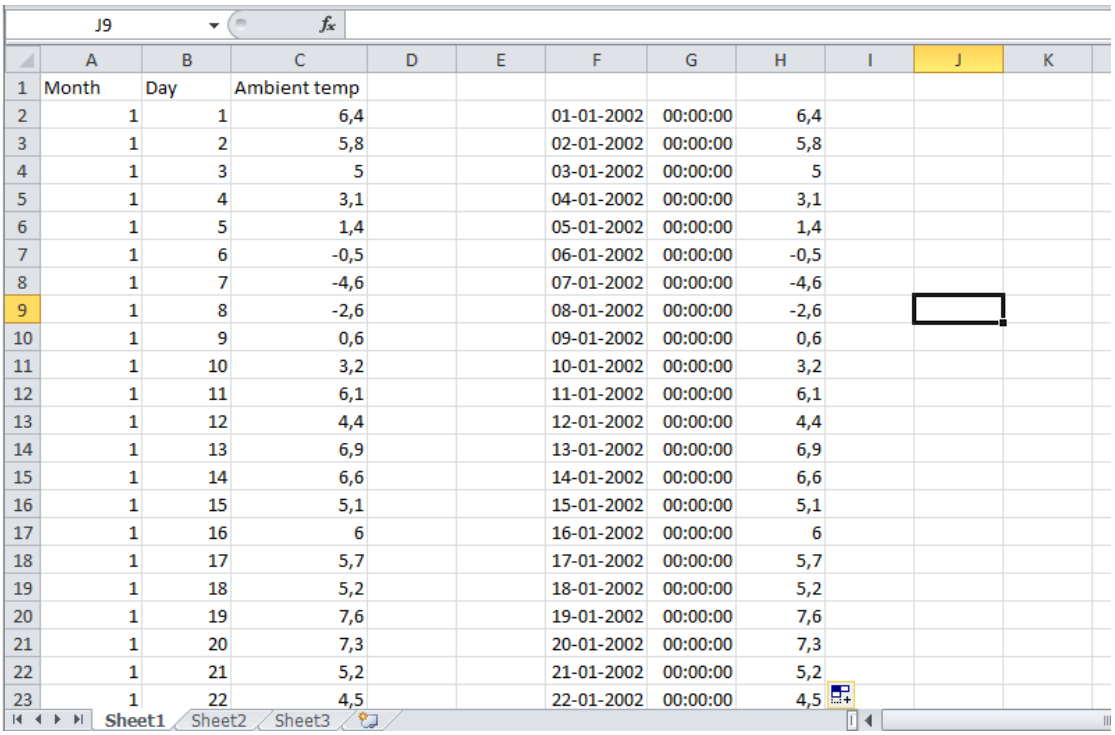


	A	B	C	D	E	F	G	H	I	J	K
1	Month	Day	Ambient temp								
2	1	1	6,4			01-01-2002	00:00:00	6,4			
3	1	2	5,8								
4	1	3	5								
5	1	4	3,1								
6	1	5	1,4								
7	1	6	-0,5								
8	1	7	-4,6								
9	1	8	-2,6								
10	1	9	0,6								
11	1	10	3,2								
12	1	11	6,1								
13	1	12	4,4								
14	1	13	6,9								
15	1	14	6,6								
16	1	15	5,1								
17	1	16	6								
18	1	17	5,7								
19	1	18	5,2								
20	1	19	7,6								
21	1	20	7,3								
22	1	21	5,2								
23	1	22	4,5								

Figure 20. Insertion of date and time into the spreadsheet

The date and time from energyPRO is now copied into the spreadsheet.

Use this format for date and time to create new columns for the ambient temperature:



	A	B	C	D	E	F	G	H	I	J	K
1	Month	Day	Ambient temp								
2	1	1	6,4			01-01-2002	00:00:00	6,4			
3	1	2	5,8			02-01-2002	00:00:00	5,8			
4	1	3	5			03-01-2002	00:00:00	5			
5	1	4	3,1			04-01-2002	00:00:00	3,1			
6	1	5	1,4			05-01-2002	00:00:00	1,4			
7	1	6	-0,5			06-01-2002	00:00:00	-0,5			
8	1	7	-4,6			07-01-2002	00:00:00	-4,6			
9	1	8	-2,6			08-01-2002	00:00:00	-2,6			
10	1	9	0,6			09-01-2002	00:00:00	0,6			
11	1	10	3,2			10-01-2002	00:00:00	3,2			
12	1	11	6,1			11-01-2002	00:00:00	6,1			
13	1	12	4,4			12-01-2002	00:00:00	4,4			
14	1	13	6,9			13-01-2002	00:00:00	6,9			
15	1	14	6,6			14-01-2002	00:00:00	6,6			
16	1	15	5,1			15-01-2002	00:00:00	5,1			
17	1	16	6			16-01-2002	00:00:00	6			
18	1	17	5,7			17-01-2002	00:00:00	5,7			
19	1	18	5,2			18-01-2002	00:00:00	5,2			
20	1	19	7,6			19-01-2002	00:00:00	7,6			
21	1	20	7,3			20-01-2002	00:00:00	7,3			
22	1	21	5,2			21-01-2002	00:00:00	5,2			
23	1	22	4,5			22-01-2002	00:00:00	4,5			

Figure 21. Insertion of ambient temperatures into the spreadsheet

Columns with the correct date and time format are now created.

Now you can copy the columns into the time series in energyPRO as shown on Figure 22.

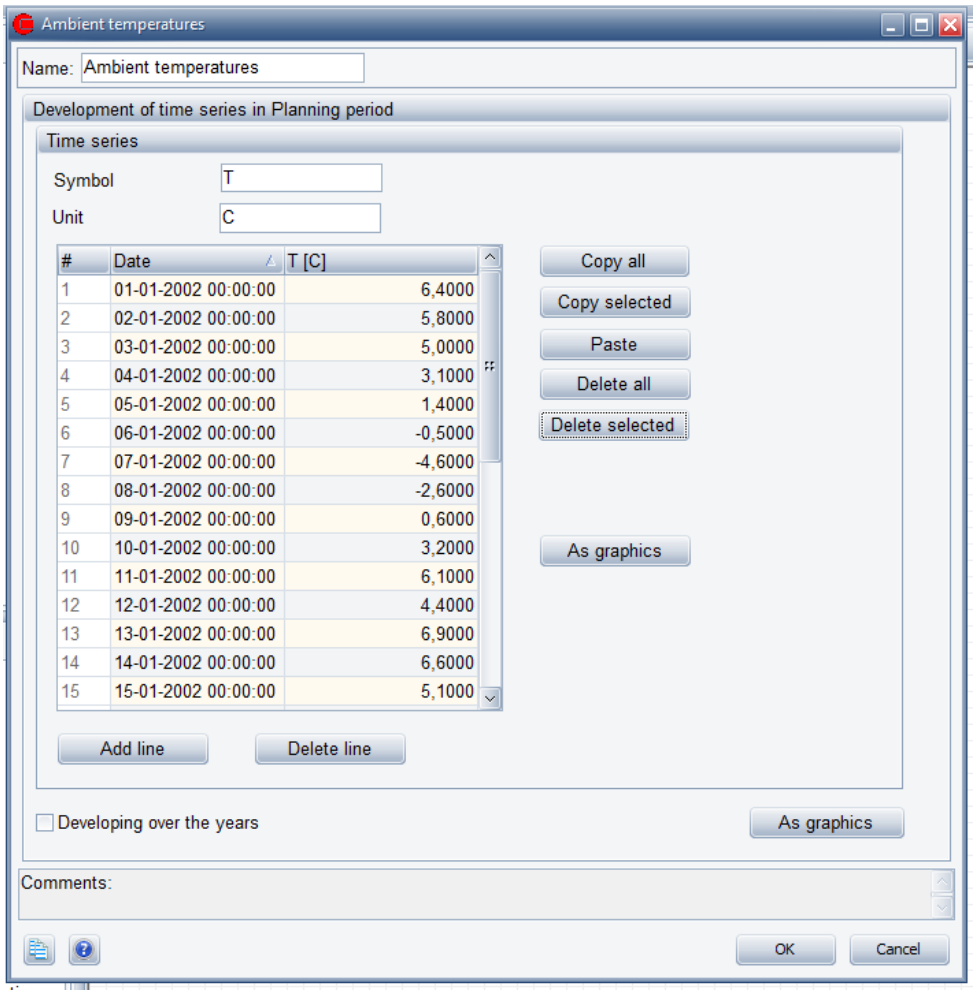


Figure 22. New time series created

Data from the spreadsheet has now been copied into the time series.

EMD International A/S
Niels Jernes Vej 10 • DK-9220 Aalborg Ø • Denmark
Tel.: +45 9635 4444 • Fax: +45 9635 4446 • E-mail: emdmd.dk • www.emd.dk