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Guideline to EnergyPLAN Exercise 5:

Advanced Energy System Analysis: Feasibility Studies and Market Exchange Studies

In Exercise 5, you are asked to conduct Feasibility Studies and Market Exchange Studies of pre-defined energy systems.

Exercise 5.1: Make a Feasibility Study of the IDA Energy plan 2030

Open the EnergyPLAN model. Load the input data set "Denmark2030Alternative.txt", which is a model of the IDA Energy Plan 2030 system also used in exercise 4.

Calculate the socioeconomic costs of the system without any electricity exchange for the three fuel price alternatives already loaded into the model. Use a CO_2 cost of 150 DKK/ton.

How to do exercise 5.1:

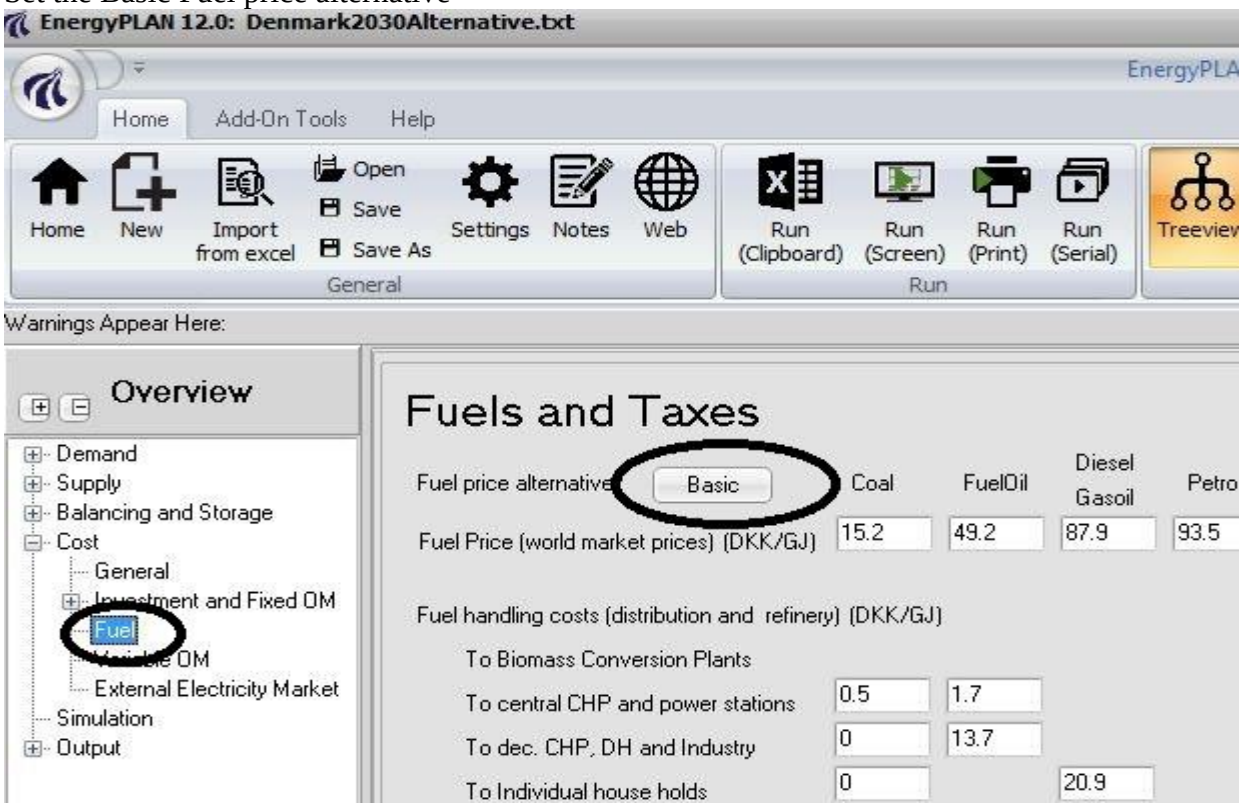
Step 1: Open the EnergyPLAN model and load the input data set "Denmark2030Alternative.txt"**.** The data set is part of the files, when you download the EnergyPLAN model. If for some reason you do not have the data set, it can be downloaded from the following address: : http://www.energyplan.eu/wp-content/uploads/2014/06/EnergyPLAN_DK.zip.

Step 2: Save as exercise 5.

Step 3: Open the Simulation window:
Set the "Market Economic Simulation"

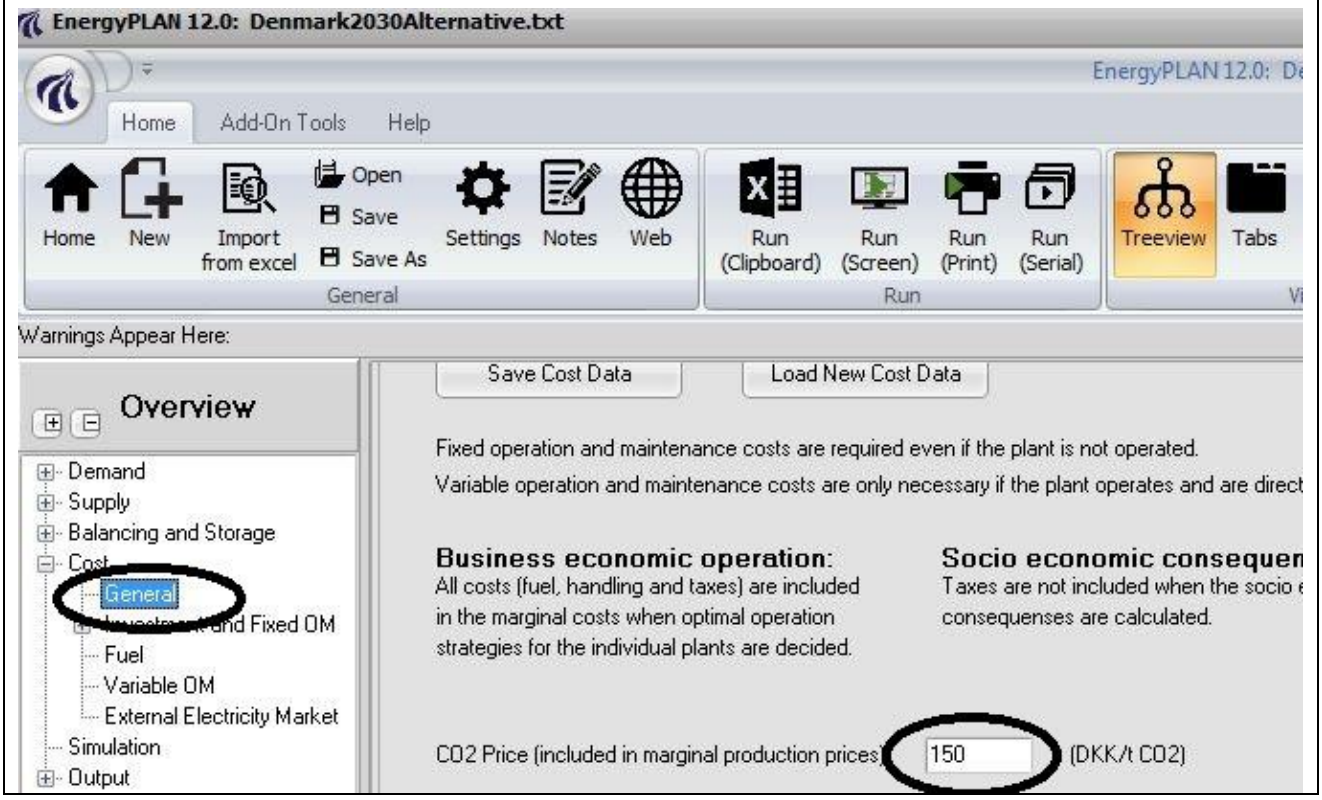
Step 4. Open the "Fuel" window under the "Cost" tab

Set the Basic Fuel price alternative

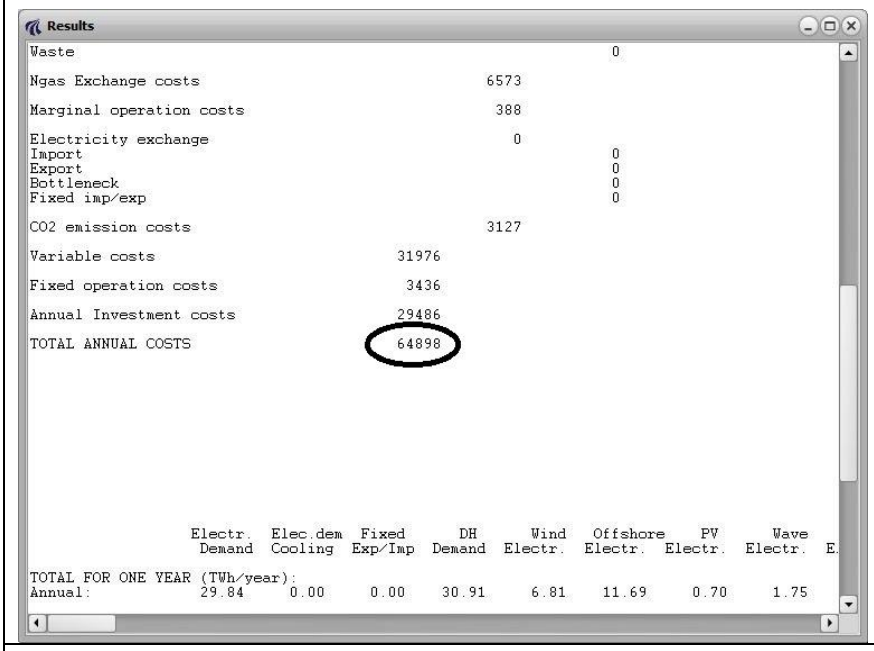


Step 5. Open the "General" window under the "Cost" tab

Set the CO_2 price to 150 DKK/t CO_2

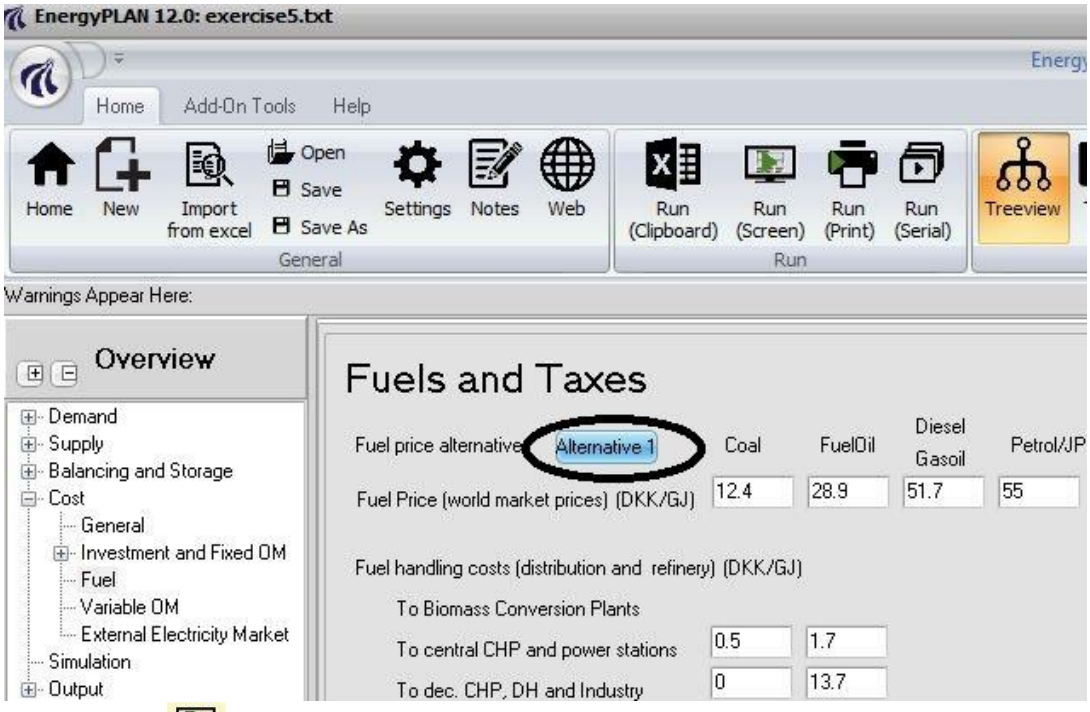


Activate the Run (Screen) button and read the results: Total annual costs of 64898 Million DKK.



Step 5: Open the Fuel window:

Set Fuel price alternative to "Alternative 1"



Activate the Run (Screen) button and read the results: Total annual costs of 57370 Million DKK.

Step 6: Open the Fuel window:
Set Fuel price alternative to "Alternative 2" and calculate:

The final results are:

Basic:	64898 Million DKK
Alternative 1:	57370 Million DKK
Alternative 2:	72480 Million DKK

Save data file from exercise 5.

Exercise 5.2: Do a market exchange analysis of exercise 5.1

Open Denmark2030Alternative and conduct a market exchange analysis. Use the same input as in exercise 5.1, i.e. the three fuel prices already loaded into the model and a CO_2 cost of 150 DKK/ton.

Open the system to the external market by setting the import/export transmission capacity to 2500 MW.

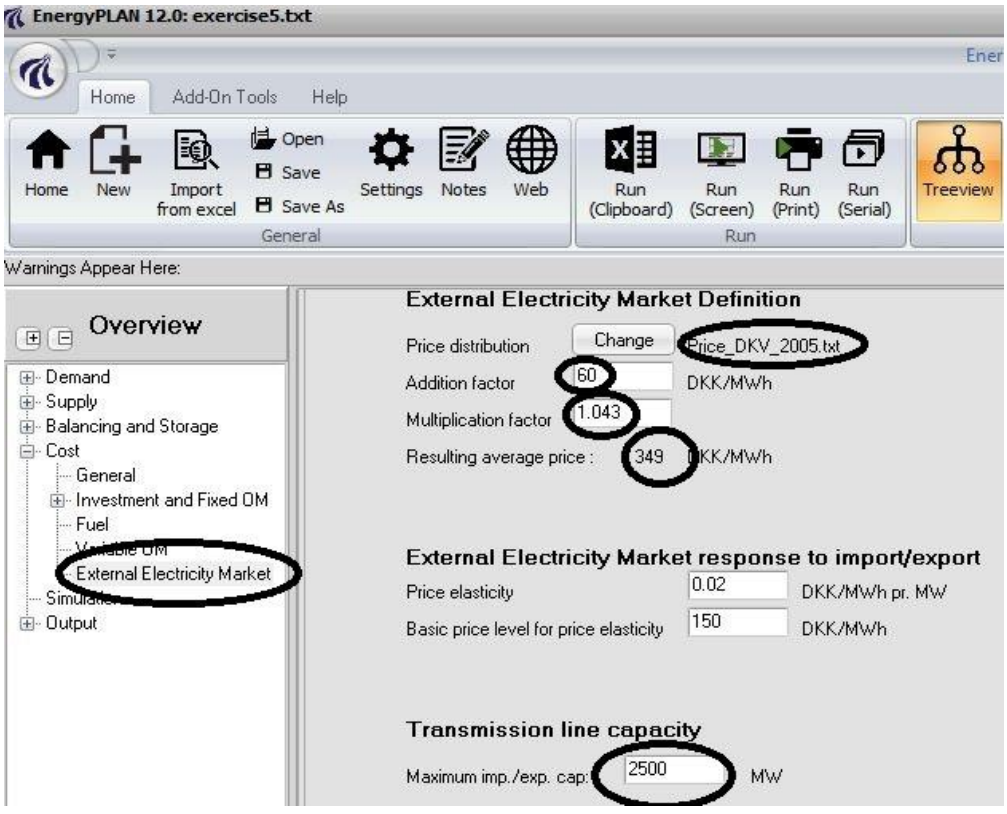
Design an external market with an average price of 349 DKK/MWh using the distribution file "Price_DKV_2005.txt" (The Nord Pool spot market prices of year 2005). The 349 DKK/MWh can be identified by using an addition factor of 60 DKK/MWh and the multiplication factor 1.043.

Calculate the new socioeconomic costs of all three fuel price alternatives.

How to do exercise 5.2: (use the data set from exercise 5.1)

Step 1: Load the data file from exercise 5.1:

Step 2: Open the "External Electricity Market" window:
Set Maximum import/export to 2500 MW (open system)



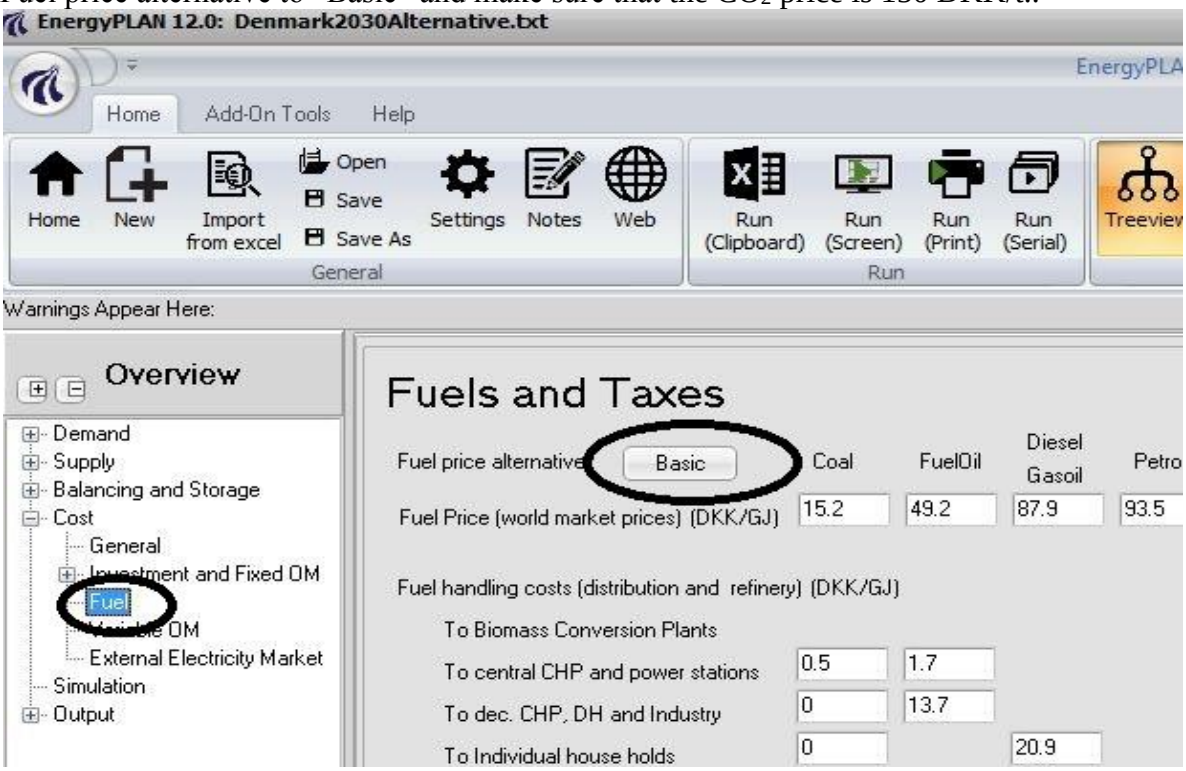
Make sure that external electricity market has an average price of 349 DKK/MWh and that the distribution file "Price_DKV_2005.txt" is active.

The 349 DKK/MWh is found by using an addition factor of 60 DKK/MWh and the multiplication factor 1.043.

Lastly, make sure that the Market Economic Simulation is on.

Step 3: Open the Fuel window:

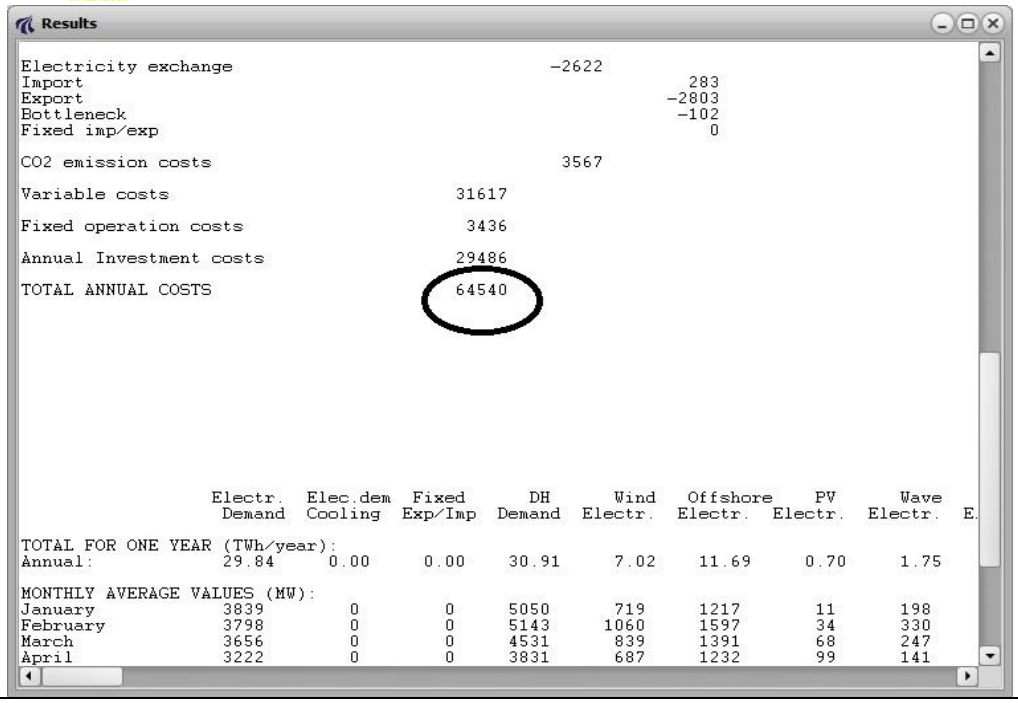
Set Fuel price alternative to "Basic" and make sure that the CO_2 price is 150 DKK/t..



Remember to check whether the CO_2 price is set to 150 DKK/t.

Activate the 

button and read the results: Total annual costs of 64540 Million DKK.



Step 4: Open the Fuel window:
Set Fuel price alternative to "Alternative 1" and "Alternative 2" and calculate. The results are:
Basic: 64540 Million DKK
Alternative 1: 56842 Million DKK
Alternative 2: 72099 Million DKK

Exercise 5.3: Do an advanced market exchange analysis of exercise 5.1

Repeat the analysis of exercise 5.2 for a 7-year period of 3 normal, 3 wet and 1 dry year using the following data:

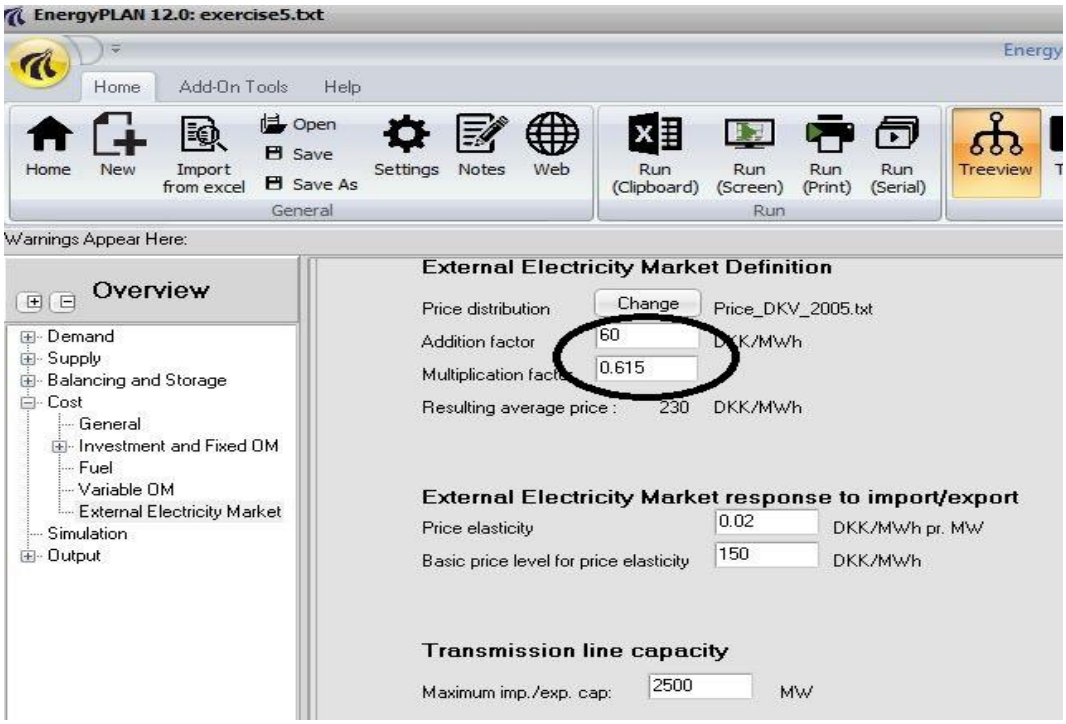
DKK/MWh	Weight	Constant	Variable	Total
Wet year	3	60	170	230
Normal year	3	60	315	374
Dry year	1	60	572	632
7 years average				349

Compare the results to the results of exercises 5.1 and 5.2

How to do exercise 5.3: (use the data set from exercises 5.1 and 5.2)

Step 1: Load the data file from exercises 5.1 and 5.2:

Step 2: Open the "External Electricity Market" window:



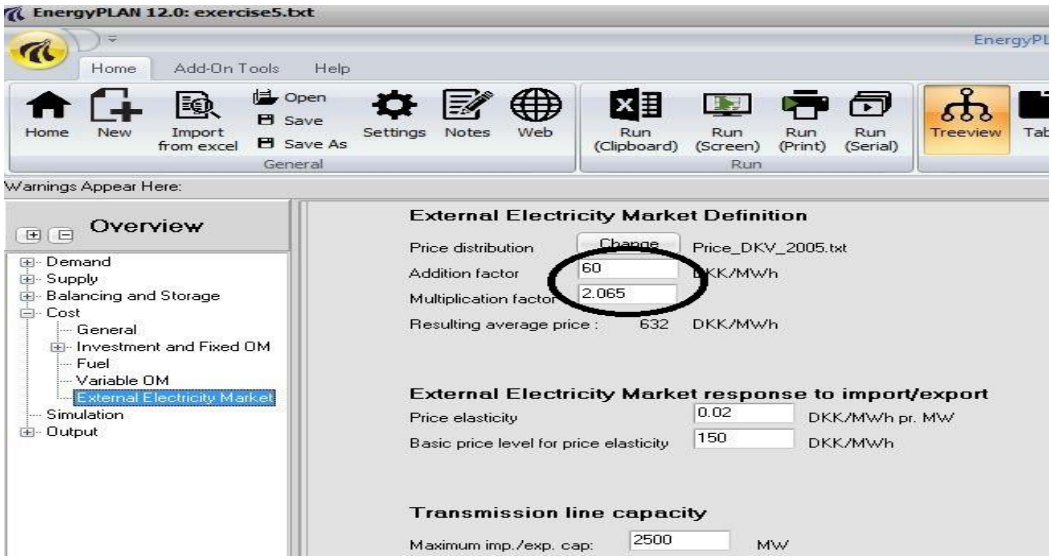
Design a "Wet year" by keeping the addition factor of 60 DKK/MWh and identifying the multiplication factor, which results in an average price of 230 DKK/MWh.

The multiplication factor is then 0.615.

Step 3: Open the Fuel window:
Set Fuel price alternative to "Basic" and calculate

Then set Fuel price alternative to "Alternative 1" and "Alternative 2" and calculate.
Wet Year:
Basic: 64651 Million DKK
Alternative 1: 57278 Million DKK
Alternative 2: 71987 Million DKK

Step 4: Repeat steps 2 and 3 for the "Normal year".



The average price of 374 DKK/MWh in a "normal year" is found by using a multip. factor of 1.132, and the average price of 632 DKK/MWh in a "dry year" by using a multiplication factor 2.065.

The results are the following:

	Weight	Average Price	Fuel price alternatives		
		DKK/MWh	Basic	Low	High
Wet year		230	64651	57278	71987
Normal year		374	64441	56724	72062
Dry year		632	63142	55084	71002
7 years average		349	64345	56727	71878
Exercise 5.1.			64898	57370	72480
Difference			553	643	602
Exercise 5.2.			64540	56842	72099
Difference			195	115	221

The following can be seen from comparing the results to those of exercises 5.1 and 5.2:

- In all cases with exchange (ex 5.2 and 5.3), better solutions (low costs) can be found compared to the situation of no exchange (ex 5.1)
- In the case of average years (ex 5.2), the net earnings from the trade of electricity on the external market is between 114 and 222 million DKK/year depending on the fuel prices.
- In the cases of "wet", "normal" and "dry" years, the net earnings are between 553 and 643 million DKK/year.

Exercise 5.4: Optimise the wind power capacity

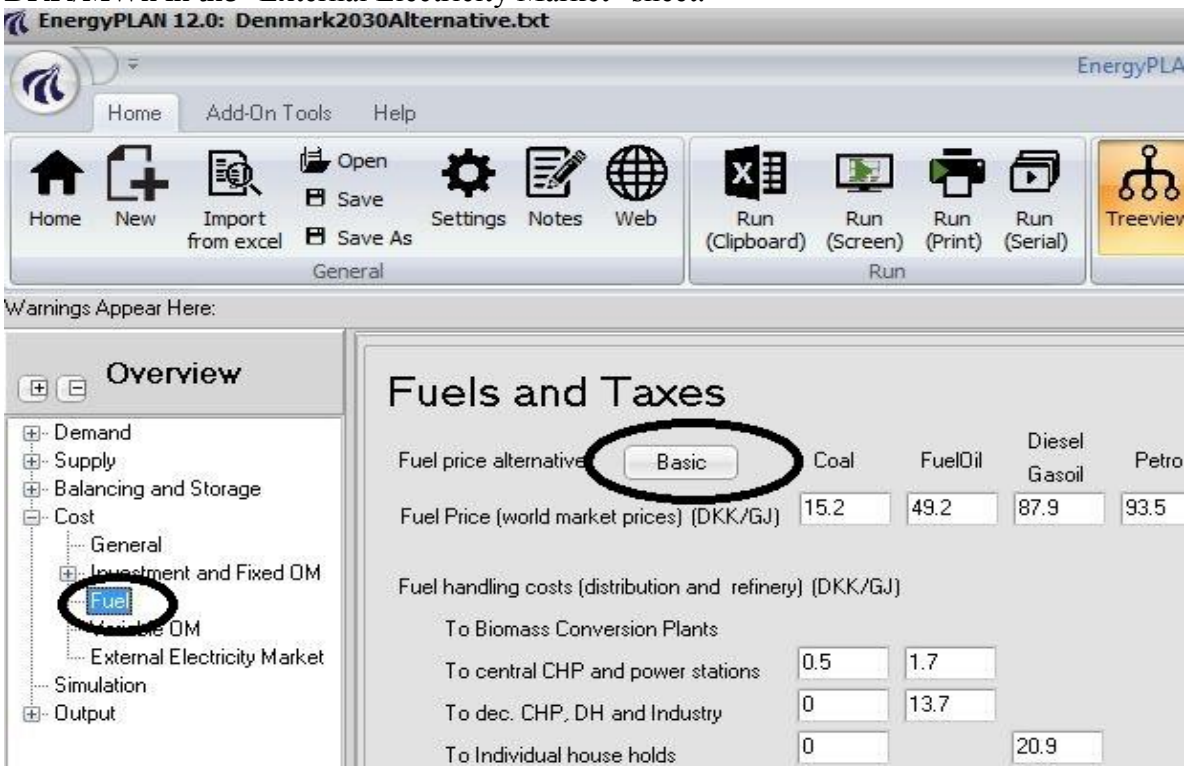
Use the input data set of exercise 5.1, and identify the optimal offshore wind power capacity given an onshore capacity of 3000 MW. Use "Basic" fuel prices.

How to do exercise 5.4: (use the data set from exercise 5.1)

Step 1: Load the data file from exercise 5.1:

Step 2: Open the Fuel window:

Set Fuel price alternative to "Basic". Remember to re-set external electricity market to 349 DKK/MWh in the "External Electricity Market" sheet.



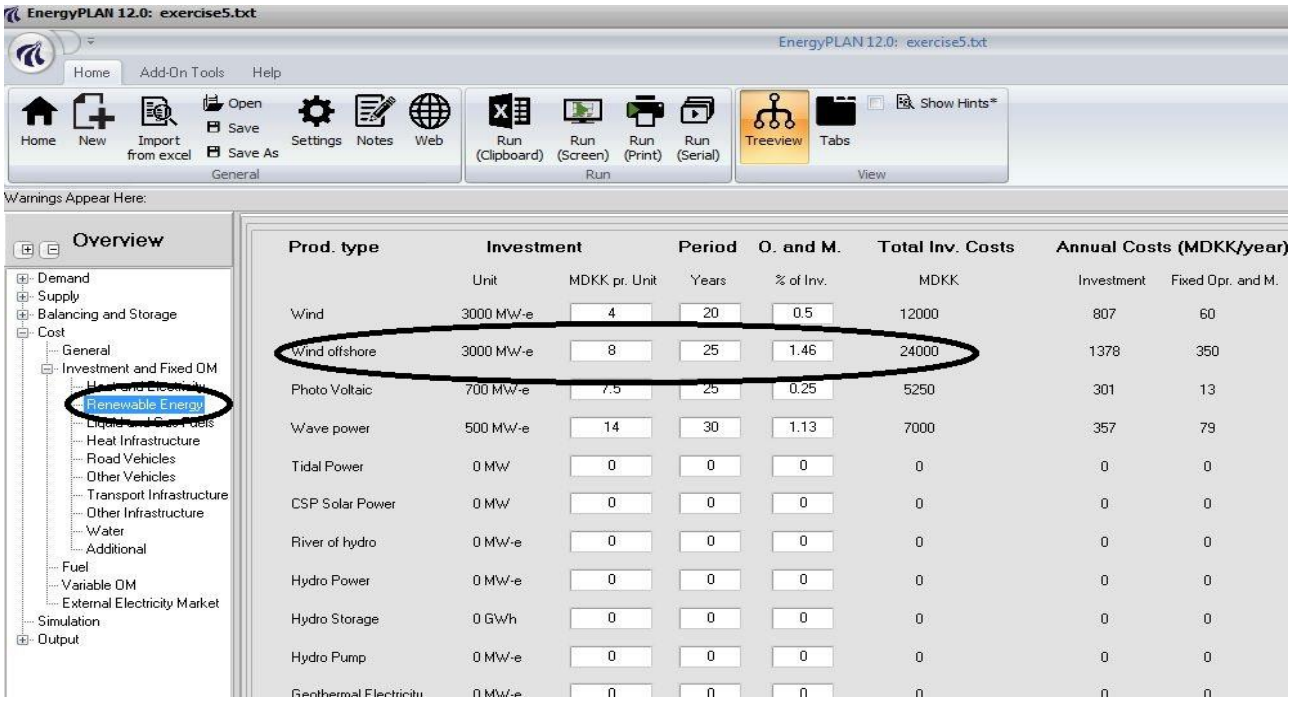
Step 3: Open the "External Electricity Market" window:

Set Maximum import/export capacity to 0 MW (closed system) in the "External Electricity Market" sheet.

Activate the 

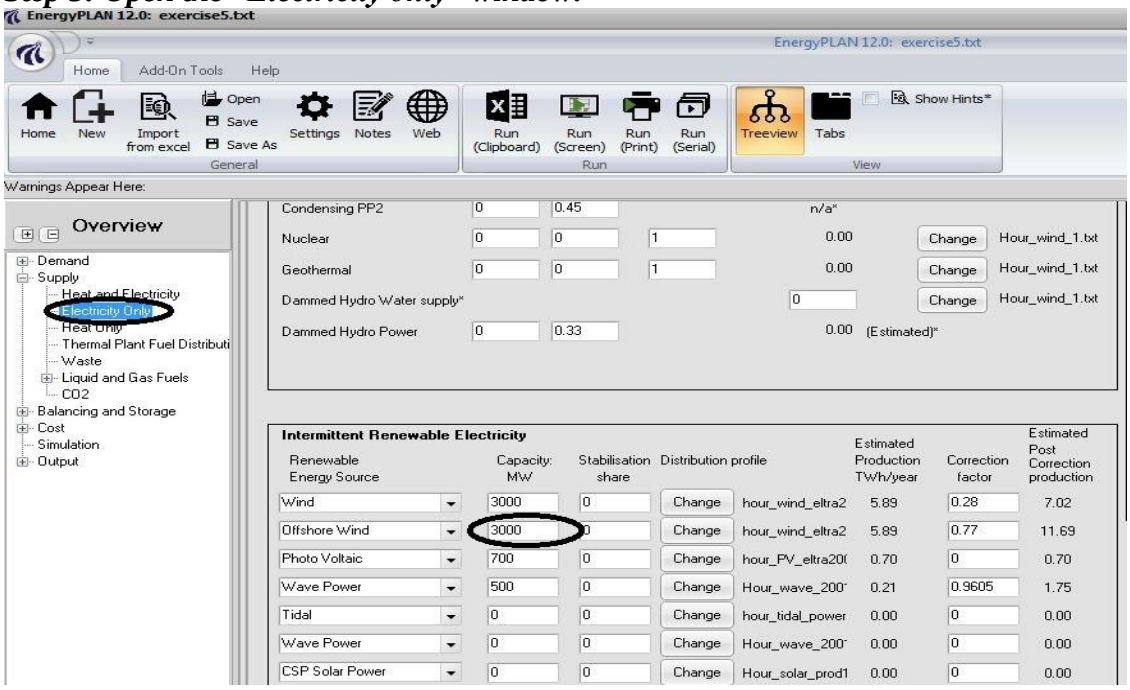
button and read the results: Total annual costs of 64898 Million DKK.

Step 4: Open the "Renewable Energy" window under the "Investment and Fixed OM" tab under the "Cost" tab:



3000 MW of offshore wind power is included in the investment costs and consequently also included in the total costs of 64898 million DKK/year.

Step 5: Open the "Electricity only" window:



The input of offshore wind power is now 3000 MW (given the total costs 64898 million DKK/year)

Now change the offshore input to e.g. 4000 MW and calculate the new result. Total costs are 64618 Million DKK/year. Such results include both savings in fuels through the increased use of wind power as well as increases in investment costs of additional 1000 MW.

Step 6: Repeat steps 4 continuously until an optimum is reached.
The answer is app. 5700 MW offshore (and 3000 MW onshore) and cost equals to 64369 million DKK/year.