

## 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 CO2 cost of 150 DKK/ton.

#### How to do exercise 5.1:

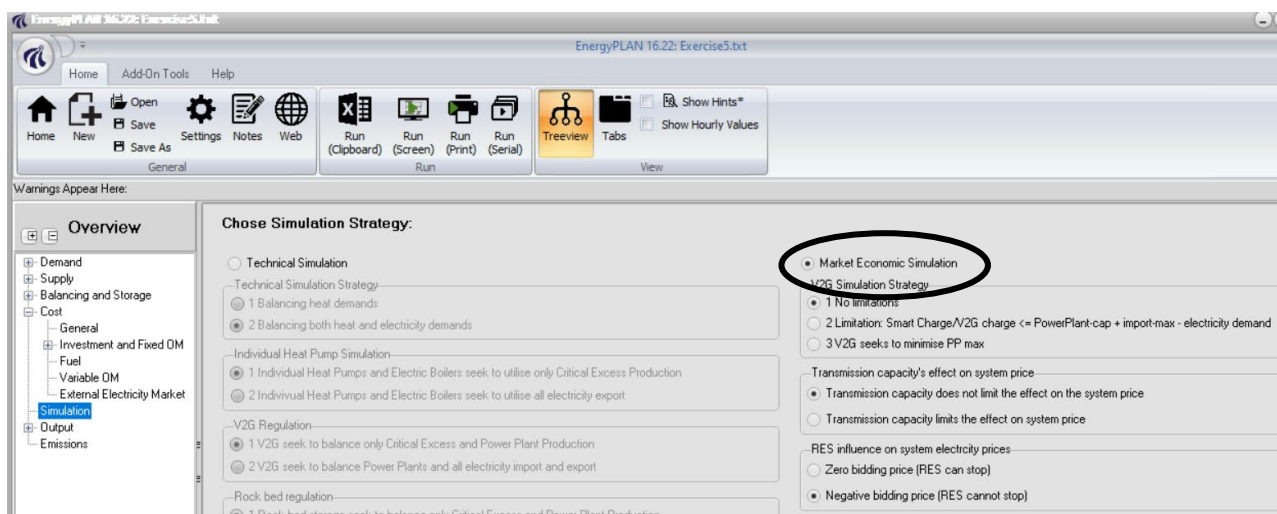
**Step 1: Open the EnergyPLAN model and load the input data set "Denmark2030Alternative.txt".**

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](http://www.energyplan.eu/wp-content/uploads/2014/06/EnergyPLAN_DK.zip).

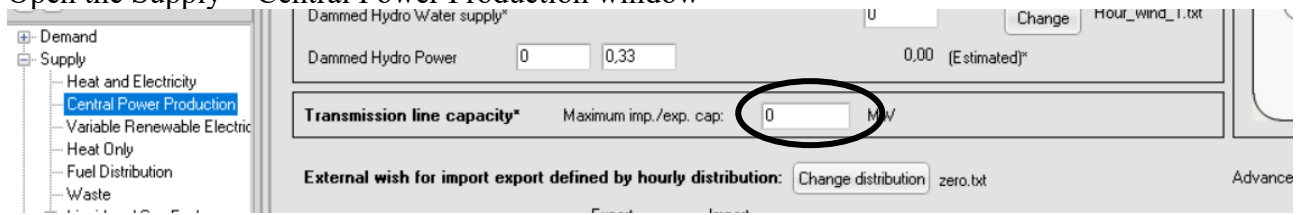
**Step 2: Save as exercise 5.**

**Step 3: Open the Simulation window:**



Choose "Market Economic Simulation"

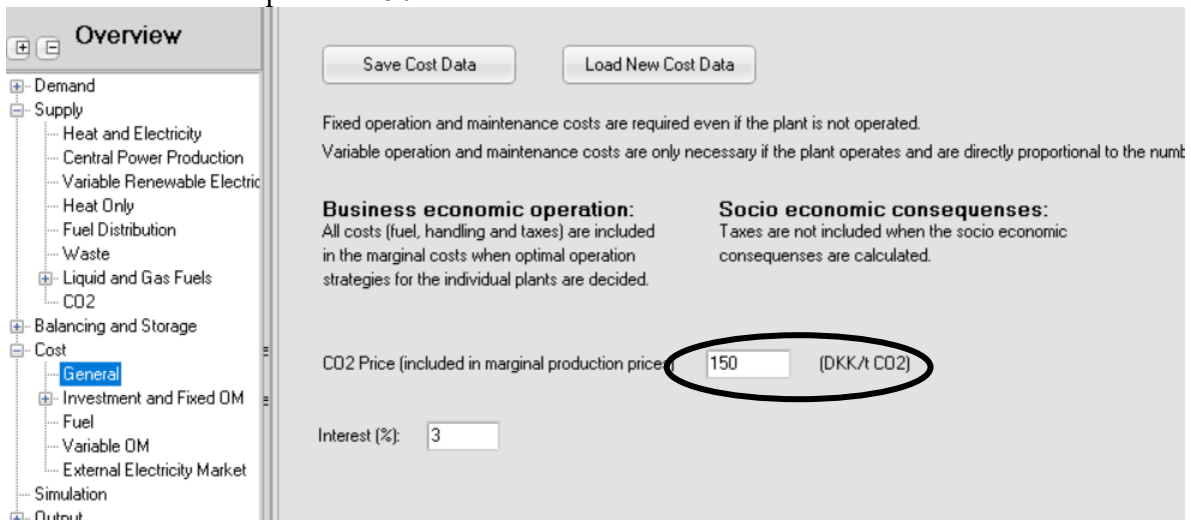
Open the Supply > Central Power Production window



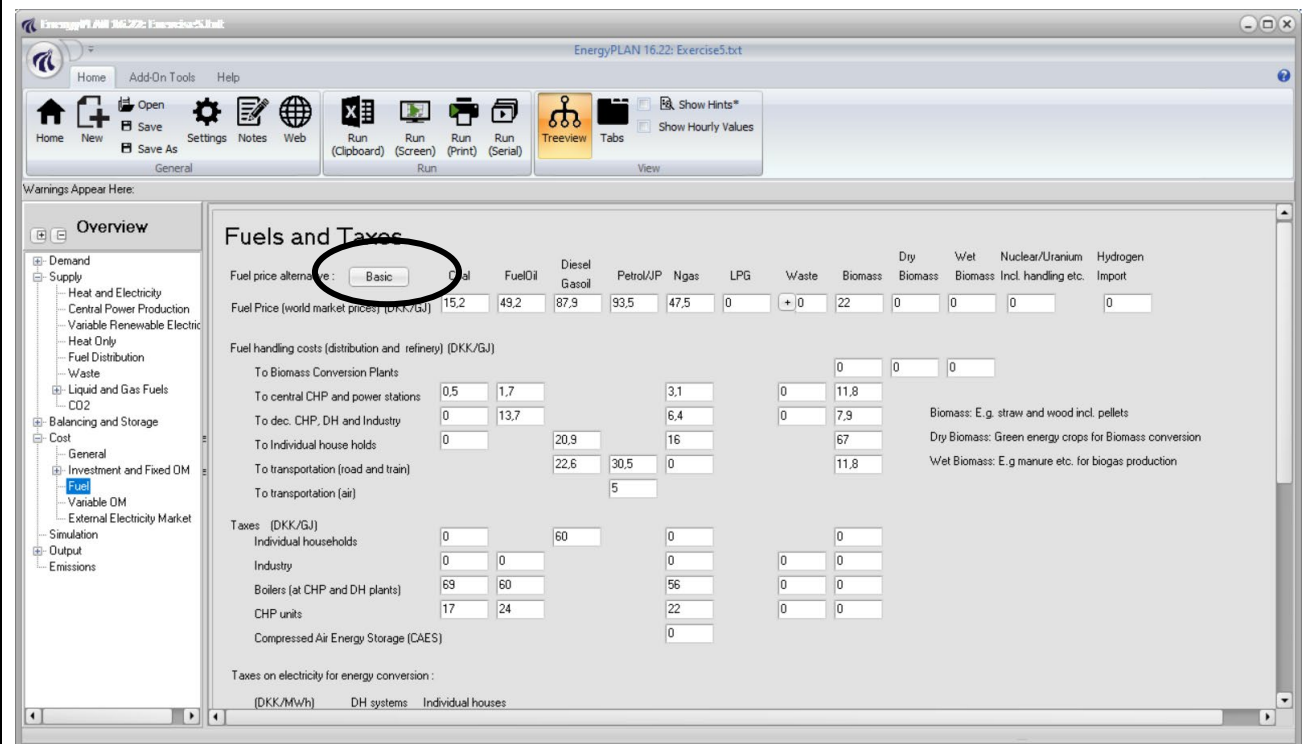
Set Maximum import/export to 0 MW (closed system).


**Step 4: Open the Cost > General window:**

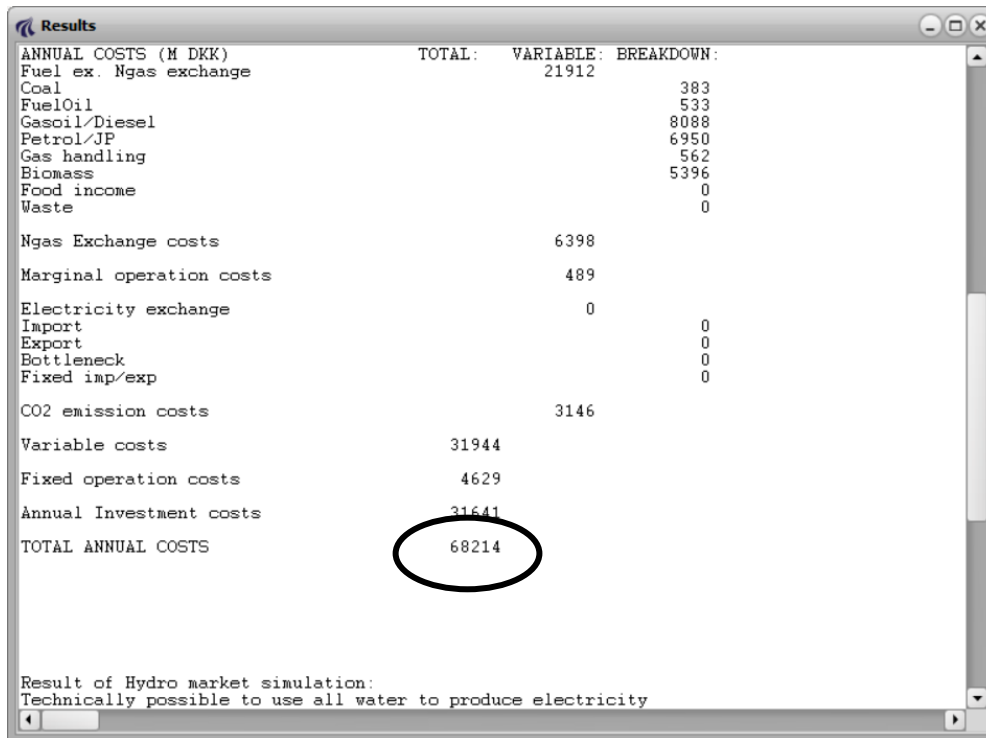
Make sure that the CO2 price is 150 DKK/t..



Open the Cost > Fuel Window and make sure to choose “Basic”



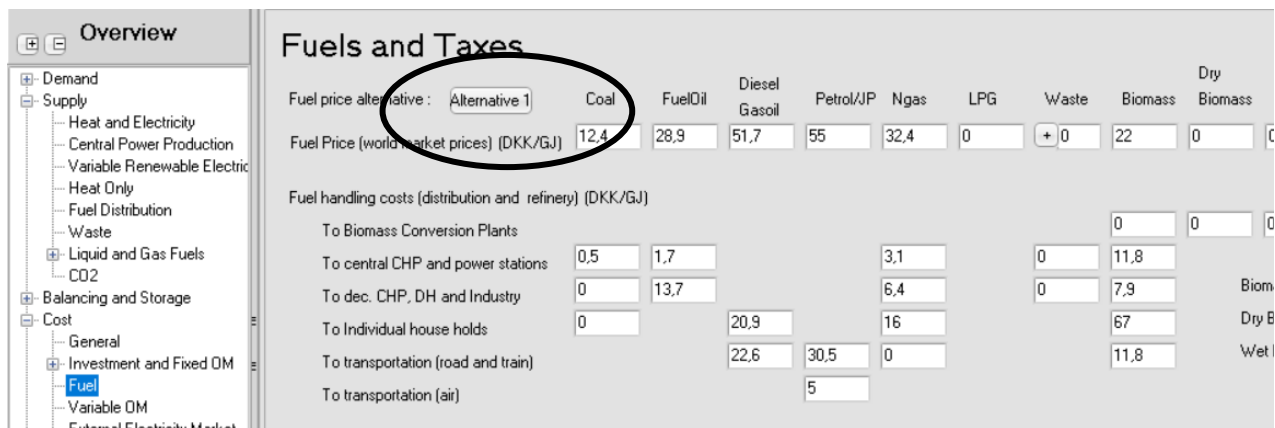
Press , calculate and read the results: Total annual costs of 68214 Million DKK.




ANNUAL COSTS (M DKK)	TOTAL:	VARIABLE:	BREAKDOWN:
Fuel ex. Ngas exchange		21912	
Coal			383
FuelOil			533
Gasoil/Diesel			8088
Petrol/JP			6950
Gas handling			562
Biomass			5396
Food income			0
Waste			0
Ngas Exchange costs	6398		
Marginal operation costs	489		
Electricity exchange	0		
Import			0
Export			0
Bottleneck			0
Fixed imp/exp			0
CO2 emission costs		3146	
Variable costs	31944		
Fixed operation costs	4629		
Annual Investment costs	31641		
<b>TOTAL ANNUAL COSTS</b>	<b>68214</b>		

Result of Hydro market simulation:  
Technically possible to use all water to produce electricity

**Step 5: Open the Cost > Fuel window:**  
Set Fuel price alternative to “Alternative 1”



Fuel price alternative:	Coal	FuelOil	Diesel Gasoil	Petrol/JP	Ngas	LPG	Waste	Biomass	Dry Biomass
Fuel Price (world market prices) (DKK/GJ)	12.4	28.9	51.7	55	32.4	0	+ 0	22	0
Fuel handling costs (distribution and refinery) (DKK/GJ)									
To Biomass Conversion Plants								0	0
To central CHP and power stations	0.5	1.7			3.1		0	11.8	
To dec. CHP, DH and Industry	0	13.7			6.4		0	7.9	Biom
To Individual house holds	0		20.9		16			67	Dry B
To transportation (road and train)			22.6	30.5	0			11.8	Wet
To transportation (air)				5					

Press , calculate and read the results: Total annual costs of 60740 Million DKK.

**Step 6: Open the Cost > Fuel window:**  
Set Fuel price alternative to “Alternative 2” and calculate:  
The final results are:  
Basic: 68214 Million DKK  
Alternative 1: 60740 Million DKK  
Alternative 2: 75779 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 CO2 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:**

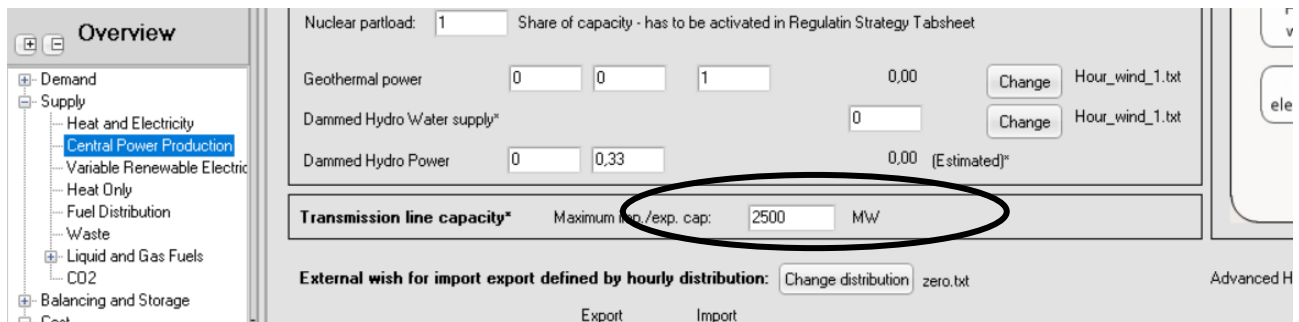
**Step 2: Open the Cost > External Electricity Market window**

The screenshot displays the 'External Electricity Market Definition' window. The 'Price distribution' is set to 'Price\_DKV\_2005.txt'. The 'Addition factor' is 60 DKK/MWh, and the 'Multiplication factor' is 1.043, resulting in an average price of 349 DKK/MWh. The 'External Electricity Market response to import/export' section shows a price elasticity of 0.0200000, a basic price level of 150 DKK/MWh, and a maximum market electricity price of 0 DKK/MWh. The sidebar on the left shows the 'External Electricity Market' selected under the 'Cost' category.

Make sure that external electricity market has an average price of 349 DKK/MWh and that it is using the distribution file “Price\_DKV\_2005.txt”.

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

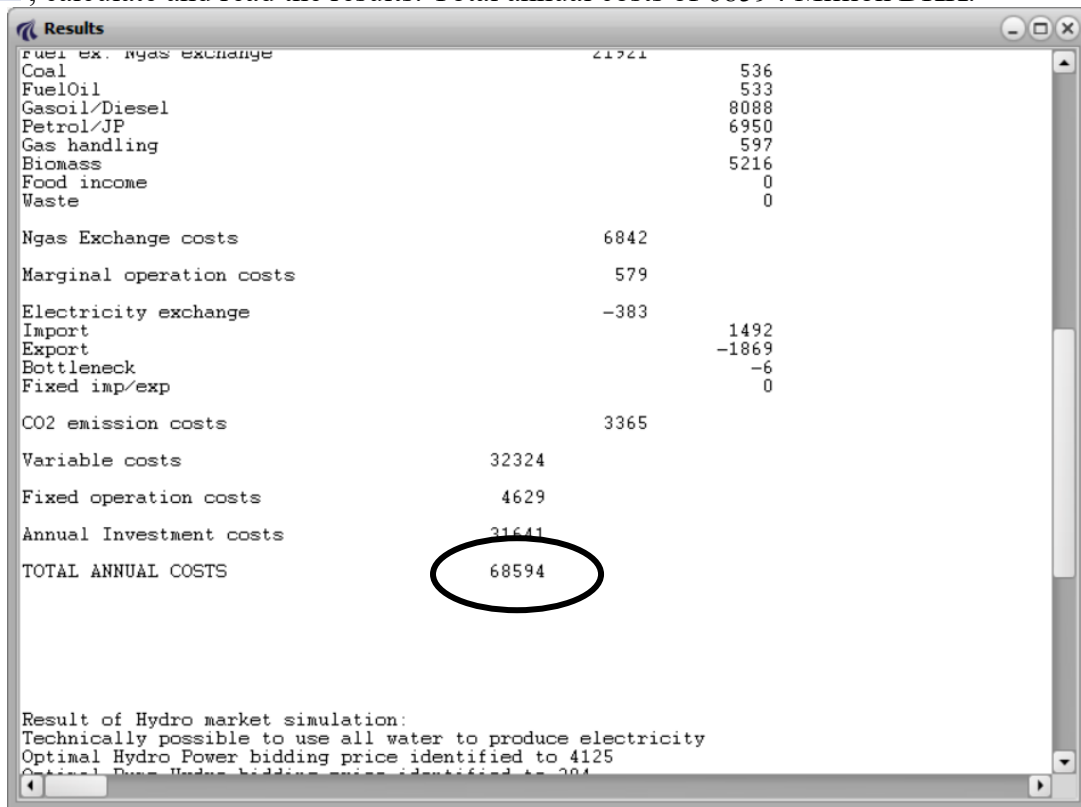
Open the Supply > Central Power Production window



Set Maximum import/export to 2500 MW (open system).

**Step 3: Open the Cost > Fuel window:**

Press , calculate and read the results: Total annual costs of 68594 Million DKK.



**Step 4: Open the Cost > Fuel window:**

Set Fuel price alternative to “Alternative 1” and “Alternative 2” and calculate.

The results are:

Basic: 68594 million DKK  
 Alternative 1: 60886 million DKK  
 Alternative 2: 76374 million DKK

### Exercise 5.3: Optimise the wind power capacity

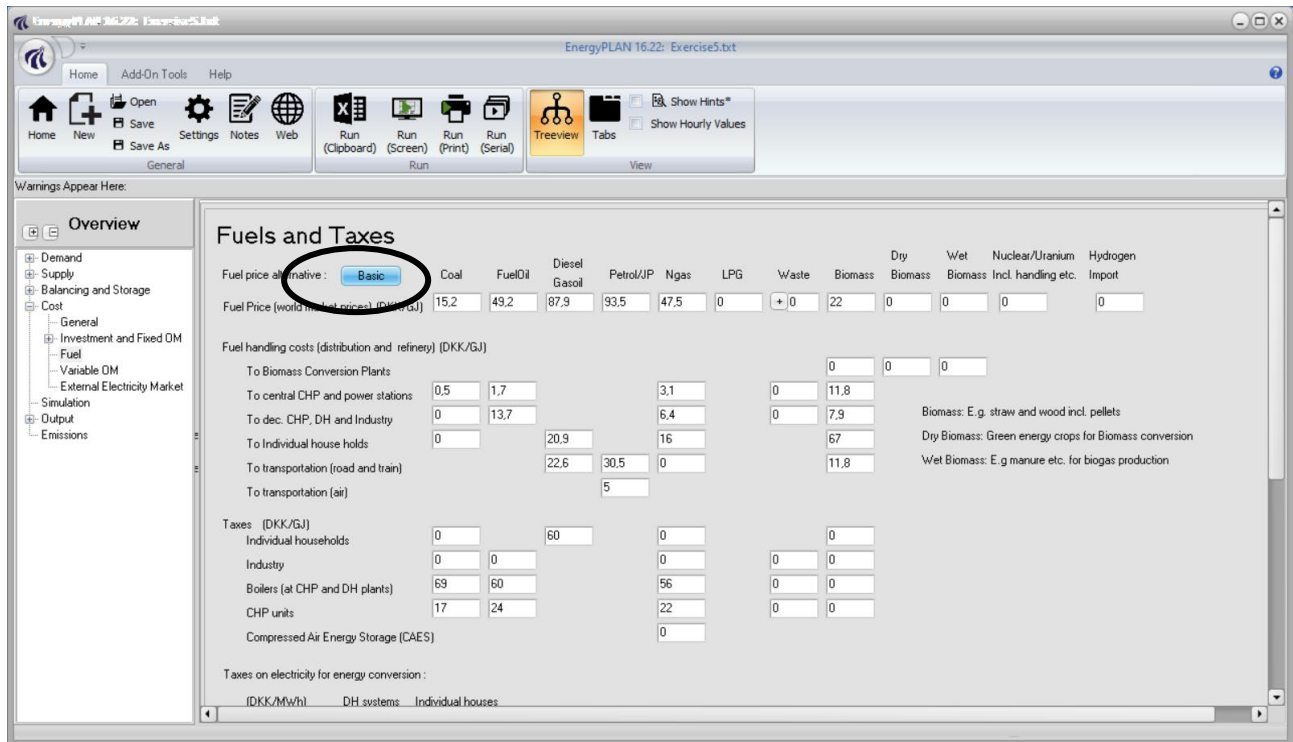
Use the input data set of exercise 5.1, and identify the optimal offshore wind power capacity given an onshore capacity of 3000 MW. Use “Basic” fuel prices.

#### How to do exercise 5.3: (use the data set from exercise 5.1)

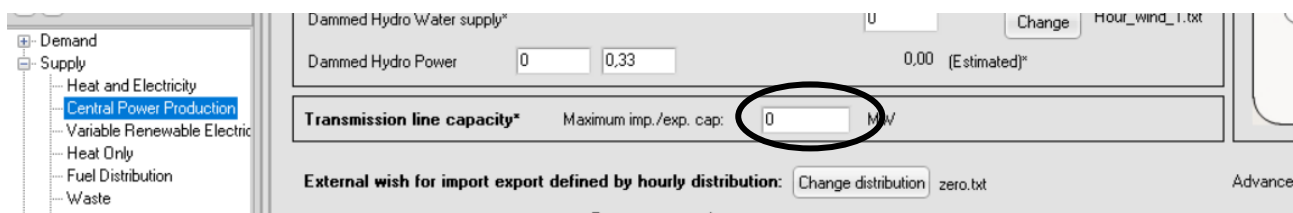
**Step 1: Load the data file from exercise 5.1 and 5.2:**

**Step 2: Open the Cost > Fuel window:**

Set Fuel price alternative to “Basic”.



**Step 3: Open the Supply > Central Power Production window**



Set Maximum import/export to 0 MW (closed system).

Press  , calculate and read the results: Total annual costs of 68594 million DKK.

**Step 4: Open the Cost > Investment > Renewable Energy window:**

Prod. type	Investment		Period		O. and M.		Total Inv. Costs		Annual Costs (MDKK/year)	
	Unit	MDKK pr. Unit	Years	% of Inv.	MDKK	Investment	Fixed Opr. and M.			
Wind	3000 MW-e	8	25	0,5	12000	807	60			
Wind offshore	3000 MW-e	8	25	1,46	24000	1378	350			
Photo Voltaic	700 MW-e	1,5	25	0,23	5250	301	13			
Wave power	500 MW-e	14	30	1,13	7000	357	79			
Tidal Power	0 MW	0	0	0	0	0	0			
CSP Solar Power	0 MW	0	0	0	0	0	0			
River of hydro	0 MW-e	0	0	0	0	0	0			
Hydro Power	0 MW-e	0	0	0	0	0	0			
Hydro Storage	0 GWh	0	0	0	0	0	0			
Hydro Pump	0 MW-e	0	0	0	0	0	0			
Geothermal Electr.	0 MW-e	0	0	0	0	0	0			
Geothermal Heat	0 TWh/year	0	0	0	0	0	0			
Solar thermal	3 TWh/year	3000	25	0,05	8130	467	4			

3000 MW of offshore wind power is included in the investment costs and consequently also included in the total costs of 68594 million DKK/year.

**Step 5: Open the Supply > Renewable Energy window:**

Renewable Energy Source	Capacity: MW	Stabilisation share	Distribution profile*	Estimated Production TWh/year	Correction factor	Estimated Post Correction production	Estimated capacity factor
Wind	3000	0	hour_wind_eltra2	5,89	0,28	7,02	0,27
Offshore Wind	3000	0	hour_wind_eltra2	5,89	0,77	11,69	0,44
Photo Voltaic	700	0	hour_PV_eltra20l	0,70	0	0,70	0,11
Wave Power	500	0	Hour_wave_200	0,21	0,9605	1,75	0,40
Tidal	0	0	hour_tidal_power	0,00	0	0,00	0,00
Wave Power	0	0	Hour_wave_200	0,00	0	0,00	0,00
CSP Solar Power	0	0	Hour_solar_prod1	0,00	0	0,00	0,00

The input of offshore wind power is now 3000 MW (given the total costs 68594 million DKK/year)

Now change the offshore input to e.g. 4000 MW and calculate the new result. Total costs are 68220 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 approx. 7500 MW offshore (and 3000 MW onshore) and cost equal to approx. 67490 million DKK/year.