

## 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<sub>2</sub> 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".**

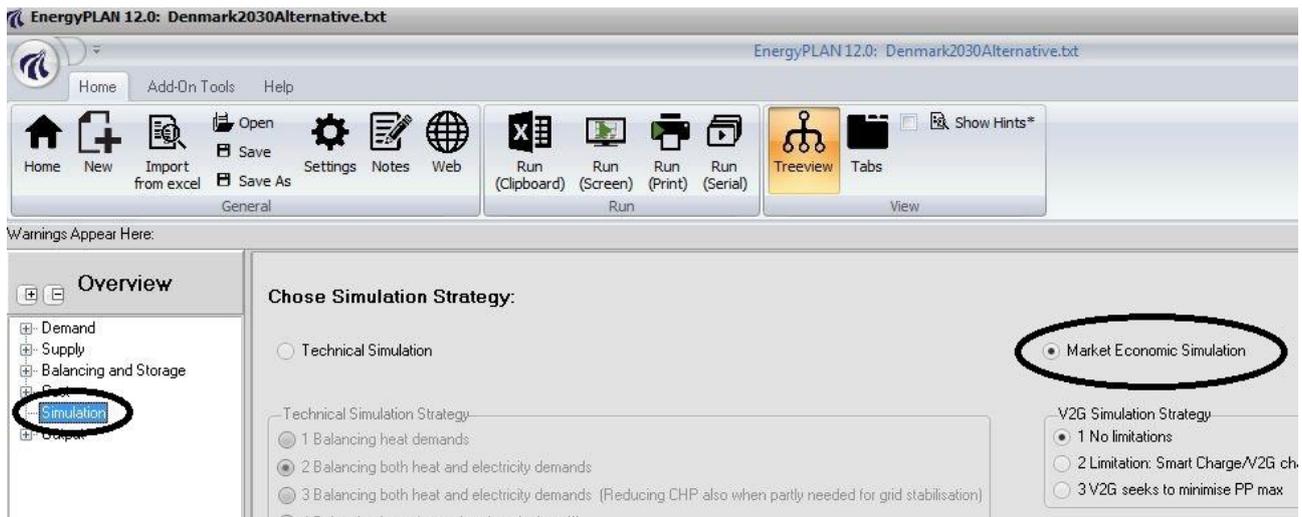
The data set is part of the files, when you download the EnergyPLAN model. If for some reason you do not have the data set, it can be downloaded from the following address :

[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:**

Set the "Market Economic Simulation"



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

Set the Basic Fuel price alternative

EnergyPLAN 12.0: Denmark2030Alternative.txt

Home Add-On Tools Help

Home New Import from excel Save Save As Settings Notes Web Run (Clipboard) Run (Screen) Run (Print) Run (Serial) Treeview

Warnings Appear Here:

**Overview**

- Demand
- Supply
- Balancing and Storage
- Cost
  - General
  - Investment and Fixed OM
  - Fuel**
  - Variable OM
  - External Electricity Market
- Simulation
- Output

### Fuels and Taxes

Fuel price alternative: **Basic** Coal FuelOil Diesel Gasoil Petro

Fuel Price (world market prices) (DKK/GJ): 15.2 49.2 87.9 93.5

Fuel handling costs (distribution and refinery) (DKK/GJ)

- To Biomass Conversion Plants
- To central CHP and power stations: 0.5 1.7
- To dec. CHP, DH and Industry: 0 13.7
- To Individual house holds: 0 20.9

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

Set the CO<sub>2</sub> price to 150 DKK/t CO<sub>2</sub>

EnergyPLAN 12.0: Denmark2030Alternative.txt

Home Add-On Tools Help

Home New Import from excel Save Save As Settings Notes Web Run (Clipboard) Run (Screen) Run (Print) Run (Serial) Treeview Tabs

Warnings Appear Here:

**Overview**

- Demand
- Supply
- Balancing and Storage
- Cost
  - General
  - Investment and Fixed OM
  - Fuel
  - Variable OM
  - External Electricity Market
- Simulation
- Output

Save Cost Data Load New Cost Data

Fixed operation and maintenance costs are required even if the plant is not operated.  
Variable operation and maintenance costs are only necessary if the plant operates and are direct

**Business economic operation:**  
All costs (fuel, handling and taxes) are included in the marginal costs when optimal operation strategies for the individual plants are decided.

**Socio economic consequences:**  
Taxes are not included when the socio economic consequences are calculated.

CO<sub>2</sub> Price (included in marginal production prices): 150 (DKK/t CO<sub>2</sub>)



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

Results	
Waste	0
Ngas Exchange costs	6573
Marginal operation costs	388
Electricity exchange	0
Import	0
Export	0
Bottleneck	0
Fixed imp/exp	0
CO2 emission costs	3127
Variable costs	31976
Fixed operation costs	3436
Annual Investment costs	29486
<b>TOTAL ANNUAL COSTS</b>	<b>64898</b>

	Electr. Demand	Elec dem Cooling	Fixed Exp/Imp	DH Demand	Wind Electr.	Offshore Electr.	PV Electr.	Wave Electr.
TOTAL FOR ONE YEAR (TWh/year):								
Annual:	29.84	0.00	0.00	30.91	6.81	11.69	0.70	1.75

**Step 5: Open the Fuel window:**

Set Fuel price alternative to “Alternative 1”

The screenshot shows the EnergyPLAN 12.0 software interface. The 'Fuels and Taxes' window is open, and 'Alternative 1' is selected in the 'Fuel price alternative' dropdown menu. The fuel prices are listed as follows:

Fuel Price (world market prices) (DKK/GJ)	Coal	FuelOil	Diesel Gasoil	Petrol/JP
	12.4	28.9	51.7	55

Fuel handling costs (distribution and refinery) (DKK/GJ):

To Biomass Conversion Plants	To central CHP and power stations	To dec. CHP, DH and Industry
	0.5	1.7
	0	13.7



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<sub>2</sub> 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)

EnergyPLAN 12.0: exercise5.txt

Home Add-On Tools Help

Home New Import from excel Save Save As Settings Notes Web Run (Clipboard) Run (Screen) Run (Print) Run (Serial) Treeview

Warnings Appear Here:

**Overview**

- Demand
- Supply
- Balancing and Storage
- Cost
  - General
  - Investment and Fixed OM
  - Fuel
  - Variable OM
  - External Electricity Market**
  - Simulation
- Output

**External Electricity Market Definition**

Price distribution:

Addition factor:  DKK/MWh

Multiplication factor:

Resulting average price:  DKK/MWh

**External Electricity Market response to import/export**

Price elasticity:  DKK/MWh pr. MW

Basic price level for price elasticity:  DKK/MWh

**Transmission line capacity**

Maximum imp./exp. cap.:  MW

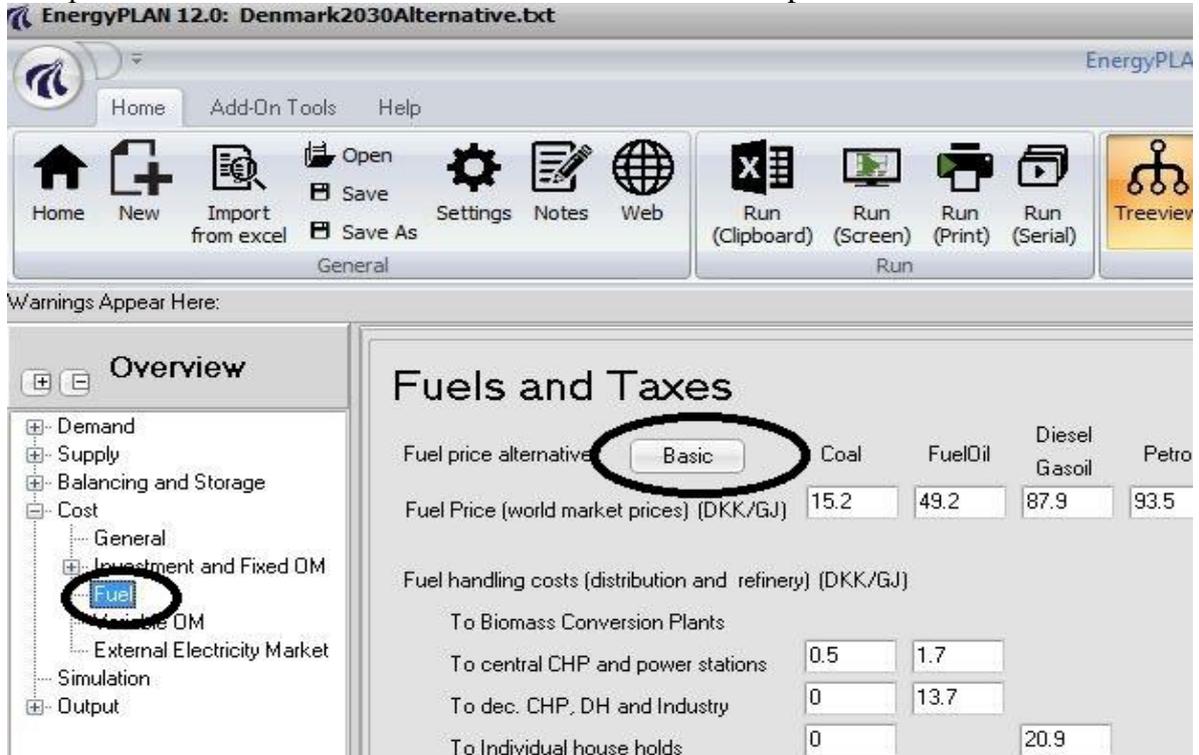
Make sure that external electricity market has an average price of 349 DKK/MWh and that the distribution file "Price\_DKV\_2005.txt" is active.

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.

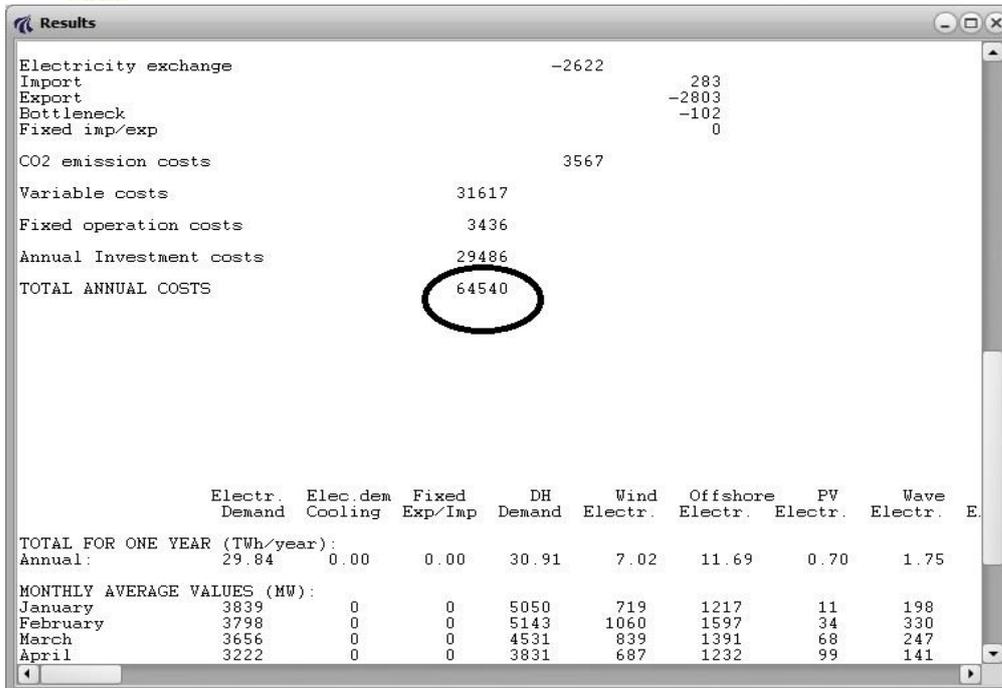
**Step 3: Open the Fuel window:**

Set Fuel price alternative to “Basic” and make sure that the CO<sub>2</sub> price is 150 DKK/t..



Remember to check whether the CO<sub>2</sub> 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:

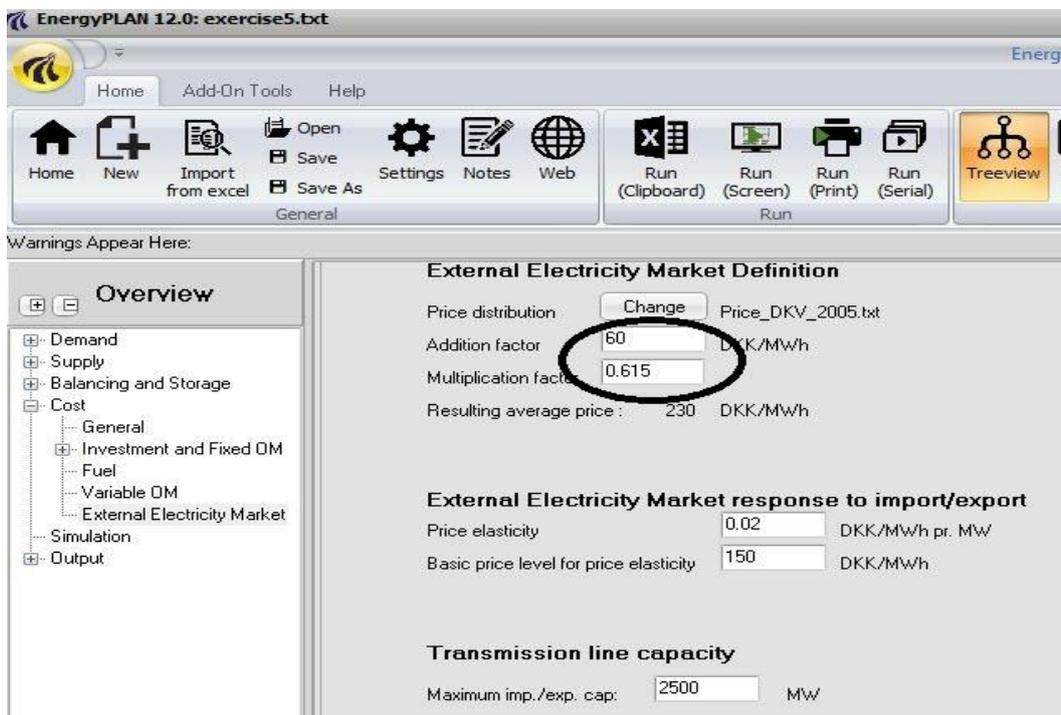
DKK/MWh	Weight	Constant	Variable	Total
Wet year	3	60	170	230
Normal year	3	60	315	374
Dry year	1	60	572	632
7 years average				349

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:**

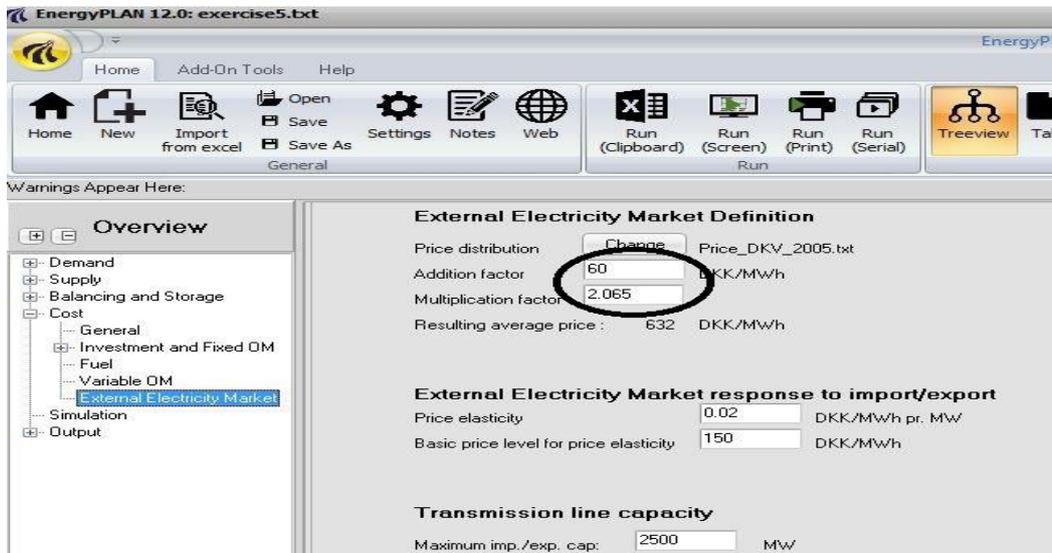
Set Fuel price alternative to “Basic” and calculate

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 DKK/MWh	Fuel price alternatives		
			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**

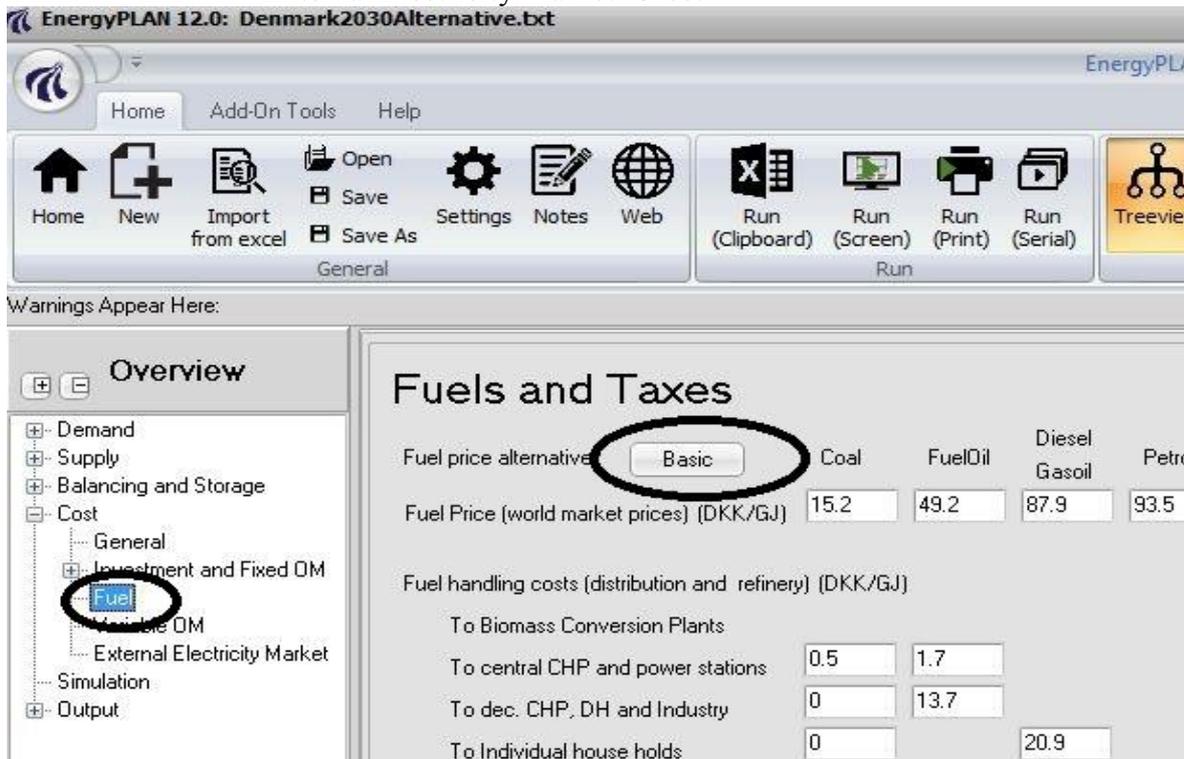
Use the input data set of exercise 5.1, and identify the optimal offshore wind power capacity given an onshore capacity of 3000 MW. Use “Basic” fuel prices.

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

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

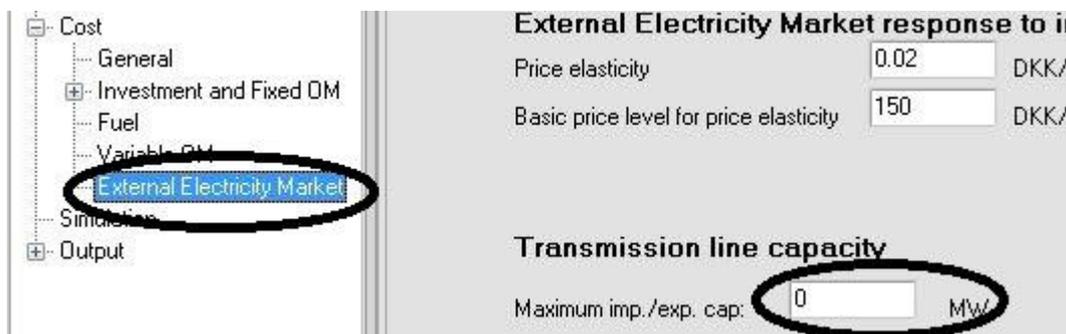
**Step 2: Open the Fuel window:**

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:**

The screenshot shows the EnergyPLAN 12.0 interface with the 'Renewable Energy' window open. The 'Wind offshore' row is circled in red. The table below shows the data for various production types.

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	4	20	0.5	12000	807	60			
Wind offshore	3000 MW-e	8	25	1.46	24000	1378	350			
Photo Voltaic	700 MW-e	7.5	25	0.25	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 Electricity	0 MW-e	0	0	0	0	0	0			

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 screenshot shows the EnergyPLAN 12.0 interface with the 'Electricity Only' window open. The 'Offshore Wind' row in the 'Intermittent Renewable Electricity' table is circled in red.

Renewable Energy Source	Capacity MW	Stabilisation share	Distribution profile	Estimated Production TWh/year	Correction factor	Estimated Post Correction production
Wind	3000	0	hour_wind_eltra2	5.89	0.28	7.02
Offshore Wind	3000	0	hour_wind_eltra2	5.89	0.77	11.69
Photo Voltaic	700	0	hour_FV_eltra20	0.70	0	0.70
Wave Power	500	0	Hour_wave_200	0.21	0.9605	1.75
Tidal	0	0	hour_tidal_power	0.00	0	0.00
Wave Power	0	0	Hour_wave_200	0.00	0	0.00
CSP Solar Power	0	0	Hour_solar_prod1	0.00	0	0.00

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.