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 predefined 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.

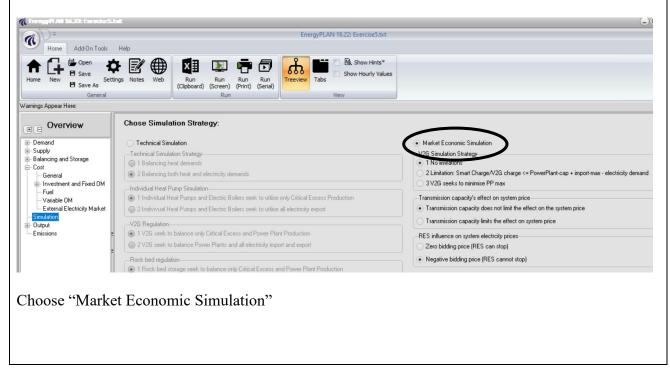
Calculate the socioeconomic costs of the system without any electricity exchange for the three fuel price alternatives already loaded into the model. Use a CO2 cost of 150 DKK/ton.

How to do exercise 5.1:

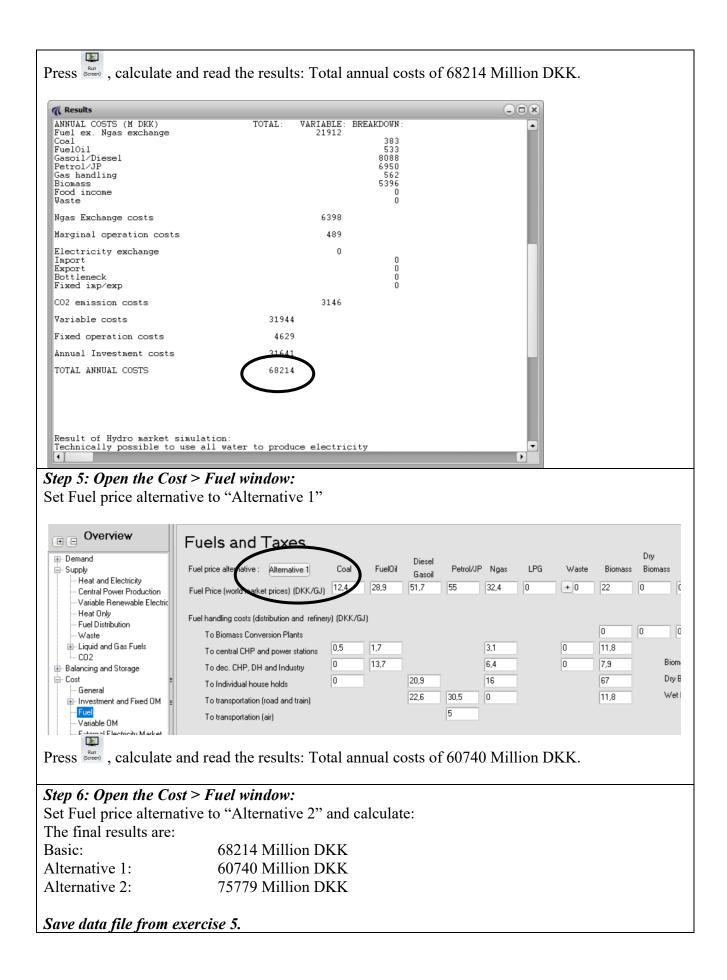
Step 1: Open the EnergyPLAN model and load the input data set "Denmark2030Alternative.txt". The data set is part of the files, when you download the EnergyPLAN model. If for some reason you do not have the data set, it can be downloaded from the following address: : http://www.energyplan.eu/wp-content/uploads/2014/06/EnergyPLAN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

Step 2: Save as exercise 5.

Step 3: Open the Simulation window:



O	Control Derror Der lastice and last
Open the Supply	> Central Power Production window Dammed Hydro Water supply* U Change Hour_wind_1.txt
 Supply Heat and Electricity 	Dammed Hydro Power 0 0,33 0,00 (Estimated)*
Central Power Productio	
Variable Renewable Ele	techic Transmission line capacity* Maximum imp./exp. cap: 0 MV
Heat Only Fuel Distribution Waste	External wish for import export defined by hourly distribution: Change distribution zero.txt Advance
	III Porta land
Set Maximum im	nport/export to 0 MW (closed system).
Stan A. Onan the	cost > General window:
Make sure that th	ne CO2 price is 150 DKK/t
Dverviev	Η
GG	Save Cost Data Load New Cost Data
Supply	Fixed operation and maintenance costs are required even if the plant is not operated.
- Central Power F	
Variable Renew	vable Electric
Heat Only Evel Distribution	Business economic operation: Socio economic consequenses:
Fuel Distribution Waste	n All costs (fuel, handling and taxes) are included Taxes are not included when the socio economic in the marginal costs when optimal operation consequences are calculated.
🕀 Liquid and Gas	
CO2	
Balancing and Stora	age
General	CO2 Price (included in marginal production price) 150 (DKK/t CO2)
	I Fixed OM =
- Fuel	Interest (%): 3
Variable OM External Electric	
Simulation	ally mainer
🚊 Outout	
Open the Cost $>$]	Fuel Window and make sure to choose "Basic"
🥂 Emergy 🕅 All 16222: Emercies Schulz	
	EnergyPLAN 16.22: Exercise5.txt
Home Add-On Tools Help	
	📝 🌐 🕎 🖶 🖶 🔂 🦾 🖬 🖉 & Show Hints*
Home New Settings	Notes Web Run Run Run Run Run Treeview Tabs Treeview Tabs
General Warnings Appear Here:	Run View
Overview F	Fuels and Taxos
⊕- Demand ⊖- Supply F	Fuel price alternative : Basic Qial FuelDil Crunal Petrol/JP Ngas LPG Waste Biomass Biomass Biomass Incl. handling etc. Import
- Heat and Electricity	Fuel Price (world market price) Data Column Feature Feature Data Dottings Difficiency Difficiency <thdifficiency< th=""> Difficiency</thdifficiency<>
- Variable Renewable Electric	
Fuel Distribution	Fuel handling costs (distribution and refinery) (DKK/GJ)
Waste ⊞ Liquid and Gas Fuels	To Biomass Conversion Plants To central CHP and power stations 0.5 1.7 3.1 0 11.8
CO2 ⊕ Balancing and Storage	To dec. CHP, DH and Industry 0 13.7 6.4 0 7.9 Biomass: E.g. straw and wood incl. pellets
⊡- Cost = ⊡- General	To Individual house holds 0 20.9 16 67 Dry Biomass: Green energy crops for Biomass conversion
Investment and Fixed OM = Fuel	To transportation (road and train) 22.6 30.5 0 11.8 Wet Biomass: E.g. manure etc. for biogas production
	r u uensponencin (an)
Simulation	Taxes (DKK/GJ) Individual households 0 60 0 0
Emissions	Industry 0 0 0 0 0
	Boilers (at CHP and DH plants) 69 60 56 0 0 CHD units 17 24 22 0 0
	Compressed Air Energy Storage (CAES)
T	
	Taxes on electricity for energy conversion :
	Taxes on electricity for energy conversion : (DKK/MWh) DH systems Individual houses



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.

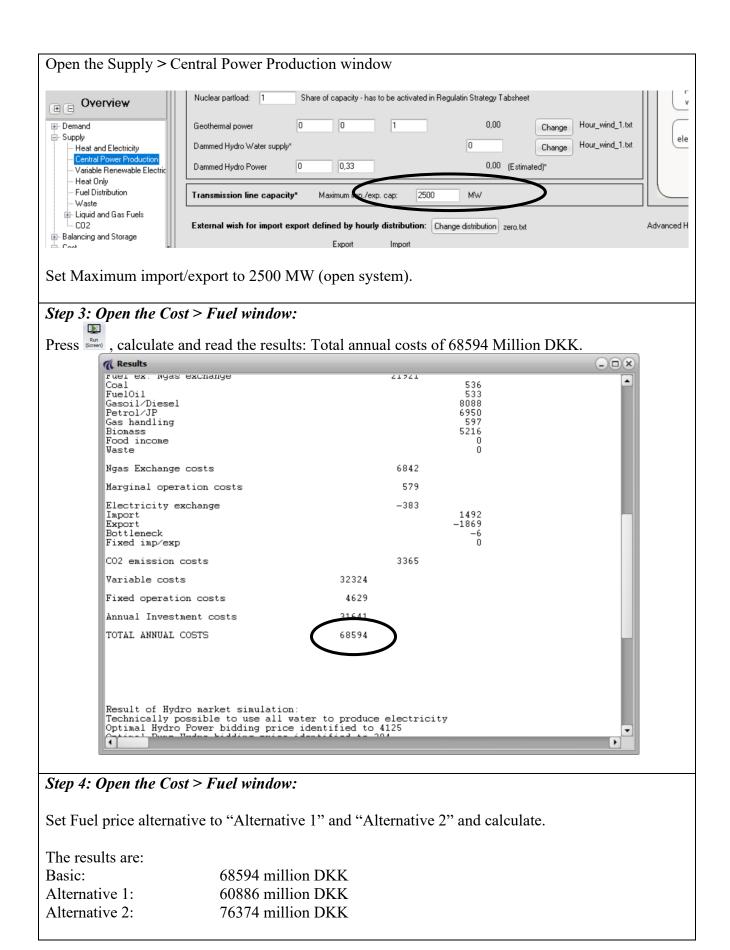
Design an external market with an average price of 349 DKK/MWh using the distribution file "Price_DKV_2005.txt" (The Nord Pool spot market prices of year 2005). The 349 DKK/MWh can be identified by using an addition factor of 60 DKK/MWh and the multiplication factor 1.043.

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

How to do exercise 5.2: (use t	he data set from exercise 5.1)	
Step 1: Load the data file from exe	rcise 5.1:	
Step 2: Open the Cost > External E	Electricity Market window	
Demand Supply Heat and Electricity Central Power Production Variable Renewable Electric Heat Only Fuel Distribution Waste Liquid and Gas Fuels CD2	External Electricity Market Definition Price distribution Change Price_DKV_2005.tx Addition factor 60 DKK/MWh Multiplication factor 1.043 Resulting average price : 349 DK./MWh	
Balancing and Storage Solution Balancing and Storage General General Function Simulation	External Electricity Market response to import/e Price elasticity 0,0200000 DKK/MWh pr. M Basic price level for price elasticity 150 DKK/MWh Maximum Market electricity price 0 DKK/MWh	

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.



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 e	xercise 5.3: (use the data set from exercise 5.1)
Step 1: Load th	he data file from exercise 5.1 and 5.2:
	<i>he Cost > Fuel window:</i> alternative to "Basic".
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	EnergyPLAN 16.22: Exercise5.txt
Home Add-On Tools	Help He
General Warnings Appear Here:	Run View
Overview	Evals and Taxas
Demand Supply Balancing and Storage Cost General Investment and Fixed DM Fuel Variable DM Estimal Electricity Market Simulation Output Emissions	Fuel such Taxes Dig Weit Nuclear/Uraniam Hydrogen Fuel price al motive: Basic Petrol/UP Ngas LPG Wate Biomass Column D <
Step 3: Open to Demand Supply Heat and Electricity Central Power Prod	
Variable Renewable Heat Only Fuel Distribution Waste	
Set Maximum	import/export to 0 MW (closed system).
Press (Green), calc	culate and read the results: Total annual costs of 68594 million DKK.

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EnergyPLAN 16.22: Exercise5.txt									
Home Add-On Tools Hel	p								
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Home New Settings	Notes Web	Run Run F			Tabs Show	Hourly Values			
B Save As	(Clip		Print) (Serial)						
General		Run			View				
arnings Appear Here:									
Question I									
Overview	Prod. type	Investm	ent	Period	O. and M.	Total Inv. Costs	Annual Cos	ts (MDKK/year)	
- Demand		Unit	MDKK pr. Unit	Years	% of Inv.	MDKK	Investment	Fixed Opr. and M.	
- Supply			more pr. one			more	mesanera	rikou opi, una m.	
- Heat and Electricity	Wind	3000 MW/-	-	- 20	0.5	12000	807	60	
- Central Power Production		000018.1		05	1.40	0.0000	4.070		
Wariable Renewable Electric Heat Only	Wind offshore	3000 MW-e	8	25	1,46	24000	1378	350	
- Fuel Distribution	Photo Voltaic	700 MW-e		(0,20	5250	301	13	
Waste	T Hoto Vokaic	100 MW-6	1,0	20	0,20	5250	301	15	
⊕- Liquid and Gas Fuels	Wave power	500 MW-e	14	30	1,13	7000	357	79	
CO2									
⊡-Balancing and Storage ⊡-Cost ≘	Tidal Power	0 MW	0	0	0	0	0	0	
General				_					
Investment and Fixed OM =	CSP Solar Power	0 MW	0	0	0	0	0	0	
- Heat and Electricity	River of hydro	0 MW-e	0	0	0	0	0	0	
Renewable Energy	niver or hydro	U MW-e	0	0	0	U	U	0	
 Liquid and Gas Fuels Heat Infrastructure 	Hydro Power	0 MW-e	0	0	0	0	0	0	
- Road Vehicles	nyao rono.						, i i i i i i i i i i i i i i i i i i i	•	
- Other Vehicles	Hydro Storage	0 GWh	0	0	0	0	0	0	
Water									
- Additional	Hydro Pump	0 MW-e	0	0	0	0	0	0	
Fuel									
- Variable OM - External Electricity Market	Geothermal Electr.	0 MW-e	0	0	0	0	0	0	
Simulation	Geothermal Heat	0 TWh/year	0	0	0	0	0	0	
- Output	ceothermai meat	u i wn/year	0	0	0	U	U	0	
Emissions	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: **Overview** Estimated Variable Renewable Electricity Estimated Post Correction 🛨 Demand Renewable Capacity: Stabilisation Distribution profile* Production Correction Estimated 🛓 - Supply capacity factor Energy Source MW TWh/year share factor production Heat and Electricity Wind 3000 0 5,89 0.28 7,02 Change hour_wind_eltra2 0,27 Central Power Production -Offshore Wind 3000 0 0.77 hour_wind_eltra2 5,89 11,69 0,44 -Change Heat Only - Fuel Distribution Photo Voltaic 700 0 0 0,70 0,70 0,11 -Change hour_PV_eltra20(- Waste Wave Power 500 0 0,21 0.9605 1,75 🗈 Liquid and Gas Fuels -Change Hour_wave_200* 0,40 - 002 Tidal 0 0 0,00 0 0,00 0.00 Change hour tidal power • - Balancing and Storage - Cost 0 0 0.00 0 0.00 0.00 Wave Power -Change Hour_wave_200° - General CSP Solar Power 0 0 Change Hour_solar_prod1 0,00 0 0,00 - Investment and Fixed OM -0,00 Heat and Electricity 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.