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Guideline to EnergyPLAN Exercise 3: More Simple Energy System Analyses.

Exercise 3 continues from exercise 2 and here you are asked to implement more energy system improvements in the energy system. Through the exercise and the guideline, you learn step by step how to analyse more changes to the energy system.

Exercise 3 continues with the system defined in exercise 2, which is:

- Electricity demand of 34.3 TWh/year and "hour-eldemand-eltra-2001"
- Condensing power plant: 9000 MW coal –fired
- 2000 MW on-shore wind power using "Hour_wind_eltra2001"
- 3000 MW off-shore wind power using "OffshoreHornsRef2003RAMSES.txt"
- Annual district heating demand of total 27.43 TWh divided into 1.59 TWh district heating oil-boilers, 10 TWh small-scale CHP and 15.84 TWh large-scale CHP extraction plants (distribution "Hour_distr-heat-2-50procent.txt").
- Decentralised CHP of total 1350 MW, eff-th = 50%, eff-el = 41% on natural gas, and Heat Pump of 300 MWe, COP=3.
- Large-scale CHP of total 2000 MW, eff-th = 50%, eff-el = 41% on coal.
- Fuel demand for individual house heating of total 14.42 TWh divided into 0.01 coal, 4.2 oil, 5.66 natural gas and 4.55 biomass.
- Industrial fuel demand of 53.66 TWh divided into 3.37 coal, 26.92 oil, 18.19 natural gas and 5.18 biomass (including fuel for district heating and electricity production).
- Industrial district heating production of 1.73 TWh and an electricity production of 2.41 TWh. Use the hour distribution file "const".
- Fuel demand for transportation: 13.25 TWh Jet Petrol, 27.50 TWh Diesel and 28.45 TWh Petrol.

The system has a primary energy supply of 201.57 TWh/year and CO2 emissions of 47.14 Mt. and excess electricity production of 0.72 TWh/year.

Exercise 3.1: Add Waste Resources

Open the EnergyPLAN model. Load the data of exercise 2. Add 6 TWh/year of waste resources to the system. Divide the resources geographically into

- 1 TWh in gr. 1,
- 2 TWh in gr. 2 and
- 3 TWh in gr. 3.

Question 3.1.1: What are the excess production, the primary energy supply and the CO2 emission of the system, IF all waste resources are converted into heat with an efficiency of 80%?

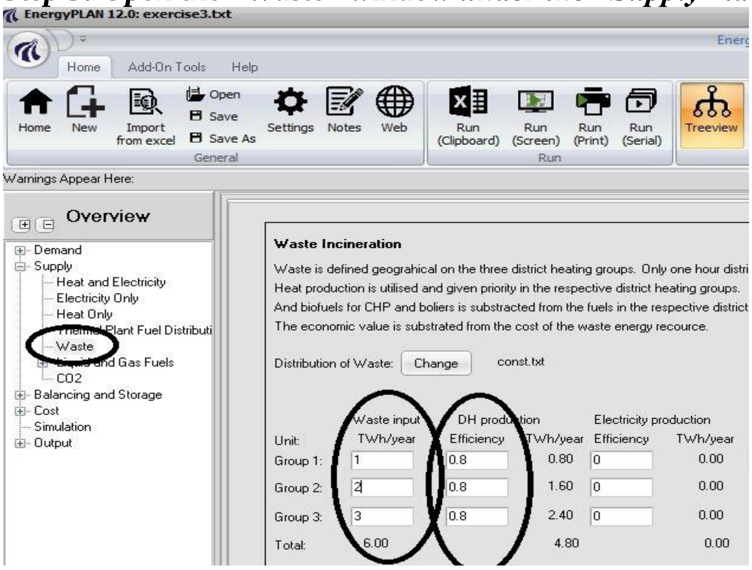
Question 3.1.2: What are the excess production, the primary energy supply and the CO2 emission of the system, IF all waste resources are utilised in CHP with an electric efficiency of 30% and a heat efficiency of 50%?

How to do exercise 3.1: Use Input data file from exercise 2

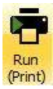
Step 1: Open the EnergyPLAN model and load data from exercise 2.

Step 2: Save as exercise 3.

Step 3: Open the "Waste" window under the "Supply" tab and add the input numbers:



Step 4: Calculate and see result in print output (or clipboard)

Activate the 

button and read the results of question 3.1.1:

	Demand: Distr. heating MW	Production: Solar MW	Waste+ CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Consumption: Elec. demand MW	Flex.& Transp. MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW
January	4481	0	743	169	2265	591	0	725	0	-12	4348	0	197	0	0	0
February	4564	0	743	174	3039	377	0	218	0	13	4349	0	126	0	0	0
March	4021	0	743	142	2555	332	0	261	0	-14	4242	0	111	0	0	0
April	3399	0	743	106	1939	393	0	206	0	11	3819	0	131	0	0	0
May	2859	0	743	75	1843	163	0	33	0	3	3609	0	54	0	0	0
June	1784	0	743	12	943	102	0	0	0	-17	3543	0	34	0	0	0
July	1784	0	743	12	980	62	0	0	0	-14	3259	0	21	0	0	0
August	1784	0	743	12	970	81	0	0	0	-24	3687	0	27	0	0	0
September	2261	0	743	40	1319	139	0	13	0	6	3748	0	46	0	0	0
October	2930	0	743	79	1689	303	0	131	0	-15	3931	0	101	0	0	0
November	3566	0	743	116	2002	438	0	260	0	7	4186	0	146	0	0	0
December	4085	0	743	146	2294	432	0	459	0	10	4154	0	144	0	0	0
Average	3123	0	743	90	1816	284	0	193	0	-4	3905	0	95	0	0	0
Maximum	7161	0	743	324	4085	900	0	3410	0	1811	6111	0	300	0	0	0
Minimum	1673	0	743	6	549	0	0	0	0	-1969	0	0	0	0	0	0
TWh/year	27,43	0,00	6,53	0,79	15,95	2,50	0,00	1,69	0,00	-0,03	34,30	0,00	0,83	0,00	0,00	0,00

	Production: Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste+ CSHP MW	CHP MW	PP MW	Balance: Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Payment Imp Million DKK	Payment Exp Million DKK
January	0	2344	0	0	274	1857	136	100	0	67	67	0	0	9
February	0	1495	0	0	274	2492	227	100	0	14	14	0	0	2
March	0	1705	0	0	274	2095	317	100	0	39	39	0	0	5
April	0	2009	0	0	274	1590	153	100	0	76	76	0	0	11
May	0	1285	0	0	274	1511	636	100	0	43	43	0	0	6
June	0	1533	0	0	274	773	1127	100	0	131	131	0	0	17
July	0	1187	0	0	274	803	1077	100	0	62	62	0	0	5
August	0	1547	0	0	274	796	1176	100	0	79	79	0	0	12
September	0	1499	0	0	274	1082	1001	100	0	62	62	0	0	10
October	0	2047	0	0	274	1385	498	100	0	172	172	0	0	30
November	0	2342	0	0	274	1642	239	100	0	165	165	0	0	27
December	0	2061	0	0	274	1881	205	100	0	124	124	0	0	16
Average	0	1755	0	0	274	1489	567	100	0	86	86	0	Average price	
Maximum	0	4968	0	0	274	3350	3795	100	0	2526	2526	0	(DKK/MWh)	
Minimum	0	1	0	0	274	450	0	100	0	0	0	0	214	199
TWh/year	0,00	15,42	0,00	0,00	2,41	13,08	4,98		0,00	0,76	0,76	0,00	0	151

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	Wave	Hydro	Solar.Th.	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	20,65	0,08	0,39	11,07	-	-	-	-	-	-	-	-	-	-	-	-	0,01	3,37	35,58	-1,68	33,89	12,17	11,59
Oil	0,88	-	-	0,08	0,39	-	-	-	-	-	-	-	-	-	-	-	-	69,20	4,20	26,92	101,67	0,00	101,67	27,08	27,08
N.Gas	-	11,25	-	0,08	0,39	-	-	-	-	-	-	-	-	-	-	-	-	-	5,66	18,19	35,57	0,00	35,57	7,26	7,26
Biomass	-	-	-	0,08	0,39	-	-	-	6,00	-	-	-	-	-	-	-	-	-	4,55	5,18	16,20	0,00	16,20	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	3,93	11,49	-	-	-	-	-	-	15,42	0,00	15,42	0,00	0,00
H2 etc.	-	-	-	0,00	0,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	0,88	11,25	20,65	0,31	1,57	11,07	-	-	6,00	-	-	-	3,93	11,49	-	-	-	69,20	14,42	53,66	204,43	-1,68	202,75	46,51	45,94

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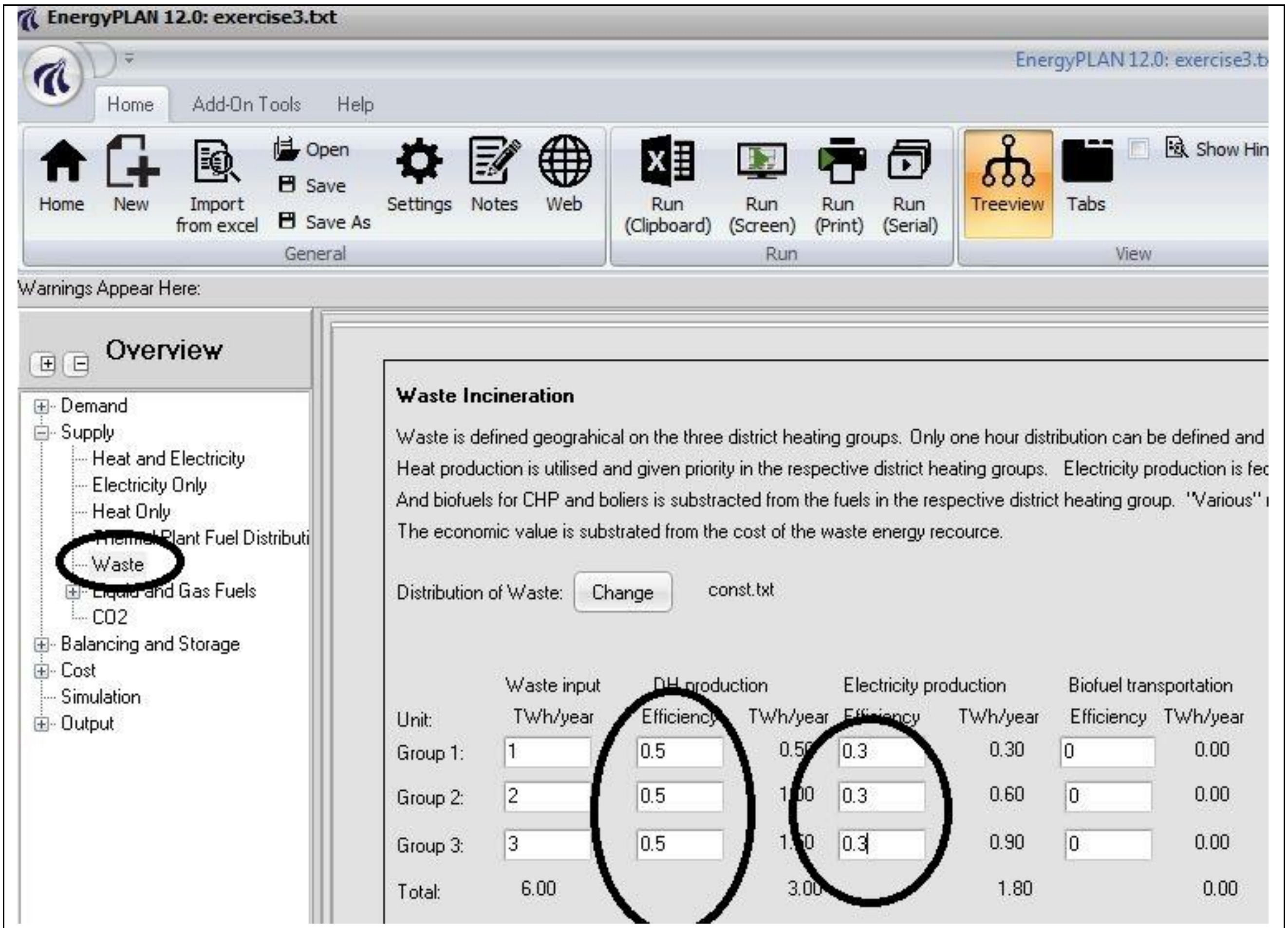
The Primary energy supply has been raised from 201.57 to 204.43 TWh/year.
The CO2 emission has been reduced from 47.14 to 46.51 Mt/year.
The Critical Excess Electricity Production (CEEP) is raised from 0.72 to 0.76 TWh/year.

Step 5: Open the Input Waste window and add new input values:



Step 6: Calculate and see result in print output (or clipboard)

Activate the  button and read the results of question 3.1.2:

The Primary energy supply has been reduced from 204.43 to 202.72 TWh/year.
The CO_2 emission has been reduced from 46.51 to 45.81 Mt/year.
The Critical Excess Electricity Production (CEEP) has raised from 0.76 to 1.03 TWh/year.

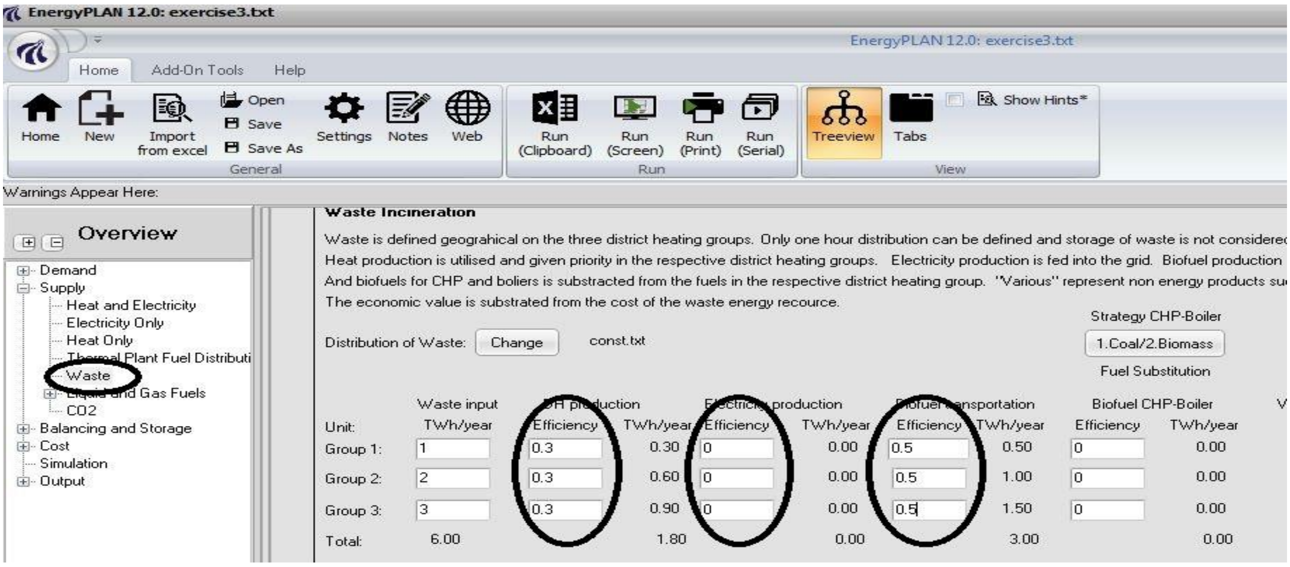
Exercise 3.2: Waste Resources used for producing biogas for transportation

Use the waste resources for producing biogas and heat instead of CHP with a biogas output of 50% and a heat output of 30%. Let the biogas replace diesel in cars by 1 to 1.

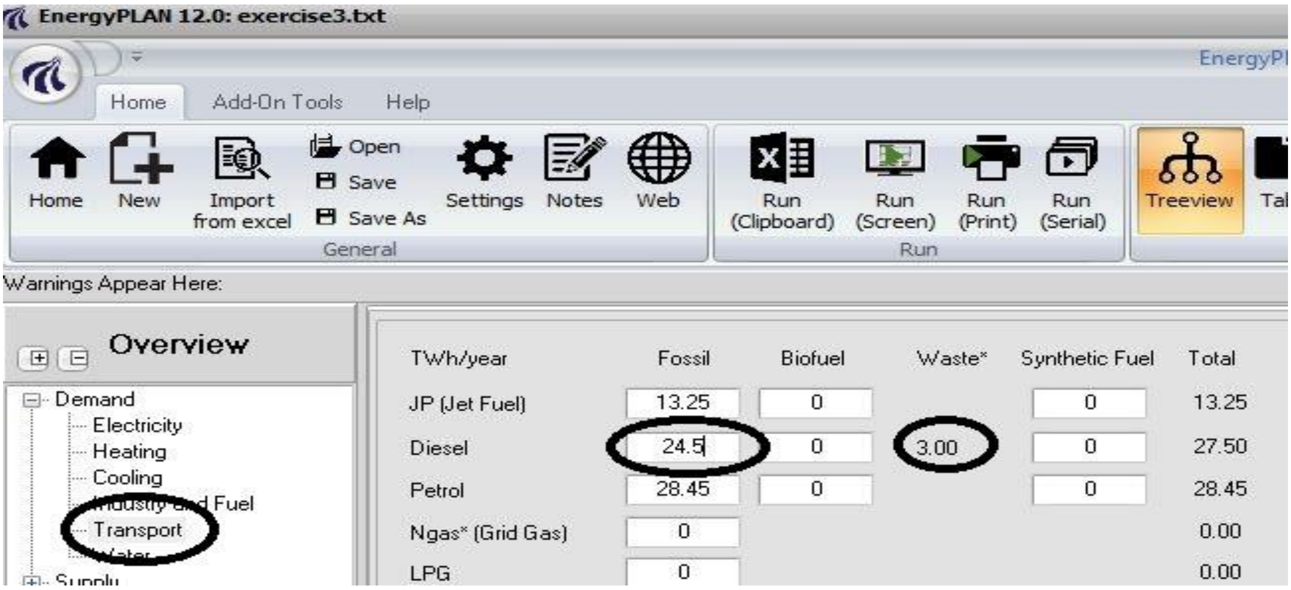
Question 3.2.1: What are the excess production, the primary energy supply and the CO2 emission of the system?

How to do exercise 3.2: Use Input data file from exercise 3.1

Step 1: Open the "Waste" window under the "Supply" tab and change the input numbers:



Step 2: Open the "Transport" window under the "Demand" tab:



Note: The biofuels from waste have already been transferred.
Change diesel from 27.5 to 24.5

Step 3: Calculate and see result in print output (or clipboard)

Activate the 

button and read the results of question 3.2.1:
The Primary energy supply has increased from 202.72 to 203.32 TWh/year.
The CO_2 emission has increased from 45.81 to 46.08 Mt/year.
The Critical Excess Electricity Production (CEEP) has decreased from 1.03 to 0.74 TWh/year.

Exercise 3.3: Wind and hydrogen for transportation

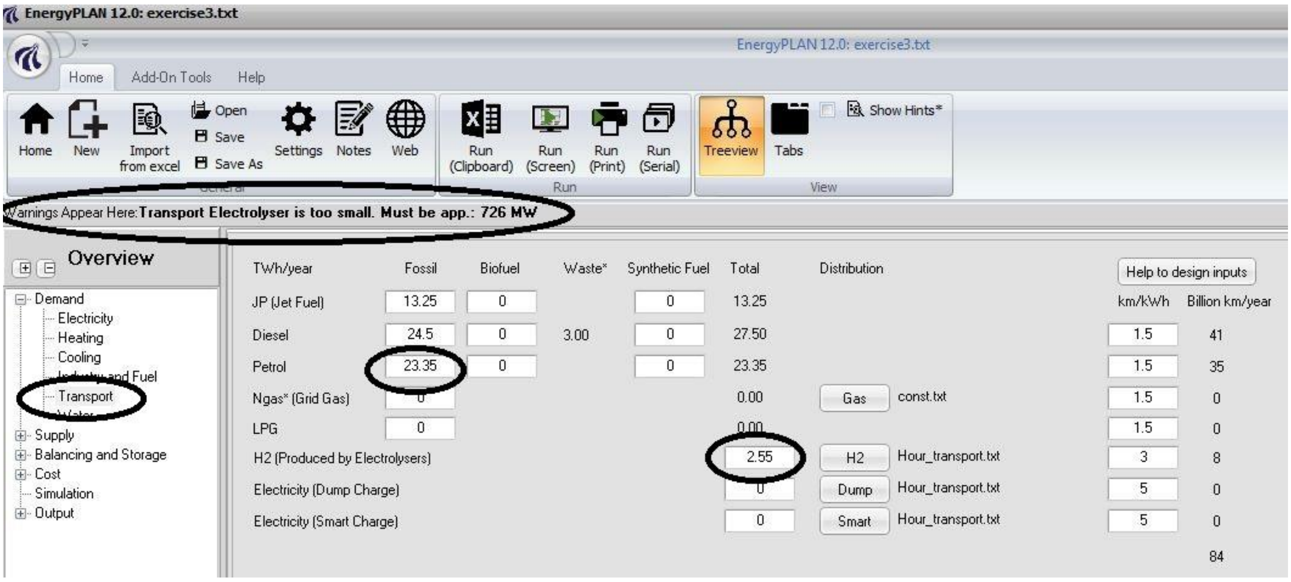
Add 2000 MW wind power producing 3.93 TWh electricity in combination with electrolysers producing 2.55 TWh hydrogen for transportation with an efficiency of 65%. Let the hydrogen replace petrol cars (1.5 km/kWh) with HFCV (3.0 km/kWh).

Question 3.3.1: What are the excess production, the primary energy supply and the CO2 emission of the system?

How to do exercise 3.3: Use Input data file from exercise 3.2

Step 1: Open the "Electricity Only" window under the "Supply" tab and increase wind power from 2000 to 4000 MW:

Step 2: Open the "Transport" window under the "Demand" tab:



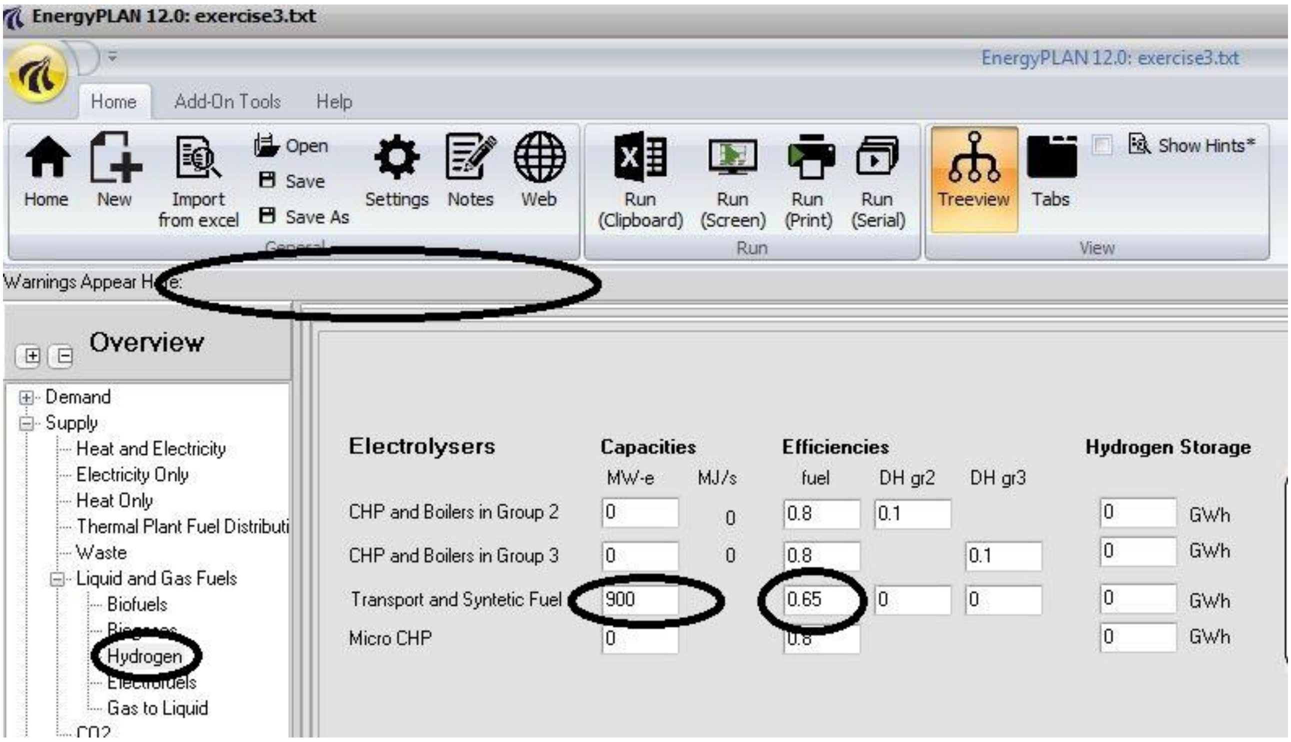
Activate the "Help to design inputs" button and receive assistance for the calculation of km transportation.

Add 2.55 TWh Hydrogen leading to 7.65 billion km/year.

Subtract 7.65 billion km/year on petrol cars equal to 5.1 TWh petrol.

NOTE that you have to add electrolysers in order to produce the hydrogen.

Step 3: Open the “Hydrogen window under the “Liquid and Gas Fuels” tab under the “Supply” tab and add electrolysers.



Add efficiency input = 65% and capacity = 900 MW.

NOTE that the remark on missing electrolysers disappears

Step 4: Calculate and see result in print output (or clipboard)

Activate the  button and read the results of question 3.3.1:

The Primary energy supply has decreased from 203.32 to 202.8 TWh/year.
The CO_2 emission has decreased from 46.08 to 44.94 Mt/year.
The Critical Excess Electricity Production (CEEP) has increased from 0.74 to 0.95 TWh/year.

Note: If you have got a different result, check if you remembered to change the wind power from 2000 to 4000 MW..!

Exercise 3.4: Add Solar Thermal in Individual houses

Add 1 TWh solar thermal (equal to app. 10% of heat demand) to individual houses with natural gas boilers. Use the hour distribution "Hour_SolarThermal_IndvDK.txt".

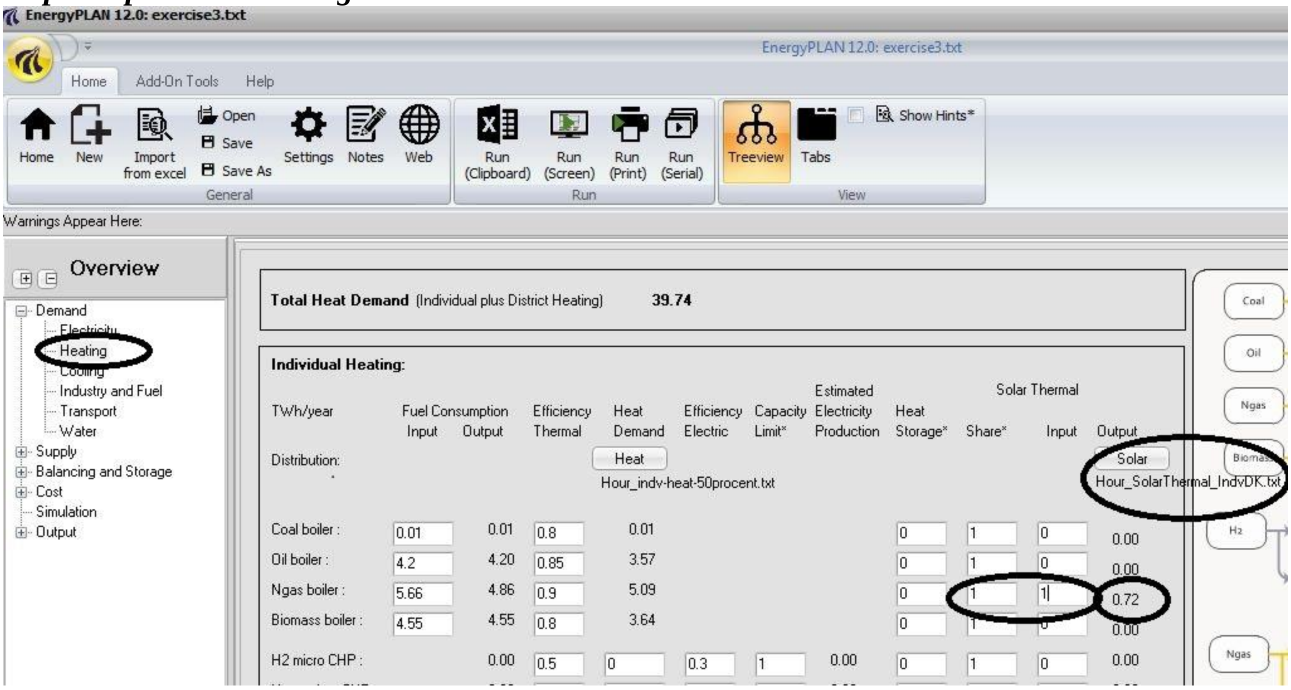
Question 3.4.1: How much of the solar thermal can be utilised?

Question 3.4.2: How much storage capacity is needed in order to utilise all solar thermal production?

Question 3.4.3: What are the excess production, the primary energy supply and the CO2 emission of the system?

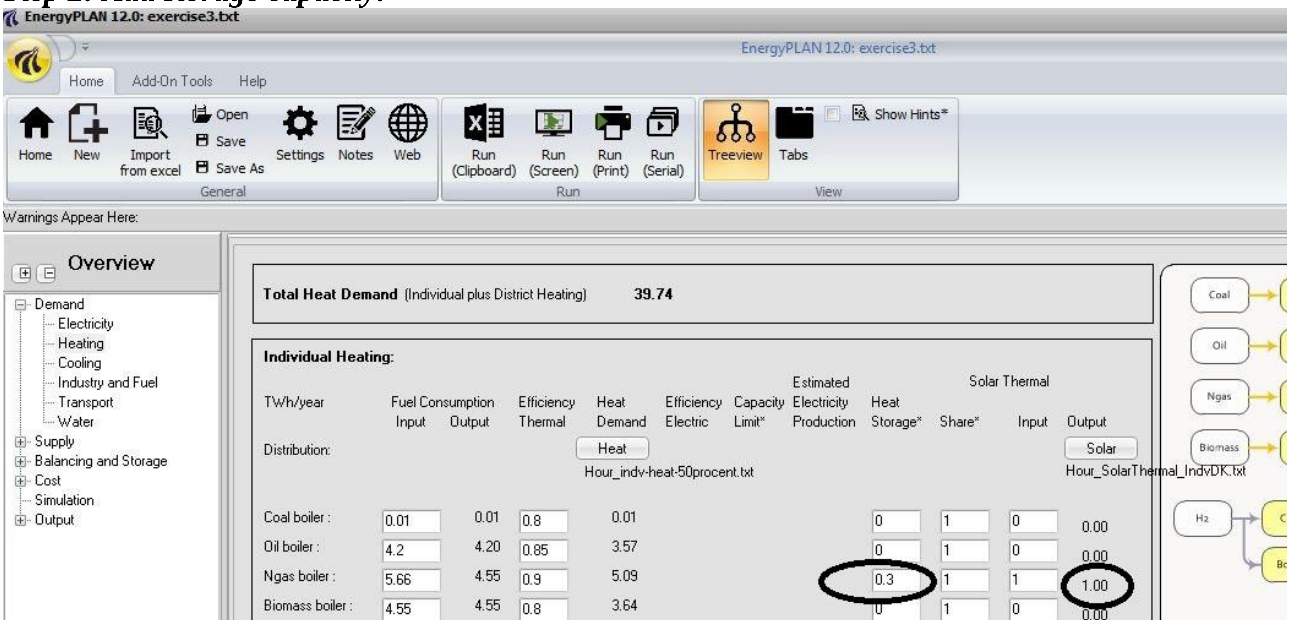
How to do exercise 3.4: Use Input data file from exercise 3.3

Step 1: Open the "Heating" window under the "Demand" tab:



Change hour distribution to "Hour_SolarThermal_IndvDK.txt";
Add 1 TWh of solar thermal to Ngas Boilers;
Read the result of question 3.4.1: 0.72 TWh of solar thermal production are utilised.

Step 2: Add storage capacity:



The answer to question 3.4.2 is found by adding heat storage capacity to the system. All solar thermal production can be utilised when the storage capacity is equal to 0.3 days of average heat demand.

Step 3: Calculate and see result in print output (or clipboard)

Activate the 

button and read the results of question 3.4.3:

The Primary energy supply has decreased from 202.8 to 202.69 TWh/year.
The CO_2 emission has decreased from 44.94 to 44.72 Mt/year.
The Critical Excess Electricity Production (CEEP) is still 0.95 TWh/year.

Exercise 3.5: Add Solar Thermal to the district heating system

Add 2 TWh solar thermal (equal to app. 20% of district heating demand) to district heating group 2. Use the hour distribution “Hour_SolarThermal_CenDK.txt”.

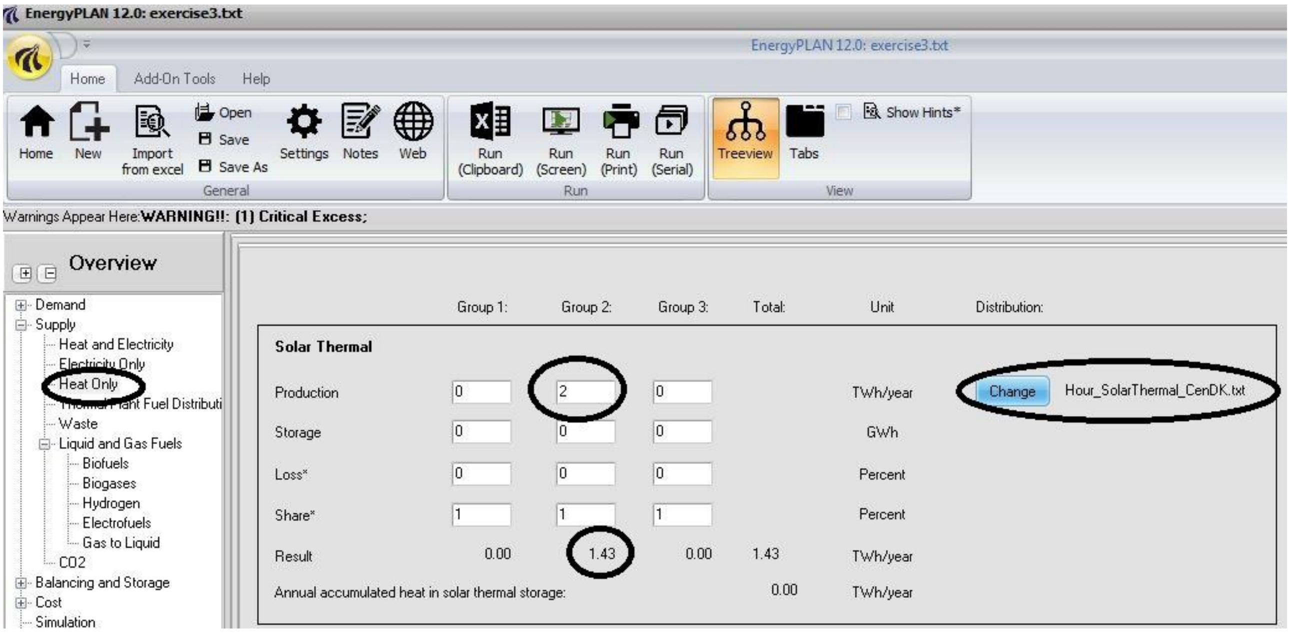
Question 3.5.1: How much of the solar thermal can be utilised?

Question 3.5.2: How much storage capacity is needed in order to utilise all solar thermal production?

Question 3.5.3: What are the excess production, the primary energy supply and the CO2 emission of the system?

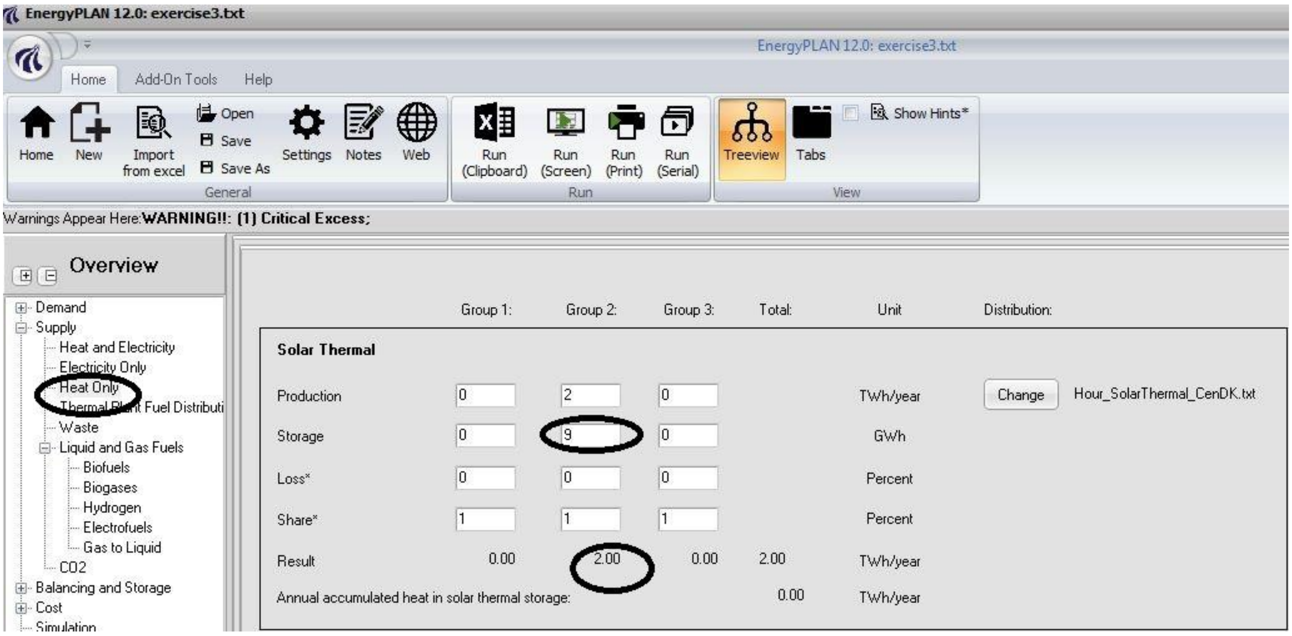
How to do exercise 3.5: Use Input data file from exercise 3.4

Step 1: Open the “Heat Only” window under the “Supply” tab:



Change hour distribution to “Hour_SolarThermal_CenDK.txt”;
Add 2 TWh of solar thermal to District Heating Group 2;
Read the result of question 3.5.1: 1.43 TWh of solar thermal production are utilised.

Step 2: Add storage capacity:



The answer to question 3.5.2 is found by adding heat storage capacity to the system. All solar thermal production can be utilised when the storage capacity is equal to 9 GWh.

Step 3: Calculate and see result in print output (or clipboard)

Activate the 

button and read the results of question 3.5.3:

The Primary energy supply has increased from 202.69 to 204.02 TWh/year.
The CO_2 emission has increased from 44.72 to 44.88 Mt/year.
The Critical Excess Electricity Production (CEEP) has increased from 0.95 to 1.00 TWh/year.

Remark: The reason for the increase in PES and CO2 is partly based on the fact that not all solar thermal and heat produced on waste can be utilised, and partly on the fact that solar thermal to some extent hinders the heat pump from utilising CEEP.

REMEMBER to save exercise 3.