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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 "DK 2013 electricity demand"
- Condensing power plant: 9000 MW coal –fired
- 2000 MW on-shore wind power using "Hour_wind_1"
- 3000 MW off-shore wind power using "DK 2013 Wind Offshore"
- 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 200.64 TWh/year and CO2 emissions of 46.45 Mt. and excess electricity production of 0 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%?

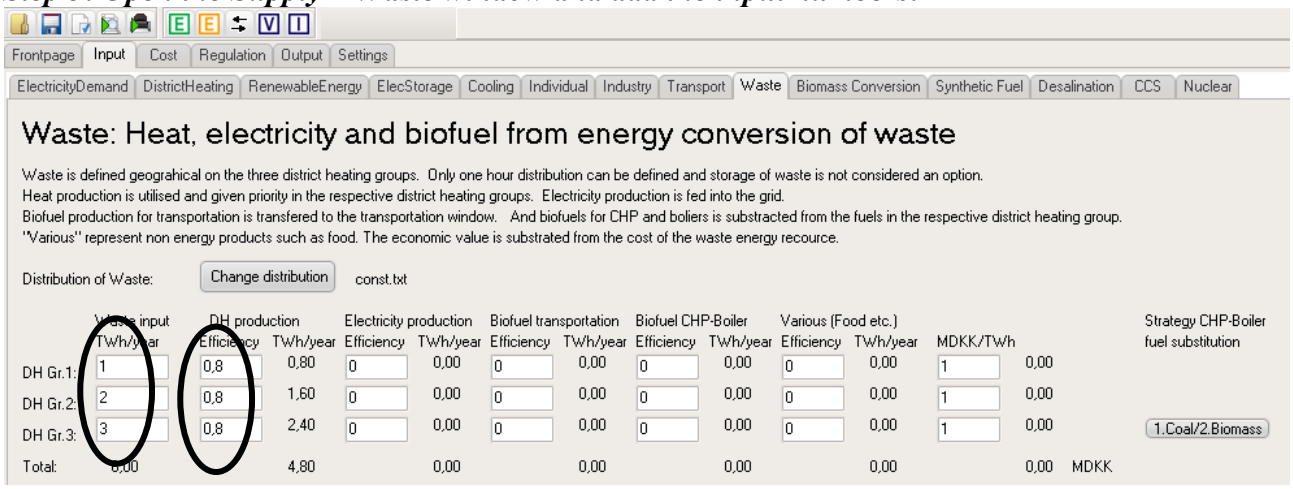
Question 3.1.2: What are the excess production, the primary energy supply and the CO2 emission of the system, IF all waste resources are utilised in CHP with an electric efficiency of 30% and a heat efficiency of 50%?

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 Supply > Waste window and add the input numbers:



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

Activate the ”Run (print)” button and read the results of question 3.1.1:

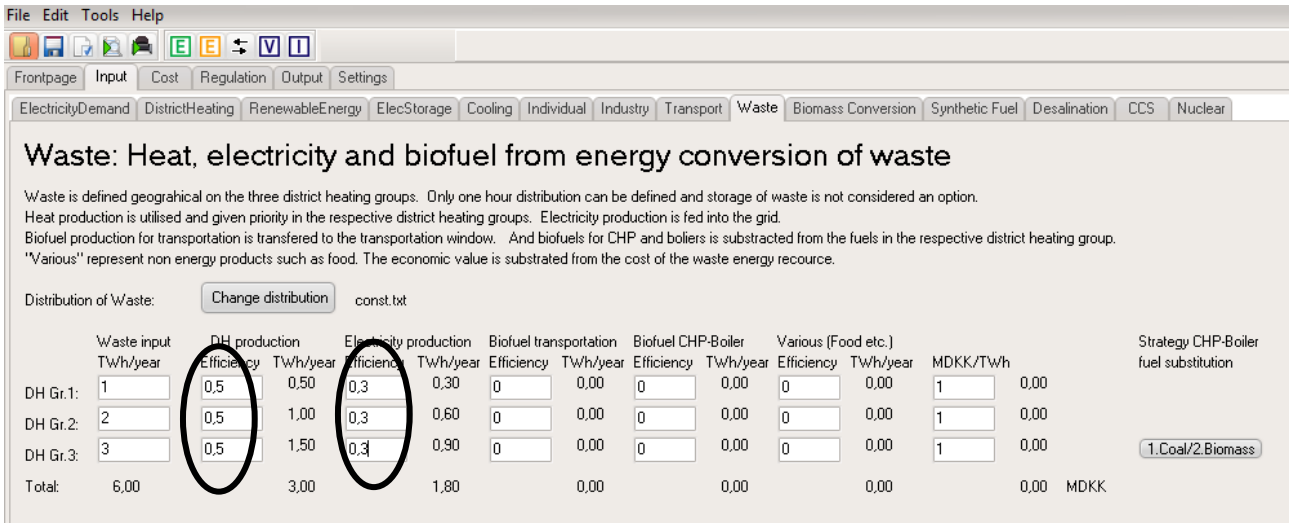
Output WARNING!!: (1) Critical Excess;

	District Heating										Electricity																Exchange	
	Demand	Production									Consumption						Production							Balance					Payment	
	Distr. heating MW	Solar MW	Waste+ CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Elec. demand MW	Flex.& Transp. MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste+ CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Imp Million DKK	Exp Million DKK
January	4674	0	821	180	2625	467	0	553	31	-3	4556	0	156	0	31	0	0	2121	0	0	197	2153	272	100	0	0	0	0	0	0
February	4768	0	821	185	2939	390	0	414	16	3	4430	0	130	0	16	0	0	1778	0	0	197	2410	192	100	0	0	0	0	0	0
March	4147	0	821	149	2351	370	0	434	36	-15	4241	0	123	0	36	0	0	2034	0	0	197	1928	242	100	0	0	0	0	0	0
April	3438	0	821	108	2367	127	0	37	28	-51	3827	0	42	0	28	0	0	1583	0	0	197	1941	177	100	0	0	0	0	0	0
May	2823	0	821	73	1840	42	0	5	29	14	3533	0	14	0	29	0	0	1410	0	0	197	1509	460	100	0	0	0	0	0	0
June	1594	0	821	3	684	60	0	0	44	-17	3524	0	20	0	44	0	0	1548	0	0	197	561	1292	100	0	9	9	0	0	1
July	1594	0	821	3	741	16	0	0	14	0	3358	0	5	0	14	0	0	994	0	0	197	608	1579	100	0	0	0	0	0	0
August	1594	0	821	3	691	42	0	0	29	9	3526	0	14	0	29	0	0	1408	0	0	197	567	1399	100	0	0	0	0	0	0
September	2139	0	821	33	1229	43	0	0	21	-8	3676	0	14	0	21	0	0	1451	0	0	197	1008	1057	100	0	1	1	0	0	0
October	2903	0	821	77	1564	222	0	113	42	65	3884	0	74	0	42	0	0	2152	0	0	197	1283	368	100	0	0	0	0	0	0
November	3630	0	821	119	2076	342	0	198	75	-2	4136	0	114	0	75	0	0	2128	0	0	197	1703	298	100	0	0	0	0	0	0
December	4221	0	821	154	1829	538	0	732	144	4	4185	0	179	0	144	0	0	2547	0	0	197	1500	264	100	0	0	0	0	0	0
Average	3123	0	821	90	1740	222	0	208	43	0	3905	0	74	0	43	0	0	1764	0	0	197	1427	635	100	0	1	1	0	Average price	
Maximum	7744	0	821	358	4085	900	0	4828	1930	4203	6203	0	300	0	1930	0	0	4868	0	0	197	3350	3376	100	0	998	998	0	(DKK/MWh)	
Minimum	1488	0	821	0	0	0	0	0	0	-2233	2322	0	0	0	0	0	0	30	0	0	197	0	0	100	0	0	0	0	182	166
TWh/year	27,43	0,00	7,21	0,79	15,28	1,95	0,00	1,82	0,37	0,00	34,30	0,00	0,65	0,00	0,37	0,00	0,00	15,49	0,00	0,00	1,73	12,53	5,58		0,00	0,01	0,01	0,00	0	1

FUEL BALANCE (TWh/year):	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste/ HTL	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th.	Transp.	household.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	16,56	0,28	0,22	12,39	-	-	-	-	-	-	-	-	-	-	-	-	0,01	3,37	32,84	-0,02	32,82	11,23	11,23
Oil	0,88	-	-	0,28	0,22	-	-	-	-	-	-	-	-	-	-	-	-	69,20	4,20	26,92	101,71	0,00	101,71	27,10	27,10
N.Gas	-	14,01	-	0,28	0,22	-	-	-	-	-	-	-	-	-	-	-	-	-	4,66	18,19	37,36	0,00	37,36	7,63	7,63
Biomass	-	-	-	0,28	0,22	-	-	-	6,00	-	-	-	-	-	-	-	-	-	4,55	5,18	16,24	0,00	16,24	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	4,15	-	11,34	-	-	-	-	-	15,49	0,00	15,49	0,00	0,00
H2 etc.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	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	14,01	16,56	1,14	0,89	12,39	-	-	6,00	-	-	-	4,15	-	11,34	-	-	69,20	13,42	53,66	203,64	-0,02	203,63	45,95	45,95

The Primary energy supply has been raised from 200,64 to 203.64 TWh/year.
The CO2 emission has been reduced from 46.45 to 45.95 Mt/year.
The Critical Excess Electricity Production (CEEP) is raised from 0 to 0.01 TWh/year.

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



Step 6: Calculate and see result in print output (or clipboard)
Activate the ”Run (print)” button and read the results of question 3.1.2:

The Primary energy supply has been reduced from 203.64 to 201.65 TWh/year.
The CO2 emission has been reduced from 45,95 to 45.12 Mt/year.
The Critical Excess Electricity Production (CEEP) is still 0.01 TWh/year.

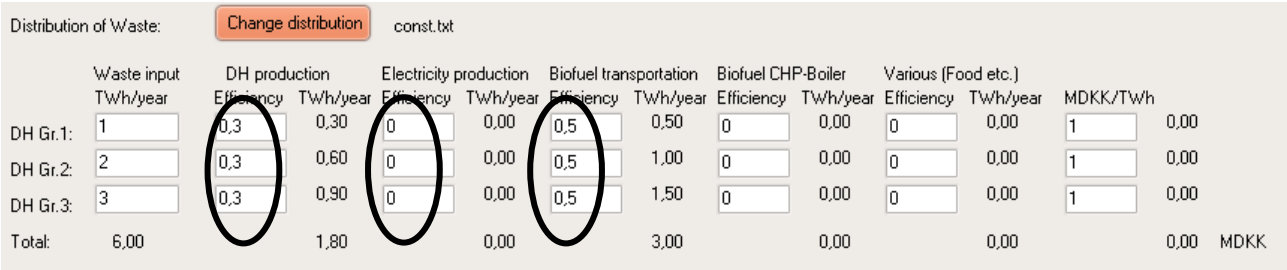
Exercise 3.2: Waste Resources used for producing biogas for transportation

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.

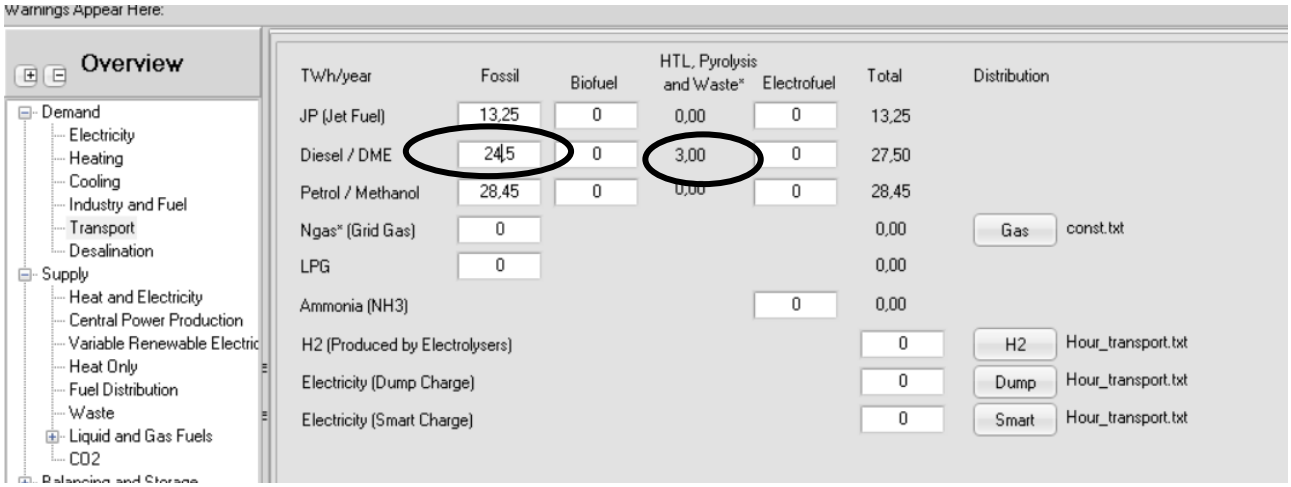
Question 3.2.1: What are the excess production, the primary energy supply and the CO2 emission of the system?

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

Step 1: Open the Supply > Waste window and change the input numbers:



Step 2: Open the Demand > Transport window:



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 ”Run (print)” button and read the results of question 3.2.1:
The Primary energy supply has increased from 201.65 to 202.45 TWh/year.
The CO2 emission has increased from 45.12 to 45,44 Mt/year.
The Critical Excess Electricity Production (CEEP) has decreased from 0,01 to 0 TWh/year.

Exercise 3.3: Wind and hydrogen for transportation

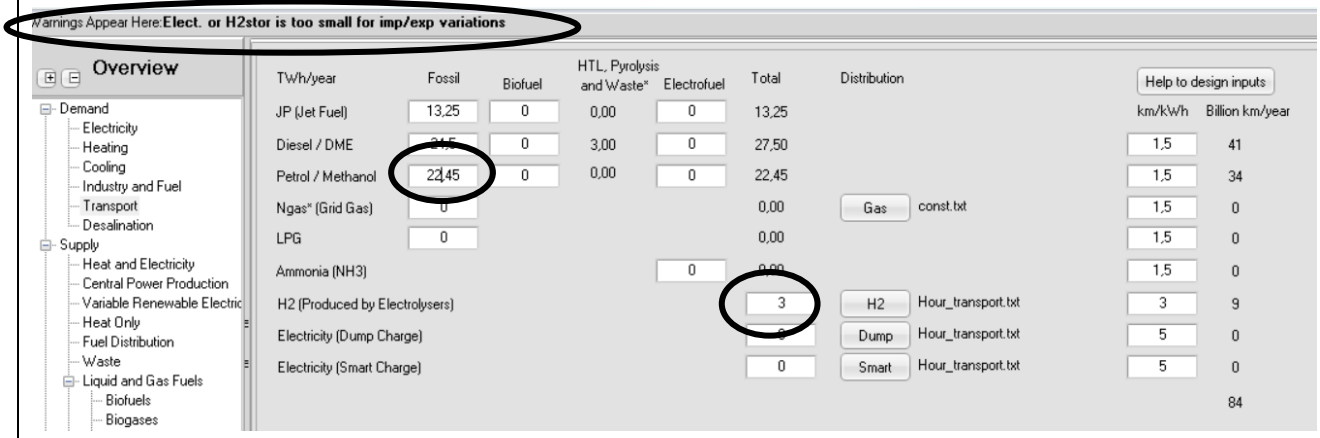
Add 2000 MW wind power producing 4,15 TWh electricity in combination with electrolysers producing 3.00 TWh hydrogen for transportation with an efficiency of 72,3% and a capacity of 500 MW. Let the hydrogen replace petrol cars (1.5 km/kWh) with HFCV (3.0 km/kWh).

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 Supply > Variable Renewable Energy window and increase wind power from 2000 to 4000 MW.

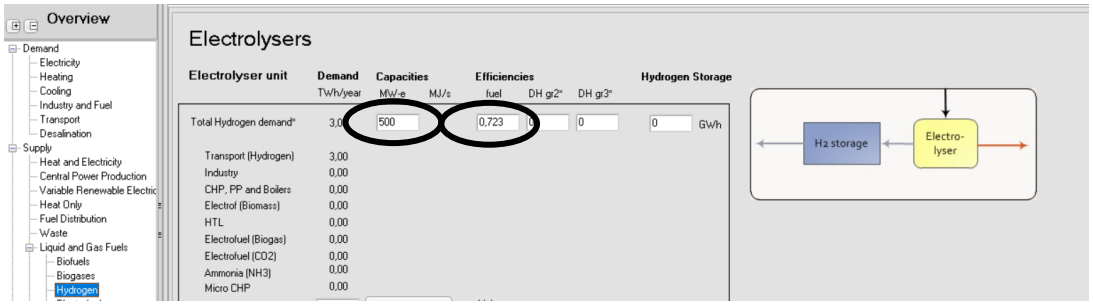
Step 2: Open the Demand > Transport window:



Activate the 

button and receive assistance for the calculation of km transportation.
Add 3 TWh Hydrogen leading to 9 billion km/year.
Subtract 9 billion km/year on petrol cars equal to 6 TWh petrol.
NOTE that you have to add electrolysers in order to produce the hydrogen.

Step 3: Open the Supply > Liquid and Gas Fuels > Hydrogen window and add electrolysers.



Add efficiency input = 72,3 % and capacity = 500 MW.

NOTE that the remark on missing electrolysers disappears

Step 4: Calculate and see result in print output (or clipboard)
Activate the ”Run (print)” button and read the results of question 3.3.1:

The Primary energy supply has decreased from 202.45 to 201.75 TWh/year.
The CO2 emission has decreased from 45.44 to 44.32 Mt/year.
The Critical Excess Electricity Production (CEEP) has increased from 0.01 to 0.02 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. 20% of heat demand) to individual houses with natural gas boilers. Use the hour distribution "Hour_SolarThermal_CenDK.txt".

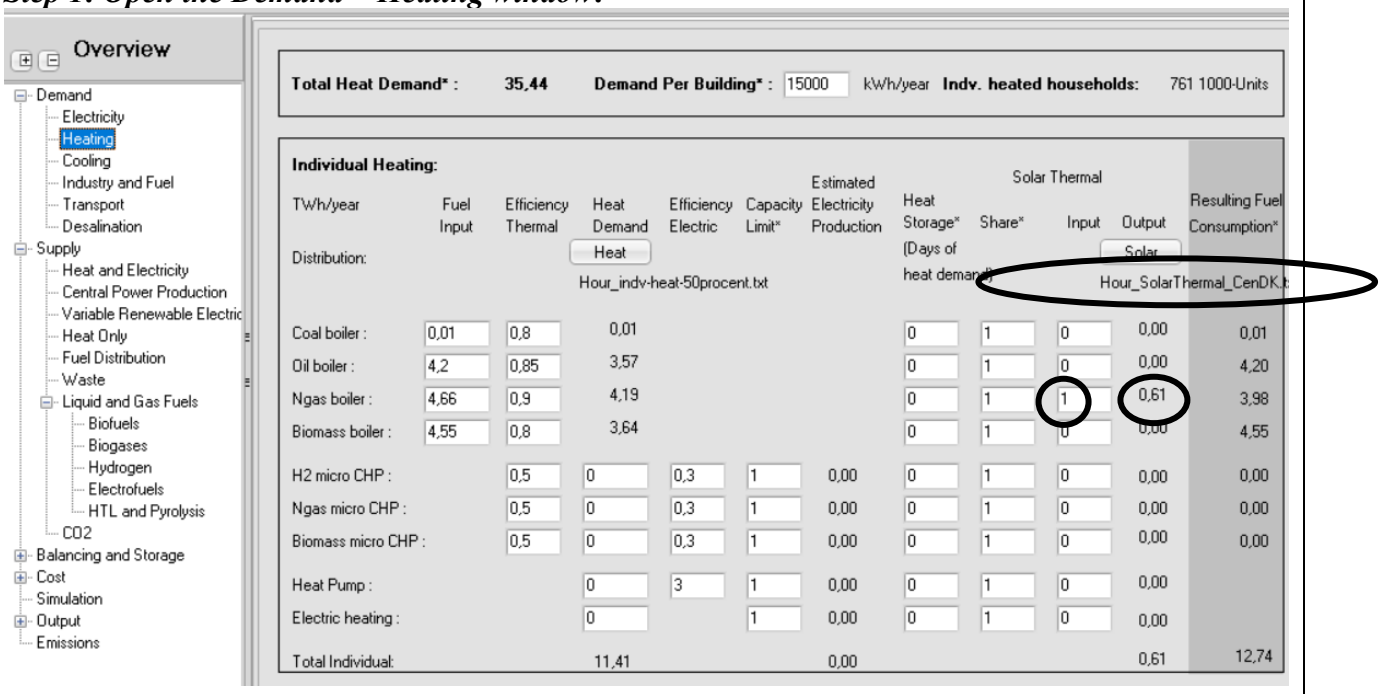
Question 3.4.1: How much of the solar thermal can be utilised?

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?

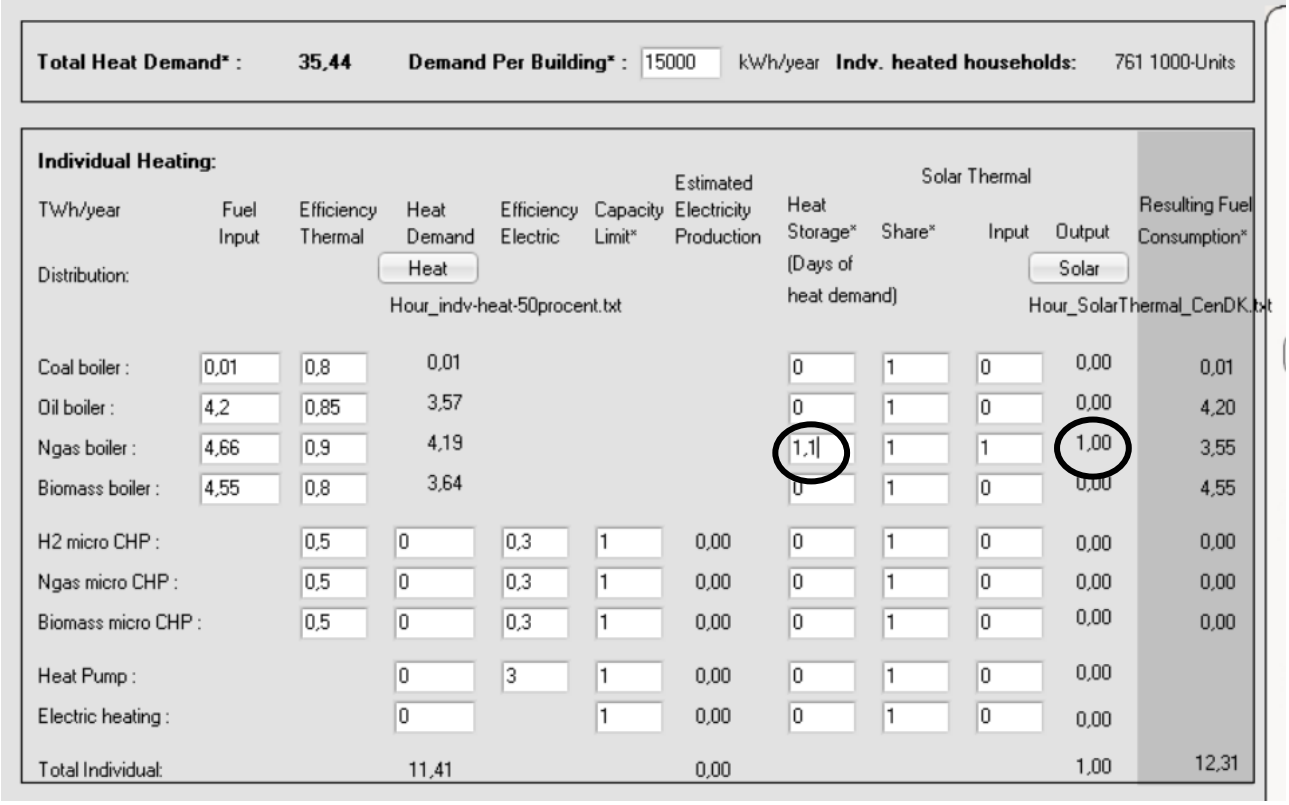
How to do exercise 3.4: Use Input data file from exercise 3.3

Step 1: Open the Demand > Heating window:



Change hour distribution to "Hour_SolarThermal_CenDK.txt"
Add 1 TWh of solar thermal to Ngas Boilers
Read the result of question 3.4.1: 0.61 TWh of solar thermal production are utilised.

Step 2: Add storage capacity:



Total Heat Demand* : 35,44 **Demand Per Building* :** 15000 kWh/year **Indv. heated households:** 761 1000-Units

Individual Heating:

TWh/year	Fuel Input	Efficiency Thermal	Heat Demand	Efficiency Electric	Capacity Limit*	Estimated Electricity Production	Solar Thermal: Heat Storage* (Days of heat demand)	Solar Thermal: Share*	Solar Thermal: Input	Solar Thermal: Output	Resulting Fuel Consumption*
Distribution:			Heat							Solar	
			Hour_indv-heat-50procent.txt							Hour_SolarThermal_CenDK.txt	
Coal boiler :	0,01	0,8	0,01				0	1	0	0,00	0,01
Oil boiler :	4,2	0,85	3,57				0	1	0	0,00	4,20
Ngas boiler :	4,66	0,9	4,19				1,1	1	1	1,00	3,55
Biomass boiler :	4,55	0,8	3,64				0	1	0	0,00	4,55
H2 micro CHP :		0,5	0	0,3	1	0,00	0	1	0	0,00	0,00
Ngas micro CHP :		0,5	0	0,3	1	0,00	0	1	0	0,00	0,00
Biomass micro CHP :		0,5	0	0,3	1	0,00	0	1	0	0,00	0,00
Heat Pump :			0	3	1	0,00	0	1	0	0,00	
Electric heating :			0		1	0,00	0	1	0	0,00	
Total Individual:			11,41			0,00				1,00	12,31

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 1.1 days of average heat demand.

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

Activate the ”Run (print)” button and read the results of question 3.4.3:
The Primary energy supply has decreased from 201.75 to 201,64 TWh/year.
The CO2 emission has decreased from 44.32 to 44.1 Mt/year.
The Critical Excess Electricity Production (CEEP) is still 0.02 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".

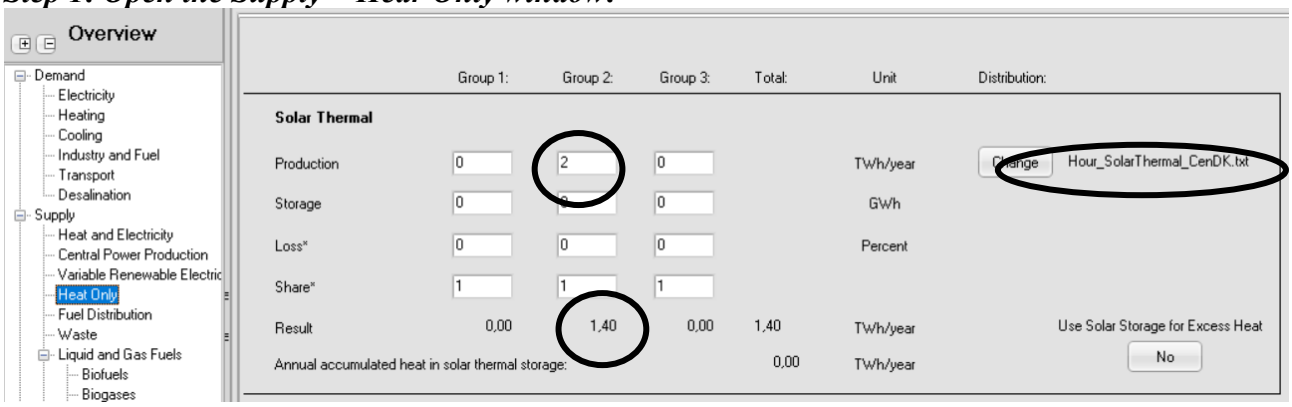
Question 3.5.1: How much of the solar thermal can be utilised?

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?

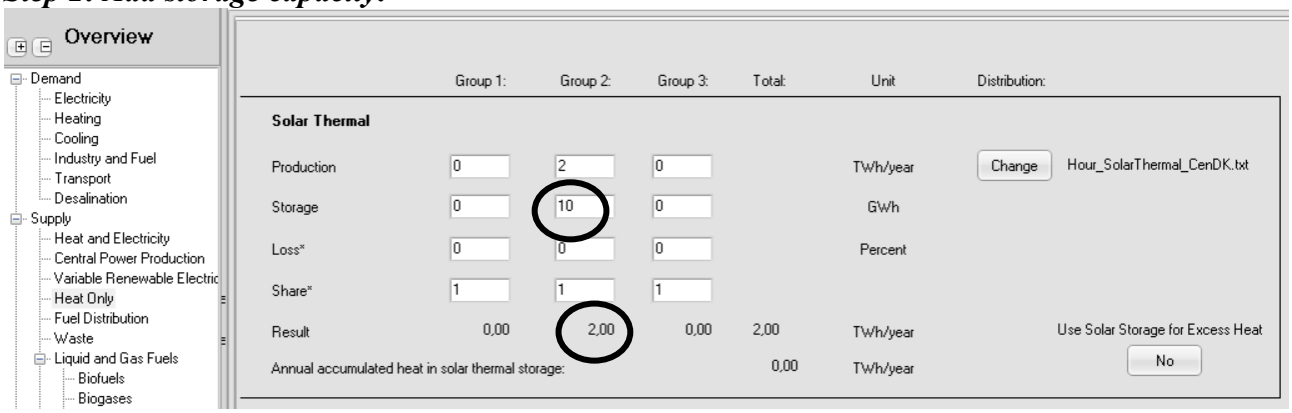
How to do exercise 3.5: Use Input data file from exercise 3.4

Step 1: Open the Supply > Hear Only window:



Change hour distribution to "Hour_SolarThermal_CenDK.txt"
Add 2 TWh of solar thermal to District Heating gr. 2
Read the result of question 3.5.1: 1.40 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 ”Run (print)” button and read the results of question 3.5.3:

The Primary energy supply has increased from 201,64 to 202.86 TWh/year.
The CO2 emission has increased from 44.1 to 44.3 Mt/year.
The Critical Excess Electricity Production (CEEP) has increased from 0.02 to 0.05 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.