

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 offshorewind 2013.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 “VpDkFjv50.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 2.41 TWh and an electricity production of 1.73 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:

Waste: Heat, electricity and biofuel from energy conversion of waste

Waste is defined geographical on the three district heating groups. Only one hour distribution can be defined and storage of waste is not considered an option. Heat production is utilised and given priority in the respective district heating groups. Electricity production is fed into the grid. Biofuel production for transportation is transferred to the transportation window. And biofuels for CHP and boilers is subtracted from the fuels in the respective district heating group. "Various" represent non energy products such as food. The economic value is subtracted from the cost of the waste energy resource.

Distribution of Waste: const.txt

	Waste input TWh/year	DH production		Electricity production		Biofuel transportation		Biofuel CHP-Boiler		Various (Food etc.)		MDKK/TWh	Strategy CHP-Boiler fuel substitution
		Efficiency	TWh/year	Efficiency	TWh/year	Efficiency	TWh/year	Efficiency	TWh/year	Efficiency	TWh/year		
DH Gr. 1:	1	0,8	0,80	0	0,00	0	0,00	0	0,00	0	0,00	1	0,00
DH Gr. 2:	2	0,8	1,60	0	0,00	0	0,00	0	0,00	0	0,00	1	0,00
DH Gr. 3:	3	0,8	2,40	0	0,00	0	0,00	0	0,00	0	0,00	1	0,00
Total:	6,00		4,80		0,00		0,00		0,00		0,00		0,00 MDKK

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;																																	
Demand	Distr. heating	District Heating										Consumption										Electricity								Balance				Exchange	
		Solar	Waste+	CSHP	DHP	CHP	HP	ELT	Boiler	EH	Ba-	Elec.	Flex.&	Transp.	HP	Elec-	EH	Hydro	Tur-	RES	Hy-	Geo-	Waste+	CSHP	CHP	PP	Stab-	Imp	Exp	CEEP	EEP	Imp	Exp		
MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	
January	4674	0	821	180	2625	467	0	553	31	-3	4556	0	156	0	31	0	0	0	2121	0	0	167	2153	272	100	0	0	0	0	0	0	0	0	0	
February	4798	0	821	165	2639	390	0	414	16	3	4430	0	130	0	16	0	0	0	1778	0	0	167	2410	162	100	0	0	0	0	0	0	0	0	0	
March	4147	0	821	146	2351	370	0	434	36	-15	4241	0	123	0	36	0	0	0	2034	0	0	167	1928	242	100	0	0	0	0	0	0	0	0	0	
April	3436	0	821	106	2367	127	0	37	28	-51	3627	0	42	0	28	0	0	0	1583	0	0	167	1641	177	100	0	0	0	0	0	0	0	0	0	
May	2823	0	821	73	1840	42	0	5	29	-14	3533	0	14	0	29	0	0	0	1410	0	0	167	1506	460	100	0	0	0	0	0	0	0	0	0	0
June	1594	0	821	3	894	60	0	44	-17	3524	0	20	0	44	0	0	0	0	1548	0	0	167	561	1292	100	0	9	9	0	0	0	0	0	1	
July	1594	0	821	3	741	18	0	14	0	0	3358	0	5	0	14	0	0	0	994	0	0	167	608	1579	100	0	0	0	0	0	0	0	0	0	0
August	1594	0	821	3	661	42	0	29	9	3526	0	14	0	29	0	0	0	0	1408	0	0	167	567	1369	100	0	0	0	0	0	0	0	0	0	0
September	2139	0	821	33	1229	43	0	21	-8	3676	0	14	0	21	0	0	0	0	1451	0	0	167	1008	1057	100	0	1	1	0	0	0	0	0	0	0
October	2903	0	821	77	1564	222	0	113	42	65	3884	0	74	0	42	0	0	0	2152	0	0	167	1283	368	100	0	0	0	0	0	0	0	0	0	0
November	3630	0	821	119	2076	342	0	198	75	-2	4136	0	114	0	75	0	0	0	2128	0	0	167	1703	268	100	0	0	0	0	0	0	0	0	0	0
December	4221	0	821	154	1829	538	0	732	144	4	4185	0	179	0	144	0	0	0	2547	0	0	167	1500	264	100	0	0	0	0	0	0	0	0	0	0
Average	3123	0	821	90	1740	222	0	208	43	0	3605	0	74	0	43	0	0	0	1764	0	0	167	1427	635	100	0	1	1	0	0	0	0	0	0	Average price
Maximum	7744	0	821	356	4085	900	0	4628	1930	4203	6203	0	300	0	1930	0	0	0	4968	0	0	167	3350	3376	100	0	998	998	0	0	0	0	0	162	166
Minimum	1498	0	821	0	0	0	0	0	0	-2233	2322	0	0	0	0	0	0	0	30	0	0	167	0	0	100	0	0	0	0	0	0	0	0	0	0
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	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	BioCon	Electro-	Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th.	Transp.	househ.	Industry Various	Total	Imp/Exp	Corrected	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:

Waste: Heat, electricity and biofuel from energy conversion of waste

Waste is defined geographical on the three district heating groups. Only one hour distribution can be defined and storage of waste is not considered an option. Heat production is utilised and given priority in the respective district heating groups. Electricity production is fed into the grid. Biofuel production for transportation is transferred to the transportation window. And biofuels for CHP and boilers is subtracted from the fuels in the respective district heating group. "Various" represent non energy products such as food. The economic value is subtracted from the cost of the waste energy recourse.

Distribution of Waste: const.txt

	Waste input TWh/year	DH production Efficiency	DH production TWh/year	Electricity production Efficiency	Electricity production TWh/year	Biofuel transportation Efficiency	Biofuel transportation TWh/year	Biofuel CHP-Boiler Efficiency	Biofuel CHP-Boiler TWh/year	Various (Food etc.) Efficiency	Various (Food etc.) TWh/year	MDKK/TWh	
DH Gr.1:	<input type="text" value="1"/>	<input type="text" value="0,5"/>	<input type="text" value="0,50"/>	<input type="text" value="0,3"/>	<input type="text" value="0,30"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="1"/>	<input type="text" value="0,00"/>
DH Gr.2:	<input type="text" value="2"/>	<input type="text" value="0,5"/>	<input type="text" value="1,00"/>	<input type="text" value="0,3"/>	<input type="text" value="0,60"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="1"/>	<input type="text" value="0,00"/>
DH Gr.3:	<input type="text" value="3"/>	<input type="text" value="0,5"/>	<input type="text" value="1,50"/>	<input type="text" value="0,3"/>	<input type="text" value="0,90"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="0"/>	<input type="text" value="0,00"/>	<input type="text" value="1"/>	<input type="text" value="0,00"/>
Total:	<input type="text" value="6,00"/>		<input type="text" value="3,00"/>		<input type="text" value="1,80"/>		<input type="text" value="0,00"/>		<input type="text" value="0,00"/>		<input type="text" value="0,00"/>	<input type="text" value="0,00"/>	MDKK

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:

Distribution of Waste: Change distribution const.txt

	Waste input TWh/year	DH production Efficiency	DH production TWh/year	Electricity production Efficiency	Electricity production TWh/year	Biofuel transportation Efficiency	Biofuel transportation TWh/year	Biofuel CHP-Boiler Efficiency	Biofuel CHP-Boiler TWh/year	Various (Food etc.) Efficiency	Various (Food etc.) TWh/year	MDKK/TWh	
DH Gr.1:	<input type="text" value="1"/>	<input type="text" value="0,3"/>	0,30	<input type="text" value="0"/>	0,00	<input type="text" value="0,5"/>	0,50	<input type="text" value="0"/>	0,00	<input type="text" value="0"/>	0,00	<input type="text" value="1"/>	0,00
DH Gr.2:	<input type="text" value="2"/>	<input type="text" value="0,3"/>	0,60	<input type="text" value="0"/>	0,00	<input type="text" value="0,5"/>	1,00	<input type="text" value="0"/>	0,00	<input type="text" value="0"/>	0,00	<input type="text" value="1"/>	0,00
DH Gr.3:	<input type="text" value="3"/>	<input type="text" value="0,3"/>	0,90	<input type="text" value="0"/>	0,00	<input type="text" value="0,5"/>	1,50	<input type="text" value="0"/>	0,00	<input type="text" value="0"/>	0,00	<input type="text" value="1"/>	0,00
Total:	6,00		1,80		0,00		3,00		0,00		0,00		0,00 MDKK

Step 2: Open the Demand > Transport window:

Warnings Appear Here:

	TWh/year	Fossil	Biofuel	HTL, Pyrolysis and Waste*	Electrofuel	Total	Distribution
JP (Jet Fuel)	<input type="text" value="13,25"/>	13,25	0	0,00	0	13,25	
Diesel / DME	<input type="text" value="24,5"/>	24,5	0	3,00	0	27,50	
Petrol / Methanol	<input type="text" value="28,45"/>	28,45	0	0,00	0	28,45	
Ngas* (Grid Gas)	<input type="text" value="0"/>	0				0,00	Gas const.txt
LPG	<input type="text" value="0"/>	0				0,00	
Ammonia (NH3)					<input type="text" value="0"/>	0,00	
H2 (Produced by Electrolysers)					<input type="text" value="0"/>	0	H2 Hour_transport.txt
Electricity (Dump Charge)					<input type="text" value="0"/>	0	Dump Hour_transport.txt
Electricity (Smart Charge)					<input type="text" value="0"/>	0	Smart Hour_transport.txt

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 electrolyzers 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:

Warnings Appear Here: **Elect. or H2stor is too small for imp/exp variations**

TWh/year	Fossil	Biofuel	HTL, Pyrolysis and Waste*	Electrofuel	Total	Distribution	Help to design inputs
JP (Jet Fuel)	13,25	0	0,00	0	13,25		
Diesel / DME	0	0	3,00	0	27,50		1,5 41
Petrol / Methanol	22,45	0	0,00	0	22,45		1,5 34
Ngas* (Grid Gas)	0				0,00	Gas const.txt	1,5 0
LPG	0				0,00		1,5 0
Ammonia (NH3)				0	0,00		1,5 0
H2 (Produced by Electrolyzers)				3		H2 Hour_transport.txt	3 9
Electricity (Dump Charge)				0		Dump Hour_transport.txt	5 0
Electricity (Smart Charge)				0		Smart Hour_transport.txt	5 0
							84

Activate the **Help to design inputs** 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 electrolyzers in order to produce the hydrogen.

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

Electrolyser unit	Demand TWh/year	Capacities MW_e	Capacities MJ/t_e	Efficiencies fuel	Efficiencies DH gr2*	Efficiencies DH gr3*	Hydrogen Storage
Total Hydrogen demand*	3,0	500	0,723		0	0	0 GWh
Transport (Hydrogen)	3,00						
Industry	0,00						
CHP, PP and Boilers	0,00						
Electrof (Biomass)	0,00						
HTL	0,00						
Electrofuel (Biogas)	0,00						
Electrofuel (CO2)	0,00						
Ammonia (NH3)	0,00						
Micro CHP	0,00						

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

NOTE that the remark on missing electrolyzers 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:

The screenshot shows the 'Heating' window in a software interface. The 'Individual Heating' table is displayed with the following data:

TWh/year	Fuel Input	Efficiency Thermal	Heat Demand	Efficiency Electric	Capacity Limit*	Estimated Electricity Production	Heat Storage* (Days of heat demand)	Share*	Solar Thermal Input	Solar Thermal Output	Resulting Fuel Consumption*
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				0	1	1	0,61	3,98
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				0,61	12,74

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		Resulting Fuel Consumption*	
								Heat Storage* (Days of heat demand)	Share* Input Output		
Distribution: <input type="button" value="Heat"/> <input type="button" value="Solar"/>											
Hour_indv-heat-50percent.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 > Heat Only window:

	Group 1:	Group 2:	Group 3:	Total:	Unit	Distribution:
Solar Thermal						
Production	0	2	0		TWh/year	Change Hour_SolarThermal_CenDK.txt
Storage	0		0		GWh	
Loss*	0	0	0		Percent	
Share*	1	1	1			
Result	0,00	1,40	0,00	1,40	TWh/year	Use Solar Storage for Excess Heat
Annual accumulated heat in solar thermal storage:				0,00	TWh/year	No

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:

	Group 1:	Group 2:	Group 3:	Total:	Unit	Distribution:
Solar Thermal						
Production	0	2	0		TWh/year	Change Hour_SolarThermal_CenDK.txt
Storage	0	10	0		GWh	
Loss*	0	0	0		Percent	
Share*	1	1	1			
Result	0,00	2,00	0,00	2,00	TWh/year	Use Solar Storage for Excess Heat
Annual accumulated heat in solar thermal storage:				0,00	TWh/year	No

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.