Henrik Lund, Aalborg University, February 2010/February 2014

Guideline to EnergyPLAN Exercise 2: Make Simple Energy System Analyses.

In exercise 2, you are asked to do a couple of energy system improvements of the energy system of exercise 1. Through the exercise and the guideline, you learn step by step how to analyse changes to the energy system.

Exercise 2 continues with the system defined in exercise 1, which is:

- Electricity demand of 49 TWh/year and "hour-eldemand-eltra-2001"
- Condensing power plant: 9000 MW coal –fired
- 2000 MW wind power using "Hour_wind_eltra2001"
- Annual district heating demand of 39.18 TWh (distribution "hour_distr_heat")
- Fuel demand for individual house heating of 23.07 TWh divided into 0.01 coal, 6.72 oil, 9.05 natural gas and 7.29 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 286.27 TWh/year and CO2 emissions of 77.62 Mt.

Exercise 2.1: Energy conservation in house heating

Open the EnergyPLAN model. Load the data of exercise 1. Assuming that the district heating demand of 39.18 TWh/year is composed of 20% grid losses, 20% hot water and 60% space heating, implement energy conservation in house heating equal to 50% of the space heating demand. Do the same for the individual house heating demand of 19.70 TWh/year assuming that the demand is composed of 25% hot water and 75% space heating.

Consequently, the annual district heating demand will decrease by 50% of 60% from 39.18 to 27.43 TWh/year. And the heat demand for individual houses will decrease by 50% of 75% from 19.70 to 12.31 TWh/year.

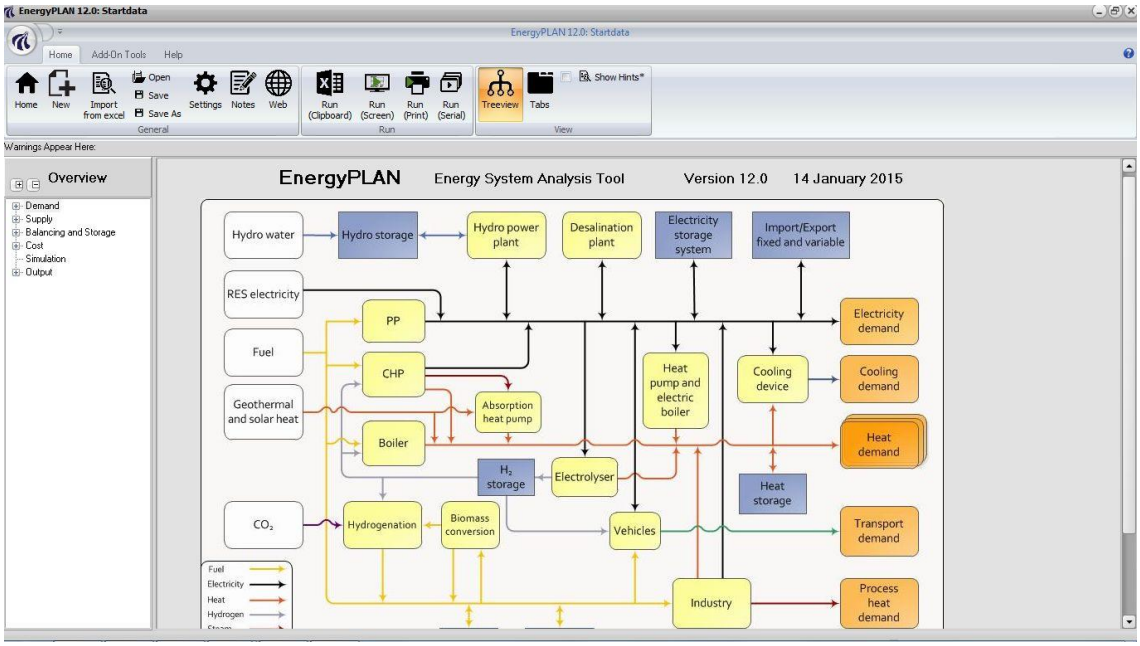
Note that such energy conservation measures change the duration curves and, consequently, the existing hour distribution curves have to be replaced by "Hour_distr-heat-2-50procent.txt" and Hour_indv-heat-50procent.txt.

Question 2.1.1: What is the peak hour district heating demand before and after implementing the energy conservation?

Question 2.1.2: What are the primary energy supply and the CO2 emission of the system after implementing such energy conservation measures?

How to do exercise 2.1:

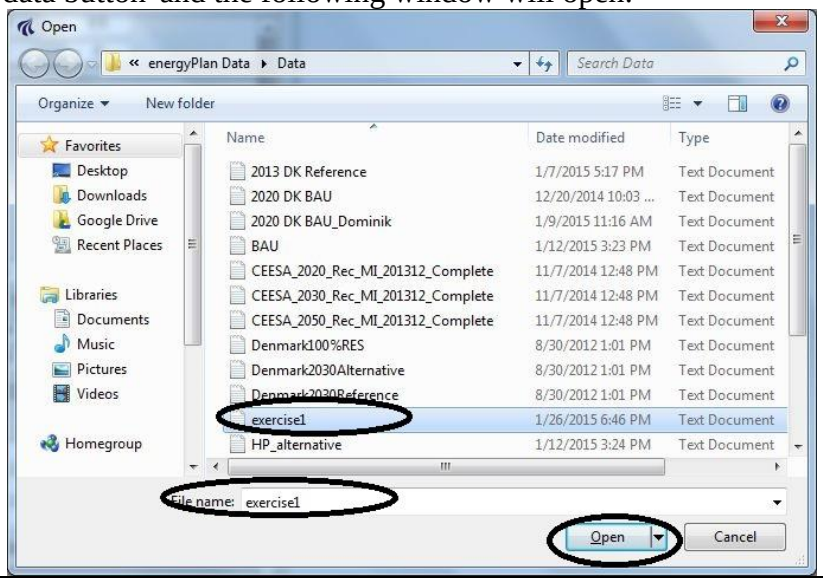
Step 1: Open the EnergyPLAN model. You will see the following front page (version 12.0):



Look at the top left-hand corner: The EnergyPLAN model is loaded with "Startdata"

Step 2: Load "Exercise 1" data.

Activate the open data button and the following window will open:

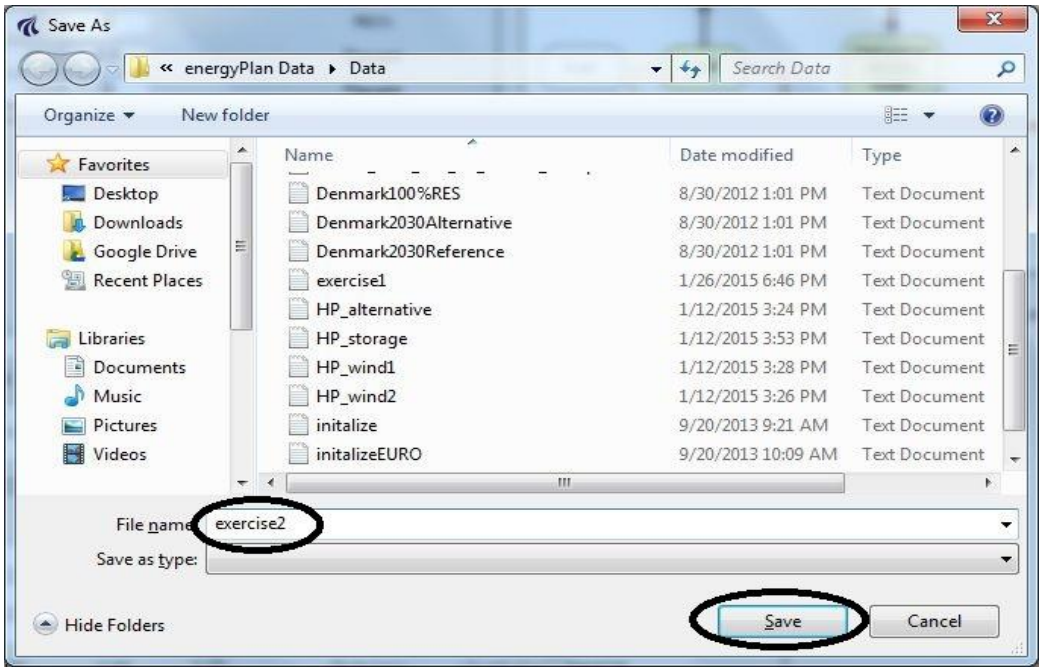


Choose “Exercise 1.txt” and activate the Open button.

Look at the top left-hand corner: The EnergyPLAN model is loaded with “Exercise 1” data.

Step 3: Save Data as Exercise 2 data

Activate “Save as” button and the following window will open:

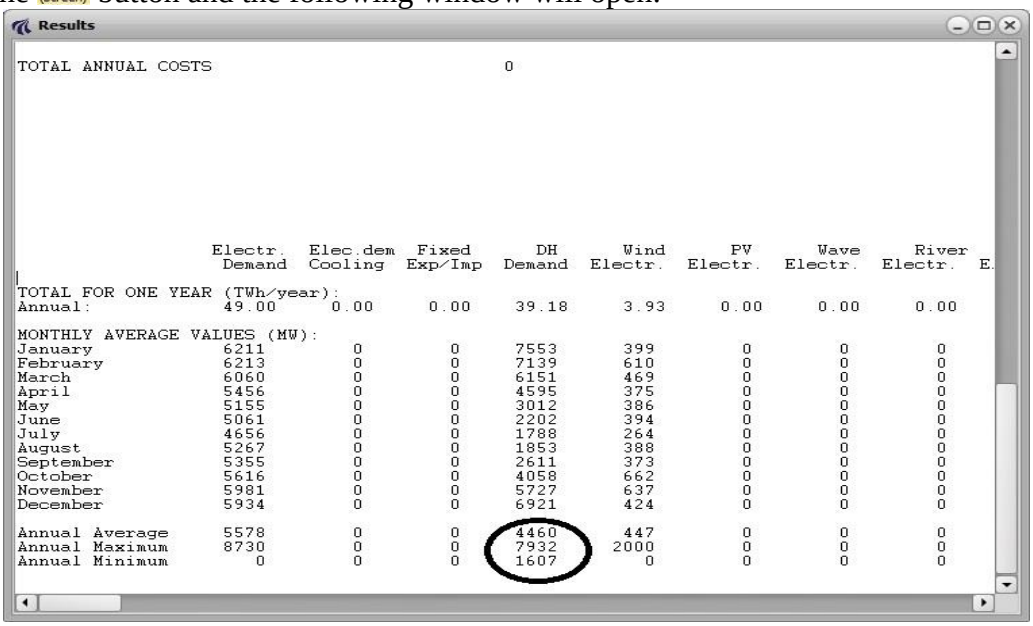


Choose a name and type in the name, e.g.: “Execise2” and activate the Save button.

Look at the top left-hand corner: The EnergyPLAN model is loaded with “Exercise2” data.

Step 4: Read the peak hour district heating demand BEFORE energy conservation.

Activate the  button and the following window will open:



Results

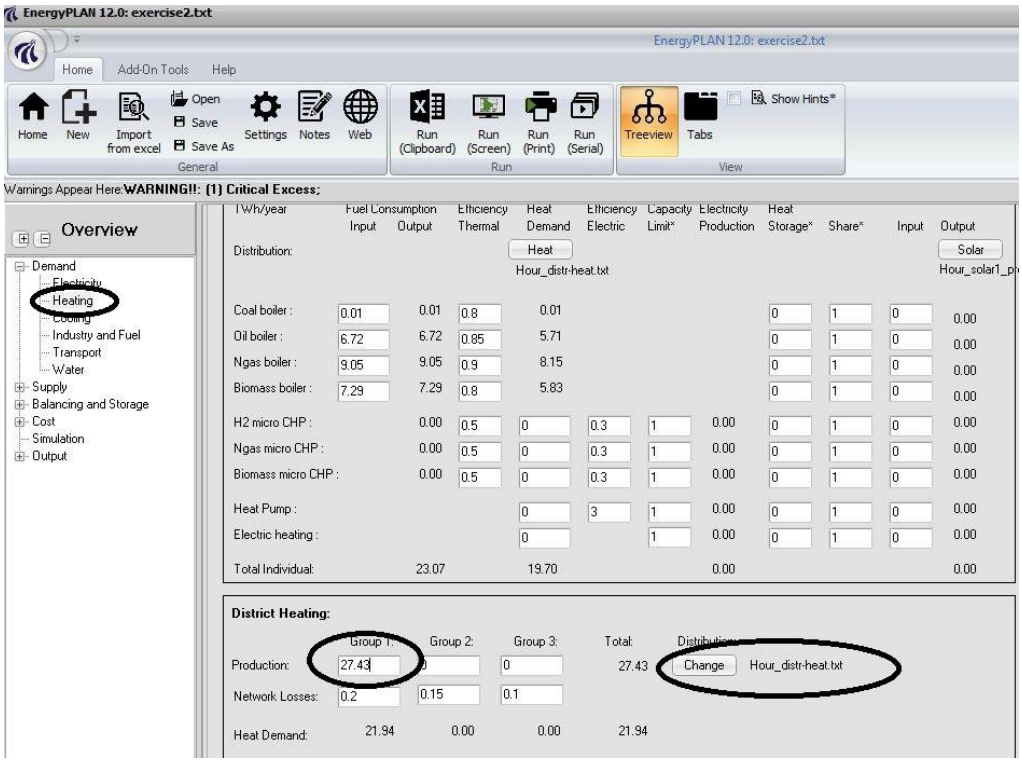
TOTAL ANNUAL COSTS 0

	Electr. Demand	Elec.dem Cooling	Fixed Exp/Imp	DH Demand	Wind Electr.	PV Electr.	Wave Electr.	River Electr.	E
TOTAL FOR ONE YEAR (TWh/year):									
Annual:	49.00	0.00	0.00	39.18	3.93	0.00	0.00	0.00	
MONTHLY AVERAGE VALUES (MW):									
January	6211	0	0	7553	399	0	0	0	
February	6213	0	0	7139	610	0	0	0	
March	6060	0	0	6151	469	0	0	0	
April	5456	0	0	4595	375	0	0	0	
May	5155	0	0	3012	386	0	0	0	
June	5061	0	0	2202	394	0	0	0	
July	4656	0	0	1788	264	0	0	0	
August	5267	0	0	1853	388	0	0	0	
September	5355	0	0	2611	373	0	0	0	
October	5616	0	0	4058	662	0	0	0	
November	5981	0	0	5727	637	0	0	0	
December	5934	0	0	6921	424	0	0	0	
Annual Average	5578	0	0	4460	447	0	0	0	
Annual Maximum	8730	0	0	7932	2000	0	0	0	
Annual Minimum	0	0	0	1607	0	0	0	0	

Read the result : 7932 MW

Step 5: Change district heating demand and hour distribution file.

Open the input district heating window by activating ”Heating” tab, under the Demand tab, and the following window will open:

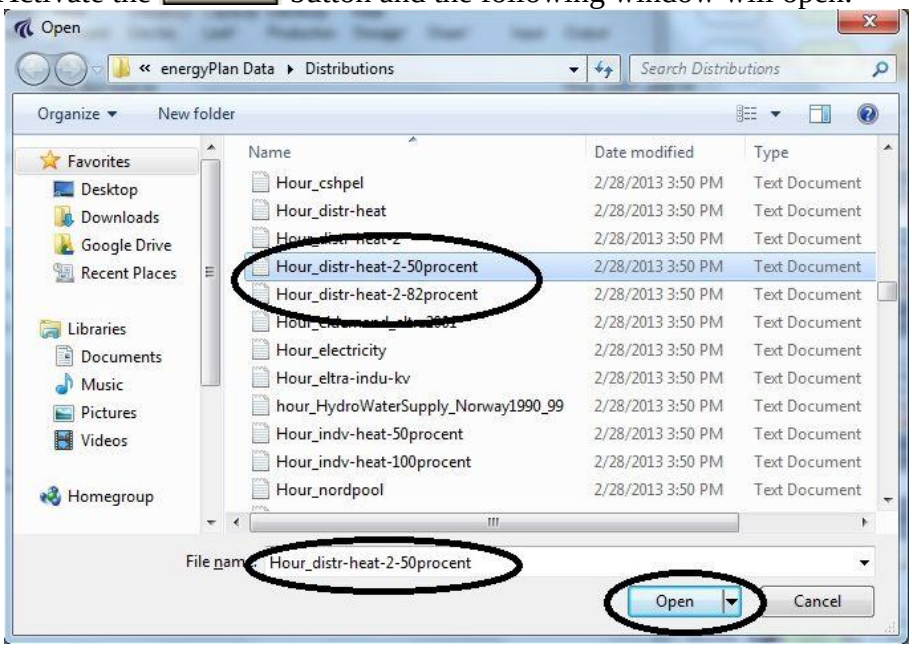


Place the cursor in the District Heating Production Group 1 input square and type in 27.43.

Look at the Distribution:
The model is loaded with “Hour-distr-heat.txt” distribution data.

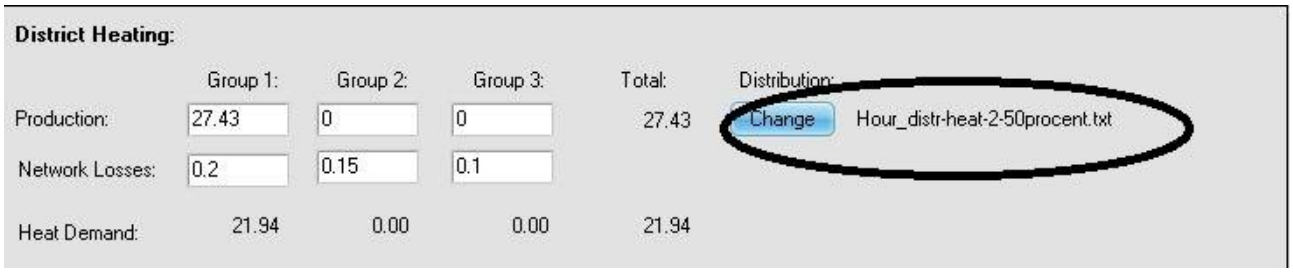
Activate the 

button and the following window will open:



Choose “Hour_distr-heat-2-50procent.txt” and activate the Open button.

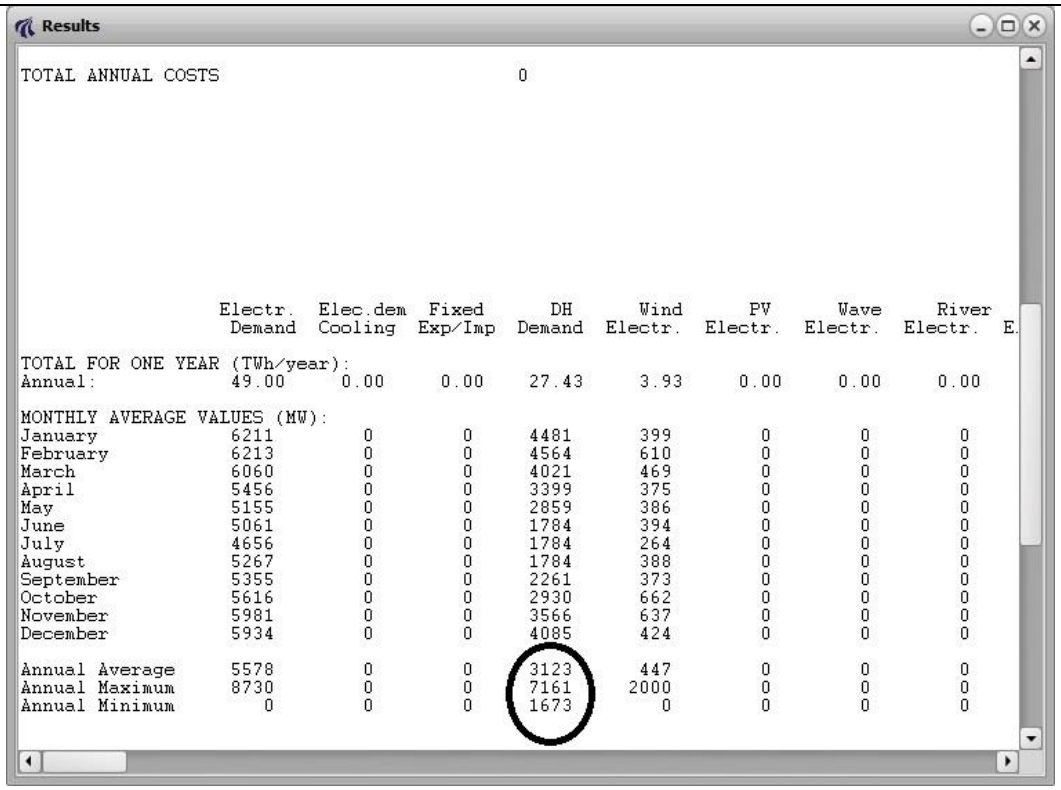
Look at the District Heating part in the “Heating” tab:
The model is loaded with “Hour-distr-heat-2-50procent.txt” distribution data.



Step 6: Read the peak hour district heating demand AFTER energy conservation.

Activate the 

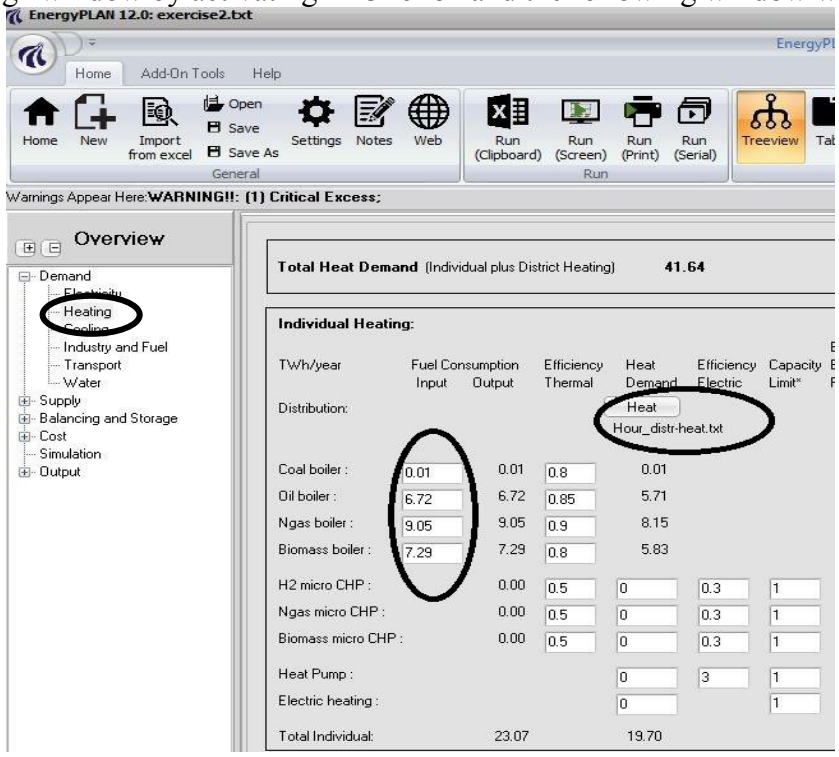
button and the following window will open:



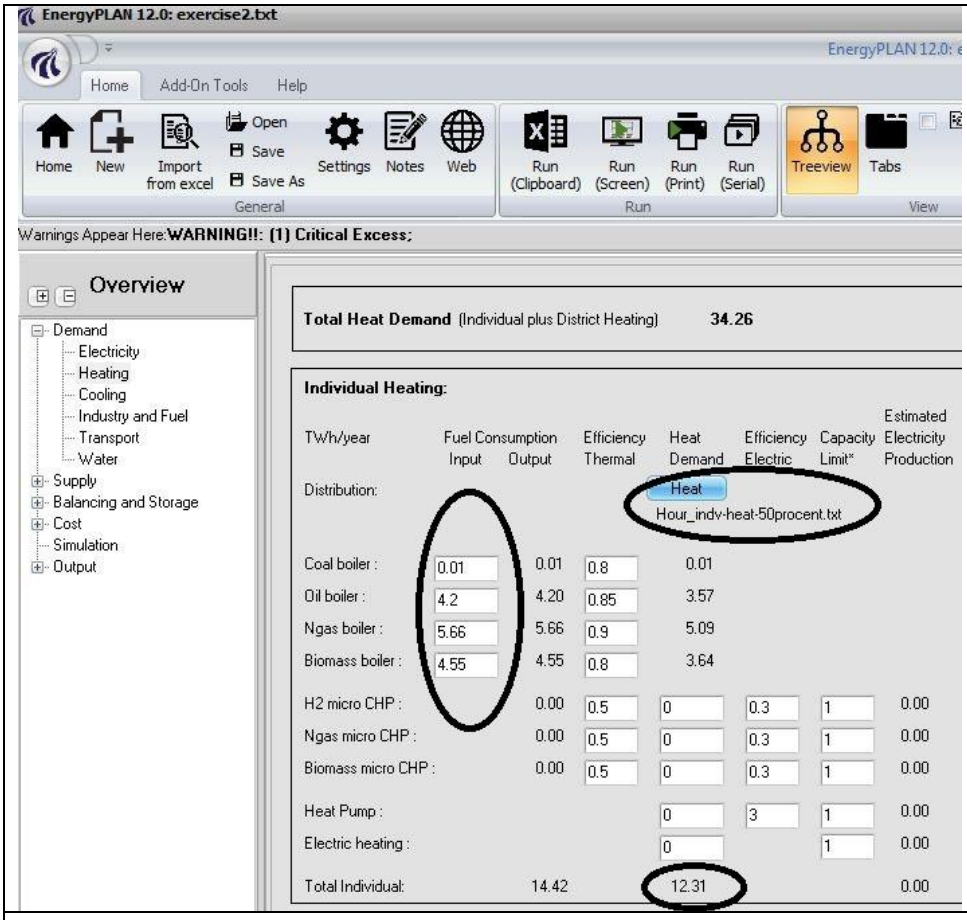
Read the result : 7161 MW

Step 7: Change heat demand and distribution file for individual houses

Open the "Heating" window by activating "Demand" and the following window will open:



Change input fuel consumption to 62.5% of previous value. And change distribution file to "Hour_indv-heat-50procent.txt" and the window will look like this:



Step 8: Save data:

Activate the "Save" button.

Step 9: Calculate and see result in print output

Activate the Run (Print) button and look at the following print output:

Input exercise2.txt — The EnergyPLAN model 12.0

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	49.00	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	0.00
Electric cooling	0.00	Total	49.00

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	27.43	0.00	0.00	27.43
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	1.73	0.00	0.00	1.73
Demand after solar and CSHP	25.70	0.00	0.00	25.70

Wind	2000 MW	3.93 TWh/year	0.00	Grid
Photo Voltaic	0 MW	0 TWh/year	0.00	stabili-
Wave Power	0 MW	0 TWh/year	0.00	sation
River Hydro	0 MW	0 TWh/year	0.00	share
Hydro Power	0 MW	0 TWh/year		
Geothermal/Nuclear	0 MW	0 TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	0		0.45		

Heatstorage: gr.2: 0 GWh gr.30 GWh
Fixed Boiler: gr.2:0.0 Per cent gr.0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	2.41	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strate(Technical regulation no. 1		
KEOL regulation	00000000	
Minimum Stabilisation share	0.00	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	0	MW
Minimum PP	0	MW
Heat Pump maximum share	0.50	
Maximum import/export	0	MW
Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	DKK/MWh
Multiplication factor	2.00	
Dependency factor	0.00	DKK/MWh pr. MW
Average Market Price	227	DKK/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level: Basic

	Capacities MW-e	Storage GWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	

CAES fuel ratio: 0.000

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	69.20	0.00	0.00
Household	0.01	4.20	5.66	4.55
Industry	3.37	26.92	18.19	5.18
Various	0.00	0.00	0.00	0.00

Output WARNING!!: (1) Critical Excess;

District Heating

	Demand: Distr. heating MW	Production: Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance MW
January	4481	0	197	4284	0	0	0	0	0	0
February	4564	0	197	4367	0	0	0	0	0	0
March	4021	0	197	3824	0	0	0	0	0	0
April	3399	0	197	3202	0	0	0	0	0	0
May	2859	0	197	2662	0	0	0	0	0	0
June	1784	0	197	1587	0	0	0	0	0	0
July	1784	0	197	1587	0	0	0	0	0	0
August	1784	0	197	1587	0	0	0	0	0	0
September	2261	0	197	2064	0	0	0	0	0	0
October	2930	0	197	2733	0	0	0	0	0	0
November	3566	0	197	3369	0	0	0	0	0	0
December	4085	0	197	3888	0	0	0	0	0	0
Average	3123	0	197	2926	0	0	0	0	0	0
Maximum	7161	0	197	6964	0	0	0	0	0	0
Minimum	1673	0	197	1476	0	0	0	0	0	0
TWh/year	27.43	0.00	1.73	25.70	0.00	0.00	0.00	0.00	0.00	0.00

Electricity and **Exchange**

	Consumption: Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Production: Turbine MW	RES MW	Hydro 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	6211	0	0	0	0	0	0	399	0	0	274	0	5539	100	0	0	0	0	0	0
February	6213	0	0	0	0	0	0	610	0	0	274	0	5329	100	0	0	0	0	0	0
March	6060	0	0	0	0	0	0	469	0	0	274	0	5319	100	0	1	1	0	0	0
April	5456	0	0	0	0	0	0	375	0	0	274	0	4807	100	0	0	0	0	0	0
May	5155	0	0	0	0	0	0	386	0	0	274	0	4495	100	0	0	0	0	0	0
June	5061	0	0	0	0	0	0	394	0	0	274	0	4393	100	0	0	0	0	0	0
July	4656	0	0	0	0	0	0	264	0	0	274	0	4118	100	0	0	0	0	0	0
August	5267	0	0	0	0	0	0	388	0	0	274	0	4605	100	0	0	0	0	0	0
September	5355	0	0	0	0	0	0	373	0	0	274	0	4708	100	0	0	0	0	0	0
October	5616	0	0	0	0	0	0	662	0	0	274	0	4680	100	0	0	0	0	0	0
November	5981	0	0	0	0	0	0	637	0	0	274	0	5069	100	0	0	0	0	0	0
December	5934	0	0	0	0	0	0	424	0	0	274	0	5236	100	0	0	0	0	0	0
Average	5578	0	0	0	0	0	0	447	0	0	274	0	4857	100	0	0	0	0	Average price	
Maximum	8730	0	0	0	0	0	0	2000	0	0	274	0	8310	100	0	889	889	0	(DKK/MWh)	
Minimum	0	0	0	0	0	0	0	0	0	0	274	0	0	100	0	0	0	0	188	162
TWh/year	49.00	0.00	0.00	0.00	0.00	0.00	0.00	3.93	0.00	0.00	2.41	0.00	42.66		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	PV	Wave	Hydro	Solar.Th	Transp	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	-	-	-	94.80	-	-	-	-	-	-	-	-	-	-	-	-	0.01	3.37	98.18	0.00	98.18	33.58	33.58
Oil	28.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	69.20	4.20	26.92	128.88	0.00	128.88	34.33	34.33
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.66	18.19	23.85	0.00	23.85	4.87	4.87
Biomass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.55	5.18	9.73	0.00	9.73	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	3.93	-	-	-	-	-	-	-	3.93	0.00	3.93	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	28.56	-	-	-	-	94.80	-	-	-	-	-	-	3.93	-	-	-	-	69.20	14.42	53.6	264.57	0.00	264.57	72.78	[illegible].78

Read the results of the question 1.2.2:
The Primary energy supply has been reduced from 286.27 to 264.57 TWh/year.
The CO_2 emission has been reduced from 77.62 to 72.78 Mt/year.

Exercise 2.2: Replace district heating boilers by CHP

Replace the 27.43 TWh of district heating boilers by:

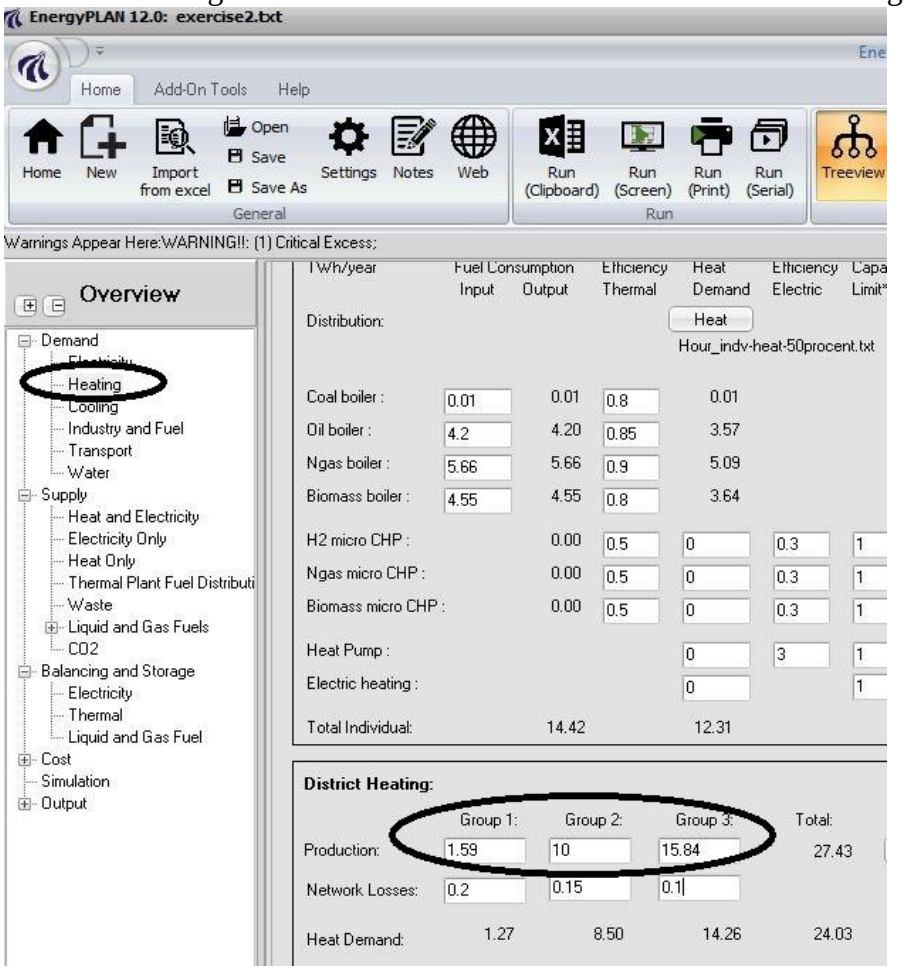
- 1.59 TWh of district heating boilers
- 10.00 TWh of small-scale CHP: 1350 MW, eff-th = 50%, eff-el = 41% on natural gas
- 15.84 TWh of large-scale CHP: 2000 MW, eff-th = 50%, eff-el = 41% on coal.
- Add boiler capacities of 5000 MJ/s in gr. 2 and gr. 3
- Add thermal storage capacity of 10 GWh in gr. 2 and gr. 3.
- Identify a 450 MW minimum production on the large-scale CHP units.
- Move 1.73 TWh of industrial excess heat production (2.41 of electricity) to gr. 3

Question 2.2.1: What are the primary energy supply and the CO2 emission of the system?

How to do exercise 2.2: Use input data file from exercise 2.1.

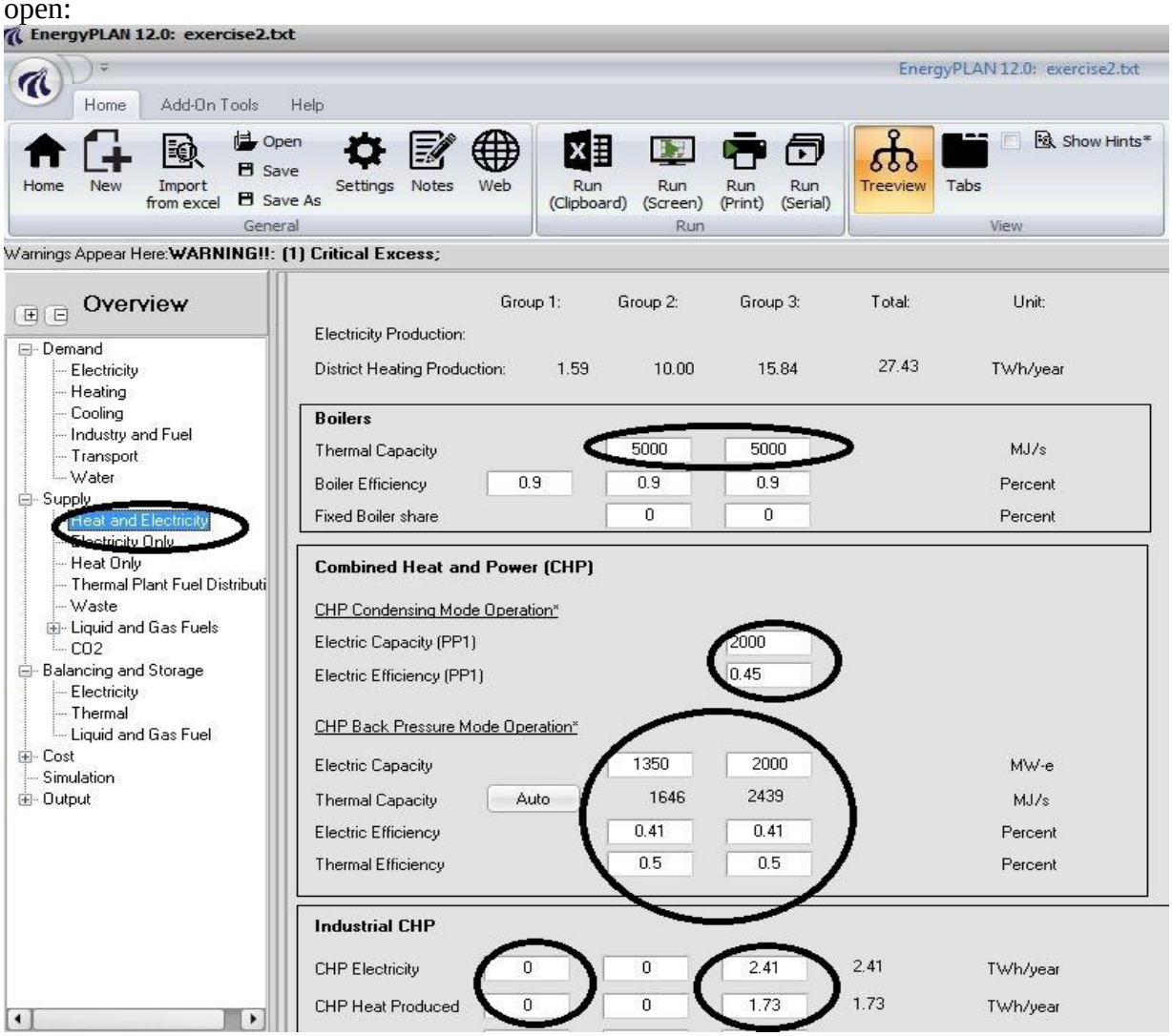
Step 1: Define individual house heating

Choose "Heating" window under the "Demand" tab and the following window will open:



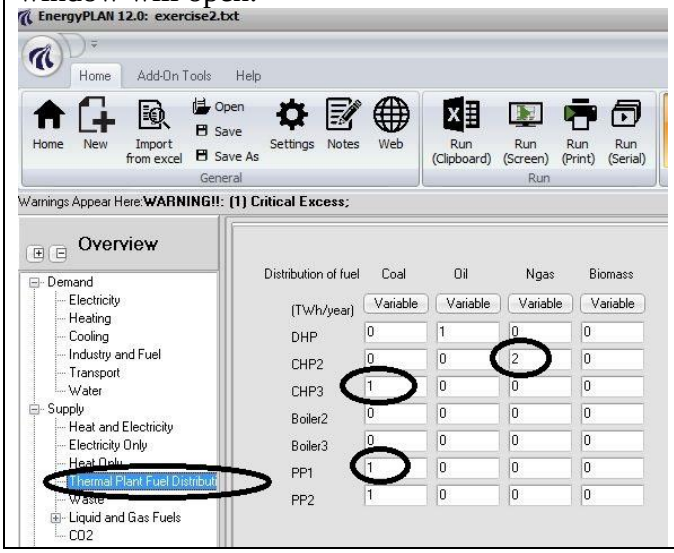
Place the cursor in the input squares and type in the various input values.

Choose “Heat and Electricity” window under the “Demand” tab and the following window will open:



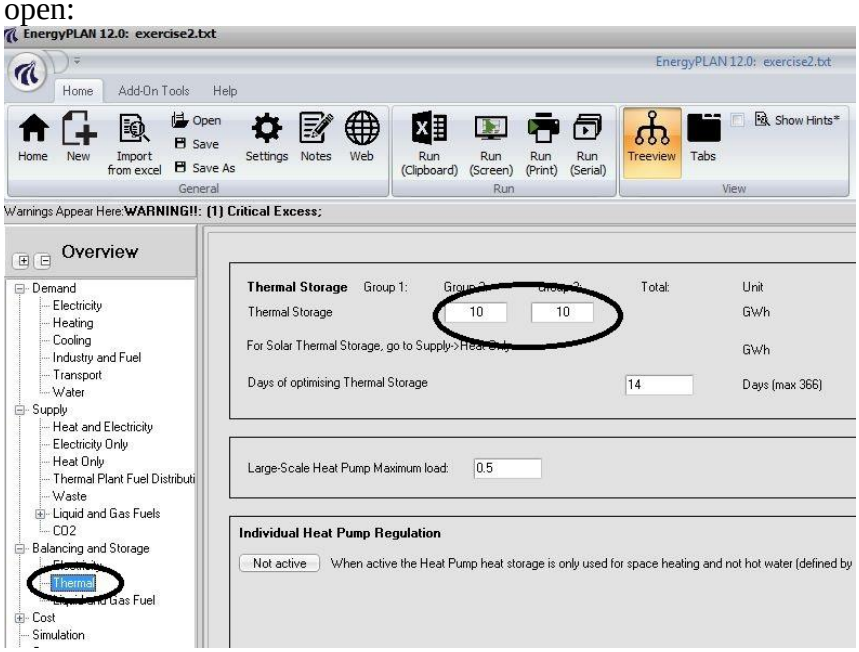
Place the cursor in the input squares and type in the various input values.

Choose “Thermal Plant Fuel Distribution” window under the “Supply” tab and the following window will open:



Place the cursor in the input squares and type in the various input values.

Choose “Thermal” window under the “Balancing and Storage” tab and the following window will open:

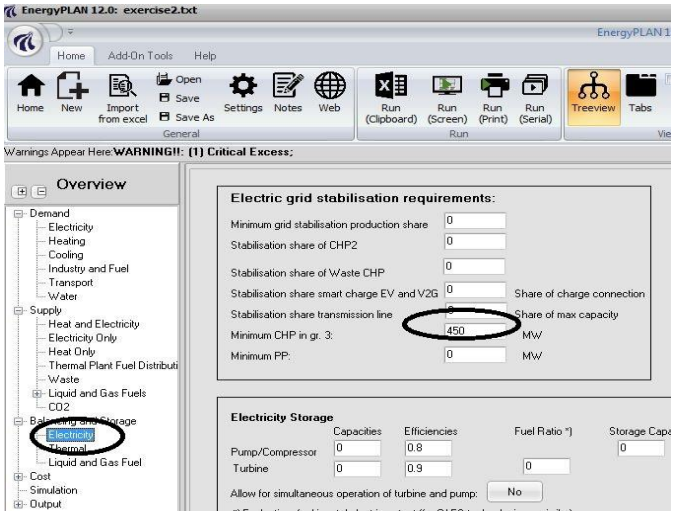


Enter the values of Thermal Storage capacities in Group 2 and Group 3.

Step 2: Define a minimum operation on large-scale CHP

Choose “Electricity” window under the “Balancing and Storage” tab.

Place the cursor in the “Minimum CHP in gr.3” input square and type in the 450 MW value.



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

Activate the 

button and look at the following print output:

Input exercise2.txt — The EnergyPLAN model 12.0

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	49.00	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	0.00
Electric cooling	0.00	Total	49.00

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	1.59	10.00	15.84	27.43
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	1.73	1.73
Demand after solar and CSHP	1.59	10.00	14.11	25.70

Wind	2000	MW	3.93	TWh/year	0.00	Grid
Photo Voltaic	0	MW	0	TWh/year	0.00	stabili-
Wave Power	0	MW	0	TWh/year	0.00	sation
River Hydro	0	MW	0	TWh/year		share
Hydro Power	0	MW	0	TWh/year		
Geothermal/Nuclear	0	MW	0	TWh/year		

	Capacities MW-e	MJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	1350	1646	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Group 3:					
CHP	2000	2439	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Condensing	2000		0.45		

Heatstorage:	gr.2:10	GWh	gr.10	GWh
Fixed Boiler:	gr.2:0.0	Per cent	gr.0.0	Per cent

Electricity prod. from	CSHP	Waste	(TWh/year)
Gr.1:	0.00	0.00	
Gr.2:	0.00	0.00	
Gr.3:	2.41	0.00	

Regulation Strate	Technical regulation no. 1		
KEOL regulation	00000000		
Minimum Stabilisation share	0.00		
Stabilisation share of CHP	0.00		
Minimum CHP gr 3 load	450	MW	
Minimum PP	0	MW	
Heat Pump maximum share	0.50		
Maximum import/export	0	MW	

Distr. Name :	Hour_nordpool.txt		
Addition factor	0.00	DKK/MWh	
Multiplication factor	2.00		
Dependency factor	0.00	DKK/MWh	pr. MW
Average Market Price	227	DKK/MWh	
Gas Storage	0	GWh	
Syngas capacity	0	MW	
Biogas max to grid	0	MW	

Fuel Price level: Basic

Capacities	Storage MW-e	GWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:	0.000			

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	69.20	0.00	0.00
Household	0.01	4.20	5.66	4.55
Industry	3.37	26.92	18.19	5.18
Various	0.00	0.00	0.00	0.00

Output WARNING!!: (1) Critical Excess;

	District Heating: Demand	Production								Electricity: Consumption						Production							Balance					Exchange
	Distr. heating MW	Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance 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	Payment Imp Million DKK	Payment Exp Million DKK
January	4481	0	197	260	3907	0	0	112	0	6	6211	0	0	0	0	0	0	399	0	0	274	3204	2335	100	0	0	0	0	0	0
February	4564	0	197	265	3896	0	0	205	0	1	6213	0	0	0	0	0	0	610	0	0	274	3195	2134	100	0	0	0	0	0	0
March	4021	0	197	233	3599	0	0	4	0	-13	6060	0	0	0	0	0	0	469	0	0	274	2952	2368	100	0	2	2	0	0	0
April	3399	0	197	197	3010	0	0	0	0	-5	5456	0	0	0	0	0	0	375	0	0	274	2468	2339	100	0	0	0	0	0	0
May	2859	0	197	166	2496	0	0	0	0	0	5155	0	0	0	0	0	0	386	0	0	274	2047	2448	100	0	0	0	0	0	0
June	1784	0	197	103	1483	0	0	0	0	0	5061	0	0	0	0	0	0	394	0	0	274	1216	3177	100	0	0	0	0	0	0
July	1784	0	197	103	1483	0	0	0	0	0	4656	0	0	0	0	0	0	264	0	0	274	1216	2901	100	0	0	0	0	0	0
August	1784	0	197	103	1483	0	0	0	0	0	5267	0	0	0	0	0	0	388	0	0	274	1216	3389	100	0	0	0	0	0	0
September	2261	0	197	131	1933	0	0	0	0	0	5355	0	0	0	0	0	0	373	0	0	274	1585	3123	100	0	0	0	0	0	0
October	2930	0	197	170	2564	0	0	0	0	0	5616	0	0	0	0	0	0	662	0	0	274	2102	2578	100	0	0	0	0	0	0
November	3566	0	197	207	3169	0	0	0	0	-6	5981	0	0	0	0	0	0	637	0	0	274	2598	2471	100	0	0	0	0	0	0
December	4085	0	197	237	3560	0	0	69	0	22	5934	0	0	0	0	0	0	424	0	0	274	2919	2319	100	0	2	2	0	0	0
Average	3123	0	197	181	2712	0	0	32	0	0	5578	0	0	0	0	0	0	447	0	0	274	2224	2633	100	0	0	0	0	Average price	(DKK/MWh)
Maximum	7161	0	197	415	4085	0	0	2085	0	2469	8730	0	0	0	0	0	0	2000	0	0	274	3350	5664	100	0	1339	1339	0	254	159
Minimum	1673	0	197	97	549	0	0	0	0	-794	0	0	0	0	0	0	0	0	0	0	274	450	0	100	0	0	0	0		
TWh/year	27.43	0.00	1.73	1.59	23.83	0.00	0.00	0.28	0.00	0.00	49.00	0.00	0.00	0.00	0.00	0.00	0.00	3.93	0.00	0.00	2.41	19.54	23.13		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	PV	Wave	Hydro	Solar.Th	Transp	Industry household	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	27.87	0.03	0.05	51.39	-	-	-	-	-	-	-	-	-	-	-	-	0.01	3.37	82.72	-0.01	82.72	28.29	28.29
Oil	1.77	-	-	0.03	0.05	-	-	-	-	-	-	-	-	-	-	-	-	69.20	4.20	26.92	102.16	0.00	102.16	27.22	27.22
N.Gas	-	19.78	-	0.03	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	5.66	18.19	43.71	0.00	43.71	8.92	8.92
Biomass	-	-	-	0.03	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	4.55	5.18	9.81	0.00	9.81	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	3.93	-	-	-	-	-	-	-	3.93	0.00	3.93	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	1.77	19.78	27.87	0.12	0.19	51.39	-	-	-	-	-	-	3.93	-	-	-	-	69.20	14.42	53.6	242.33	-0.01	242.33	64.43	64.43

Read the results of question 2.2.1:
The Primary energy supply has been reduced from 264.57 to 242.33TWh/year.
The CO2 emission has been reduced from 72.78 to 64.43 Mt/year.

Exercise 2.3: Add 3000 MW off-shore wind power

Add 3000 MW off-shore wind power.
Use the hour distribution file "OffshoreHornsRef2003RAMSES.txt"

The electricity production from CHP in combination with wind power may lead to hours in which the production exceeds the demand, known as excess electricity production. The energy system analysis will identify and quantify this excess production. However, such balancing problems depend on the regulation of the electricity production units. Basically the model differs between operating CHP units 1) to meet solely heat demand or 2) to meet both heat and electricity demands (Regulation strategy 1 and 2).

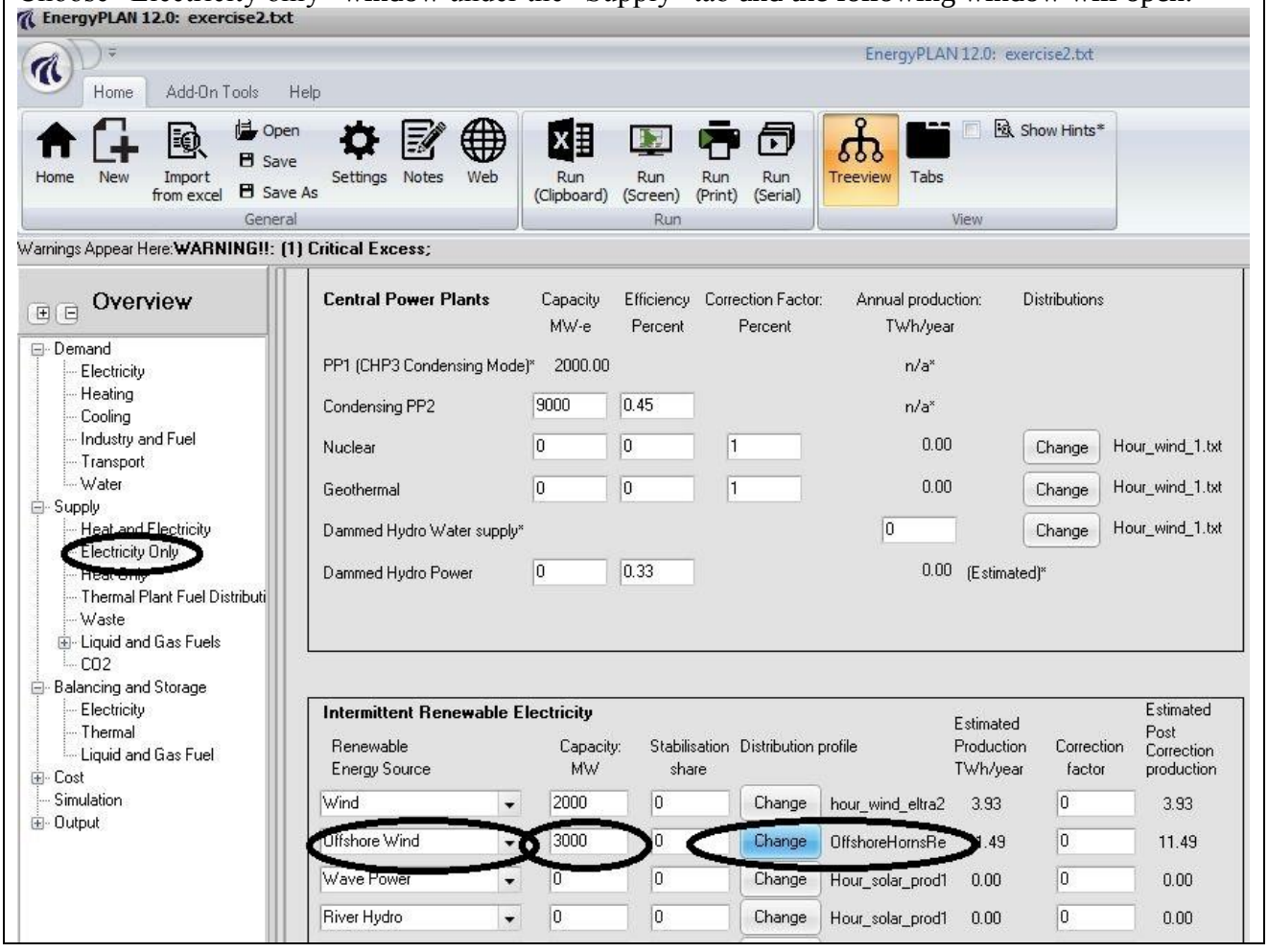
Question 2.3.1: What is 1) the excess electricity production, 2) the primary energy supply and 3) the CO2 emission of the system if the CHP units are regulated solely according to the heat demand?

Question 2.3.2: What is the answer if the CHP units are regulated according to both the heat and the electricity demand?

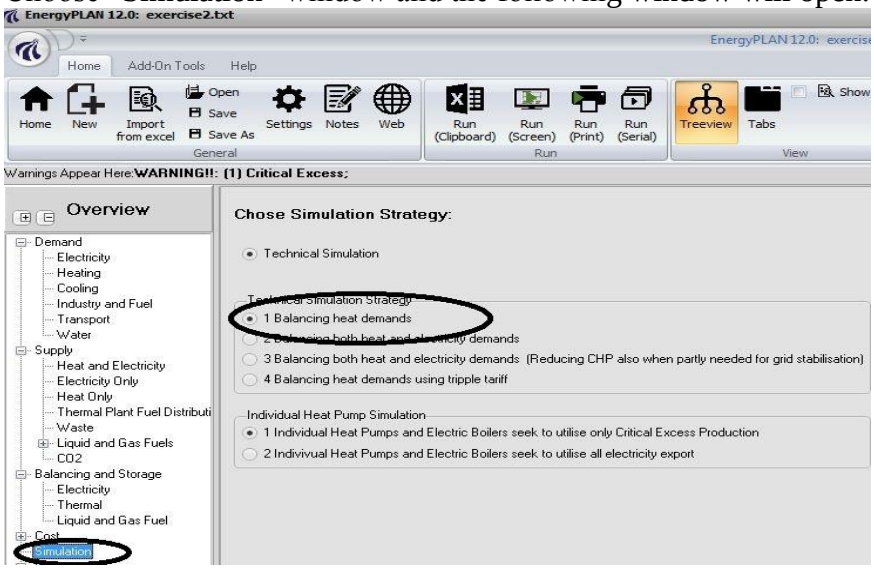
How to do exercise 2.3: Use input data file from exercise 2.2.

Step 1: Add wind power input

Choose "Electricity only" window under the "Supply" tab and the following window will open:



Instead of Photo Voltaic choose Offshore Wind and type in the capacity of 3000 MW. Change the distribution to "OffshoreHornsRef2003RAMSES.txt".
Choose "Simulation" window and the following window will open:

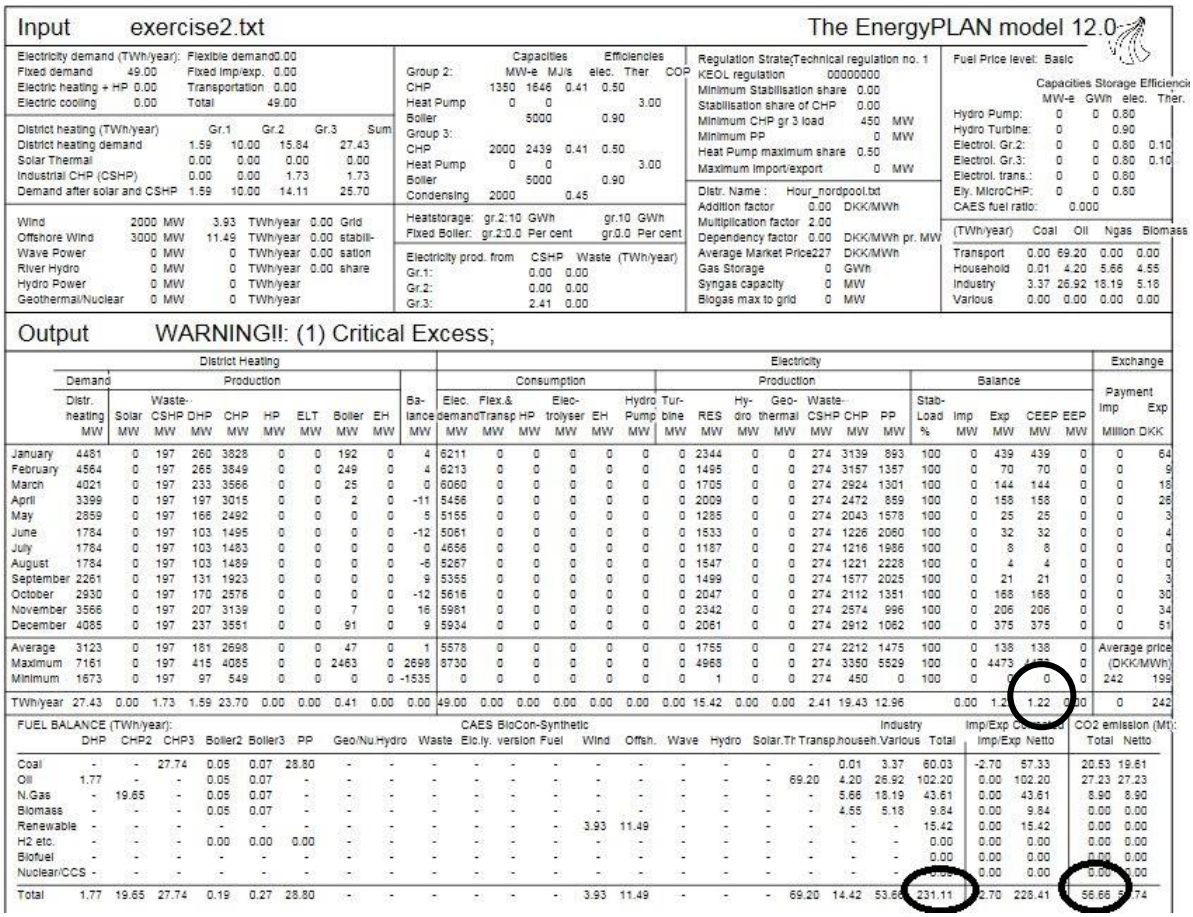


Make sure that the technical regulation strategy is 1.

Step 2: Calculate and see result in print output (or clipboard)

Activate the 

button and look at the following print output:



Input exercise2.txt — The EnergyPLAN model 12.0

Electricity demand (TWh/year): Flexible demand 0.00
Fixed demand 49.00 Fixed Imp/exp. 0.00
Electric heating + HP 0.00 Transportation 0.00
Electric cooling 0.00 Total 49.00

Capacities / Efficiencies	MW-e	MJ/s	elec.	Ther	COP
Group 2:					
CHP	1350	1646	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Group 3:					
CHP	2000	2439	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Condensing	2000		0.45		

Regulation Strate(Technical regulation no. 1
KEOL regulation 00000000
Minimum Stabilisation share 0.00
Stabilisation share of CHP 0.00
Minimum CHP gr 3 load 450 MW
Minimum PP 0 MW
Heat Pump maximum share 0.50
Maximum Import/export 0 MW

Fuel Price level: Basic

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	1.59	10.00	15.84	27.43
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	1.73	1.73
Demand after solar and CSHP	1.59	10.00	14.11	25.70

Wind	2000	MW	3.93	TWh/year	0.00 Grid
Offshore Wind	3000	MW	11.49	TWh/year	0.00 stabili-
Wave Power	0	MW	0	TWh/year	0.00 sation
River Hydro	0	MW	0	TWh/year	share
Hydro Power	0	MW	0	TWh/year	
Geothermal/Nuclear	0	MW	0	TWh/year	

Heatstorage: gr.2:10 GWh gr.10 GWh
Fixed Boiler: gr.2:0.0 Per cent gr.0.0 Per cent

Electricity prod. from	CSHP	Waste	(TWh/year)
Gr.1:	0.00	0.00	
Gr.2:	0.00	0.00	
Gr.3:	2.41	0.00	

Distr. Name : Hour_nordpool.txt
Addition factor 0.00 DKK/MWh
Multiplication factor 2.00
Dependency factor 0.00 DKK/MWh pr. MW
Average Market Price 227 DKK/MWh
Gas Storage 0 GWh
Syngas capacity 0 MW
Biogas max to grid 0 MW

Capacities	MW-e	GWh	elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:		0.000		

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	69.20	0.00	0.00
Household	0.01	4.20	5.66	4.55
Industry	3.37	26.92	18.19	5.18
Various	0.00	0.00	0.00	0.00

Output WARNING!!: (1) Critical Excess;

	District Heating: 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	Electricity: Consumption: Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	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	Exchange: Payment Imp Million DKK	Exp
January	4481	0	197	260	3828	0	0	192	0	4	6211	0	0	0	0	0	0	2344	0	0	274	3139	893	100	0	439	439	0	0	64
February	4564	0	197	265	3849	0	0	249	0	4	6213	0	0	0	0	0	0	1495	0	0	274	3157	1357	100	0	70	70	0	0	9
March	4021	0	197	233	3566	0	0	25	0	0	6060	0	0	0	0	0	0	1705	0	0	274	2924	1301	100	0	144	144	0	0	18
April	3399	0	197	197	3015	0	0	2	0	-11	5456	0	0	0	0	0	0	2009	0	0	274	2472	859	100	0	158	158	0	0	26
May	2859	0	197	166	2492	0	0	0	0	5	5155	0	0	0	0	0	0	1285	0	0	274	2043	1578	100	0	25	25	0	0	3
June	1784	0	197	103	1495	0	0	0	0	-12	5061	0	0	0	0	0	0	1533	0	0	274	1226	2060	100	0	32	32	0	0	4
July	1784	0	197	103	1483	0	0	0	0	0	4656	0	0	0	0	0	0	1187	0	0	274	1216	1986	100	0	8	8	0	0	0
August	1784	0	197	103	1489	0	0	0	0	-6	5267	0	0	0	0	0	0	1547	0	0	274	1221	2228	100	0	4	4	0	0	0
September	2261	0	197	131	1923	0	0	0	0	9	5355	0	0	0	0	0	0	1499	0	0	274	1577	2025	100	0	21	21	0	0	3
October	2930	0	197	170	2576	0	0	0	0	-12	5616	0	0	0	0	0	0	2047	0	0	274	2112	1351	100	0	168	168	0	0	30
November	3566	0	197	207	3139	0	0	7	0	16	5981	0	0	0	0	0	0	2342	0	0	274	2574	996	100	0	206	206	0	0	34
December	4085	0	197	237	3551	0	0	91	0	9	5934	0	0	0	0	0	0	2061	0	0	274	2912	1062	100	0	375	375	0	0	51
Average	3123	0	197	181	2698	0	0	47	0	1	5578	0	0	0	0	0	0	1755	0	0	274	2212	1475	100	0	138	138	0	Average price (DKK/MWh)	
Maximum	7161	0	197	415	4085	0	0	2463	0	2698	8730	0	0	0	0	0	0	4968	0	0	274	3350	5529	100	0	4473	[illegible]	0		
Minimum	1673	0	197	97	549	0	0	0	0	-1535	0	0	0	0	0	0	0	1	0	0	274	450	0	100	0	0	0	0	242	199
TWh/year	27.43	0.00	1.73	1.59	23.70	0.00	0.00	0.41	0.00	0.00	49.00	0.00	0.00	0.00	0.00	0.00	0.00	15.42	0.00	0.00	2.41	19.43	12.96		0.00	1.4[illegible]	1.22	0.00	0	242

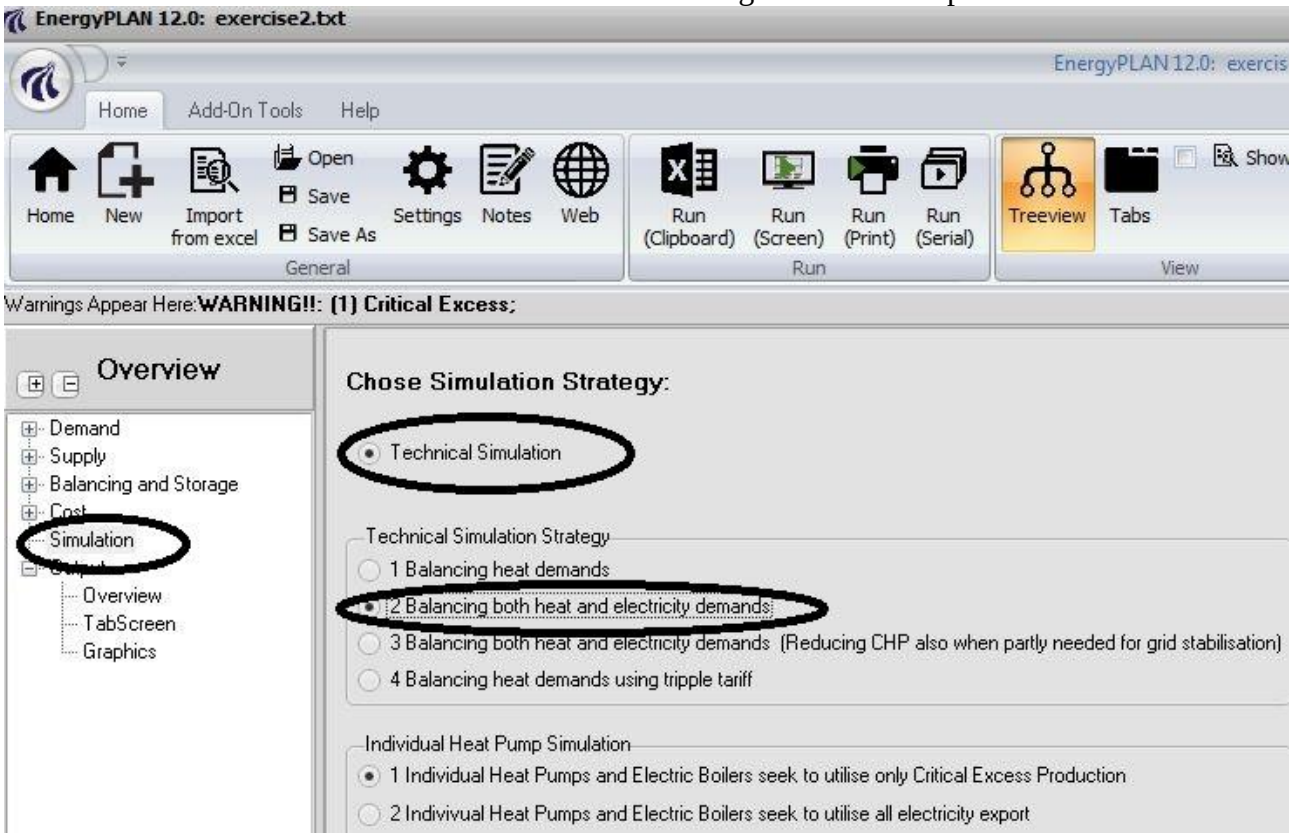
FUEL BALANCE (TWh/year):	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	Wave	Hydro	Solar.Th	Industry Transp.	household	Various	Total	Imp/Exp	Imp/Exp	Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	27.74	0.05	0.07	28.80	-	-	-	-	-	-	-	-	-	-	-	0.01	3.37	60.03	-2.70	57.33	20.53	19.61		
Oil	1.77	-	-	0.05	0.07	-	-	-	-	-	-	-	-	-	-	-	-	69.20	4.20	26.92	102.20	0.00	102.20	27.23	27.23	
N.Gas	-	19.65	-	0.05	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	5.66	18.19	43.61	0.00	43.61	8.90	8.90	
Biomass	-	-	-	0.05	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	4.55	5.18	9.84	0.00	9.84	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	1.77	19.65	27.74	0.19	0.27	28.80	-	-	-	-	-	-	3.93	11.49	-	-	-	69.20	14.42	53.66	231.11	-2.70	228.41	56.66	[illegible]	

Read the results of question 2.3.1:

The Primary energy supply has been reduced from 242.33 to 231.11 TWh/year.
The CO_2 emission has been reduced from 64.43 to 56.66 Mt/year.
Critical Excess Electricity Production (CEEP) = 1.22 TWh/year

Step 3: Change regulation strategy

Choose "Simulation" from the tree view and the following window will open:



Change from Balancing heat demands (Technical Simulation strategy) to Balancing both heat and electricity demands (Technical Simulation strategy).

Step 5: Calculate and see result in print output (or clipboard)

Activate the 

button and look at the following print output:

Input exercise23.txt — The EnergyPLAN model 12.0

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	49.00	Fixed Imp/exp.	0.00
Electric heating + HP	0.00	Transportation	0.00
Electric cooling	0.00	Total	49.00

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	1.59	10.00	15.84	27.43
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	1.73	1.73
Demand after solar and CSHP	1.59	10.00	14.11	25.70

Wind	2000	MW	3.93	TWh/year	0.00	Grid
Offshore Wind	3000	MW	11.49	TWh/year	0.00	stabili-
Wave Power	0	MW	0	TWh/year	0.00	sation
River Hydro	0	MW	0	TWh/year	0.00	share
Hydro Power	0	MW	0	TWh/year		
Geothermal/Nuclear	0	MW	0	TWh/year		

	Capacities MW-e	MJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	1350	1646	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Group 3:					
CHP	2000	2439	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Condensing	2000		0.45		

Heatstorage:	gr.2:	10	GWh	gr.3:	10 GWh
Fixed Boiler:	gr.2:	0.0	Per cent	gr.3:	0.0 Per cent

Electricity prod. from	CSHP	Waste	(TWh/year)
Gr.1:	0.00	0.00	
Gr.2:	0.00	0.00	
Gr.3:	2.41	0.00	

Regulation Strategy:	Technical regulation no. 2	
KEOL regulation	00000000	
Minimum Stabilisation share	0.00	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	450	MW
Minimum PP	0	MW
Heat Pump maximum share	0.50	
Maximum import/export	0	MW

Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	DKK/MWh
Multiplication factor	2.00	
Dependency factor	0.00	DKK/MWh pr. MW
Average Market Price	227	DKK/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level: Basic

	Capacities MW-e	Storage GWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:		0.000		

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	69.20	0.00	0.00
Household	0.01	4.20	5.66	4.55
Industry	3.37	26.92	18.19	5.18
Various	0.00	0.00	0.00	0.00

Output WARNING!! (1) Critical Excess;

	District Heating: Demand	Production								Electricity: Consumption						Production						Balance					Exchange
	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	Payment Imp Million DKK	Exp
January	4481	0	197	260	3293	0	0	727	0	4	6211	0	0	0	0	0	0	2344	0	0	274	2701	894	100	0	2	2	0	0	0
February	4564	0	197	265	3771	0	0	328	0	4	6213	0	0	0	0	0	0	1495	0	0	274	3092	1351	100	0	0	0	0	0	0
March	4021	0	197	233	3388	0	0	203	0	0	6060	0	0	0	0	0	0	1705	0	0	274	2778	1305	100	0	2	2	0	0	0
April	3399	0	197	197	2817	0	0	197	0	-8	5456	0	0	0	0	0	0	2009	0	0	274	2310	865	100	0	1	1	0	0	0
May	2859	0	197	166	2464	0	0	29	0	3	5155	0	0	0	0	0	0	1285	0	0	274	2021	1578	100	0	3	3	0	0	0
June	1784	0	197	103	1472	0	0	20	0	-10	5061	0	0	0	0	0	0	1533	0	0	274	1207	2064	100	0	18	18	0	0	2
July	1784	0	197	103	1482	0	0	5	0	-3	4656	0	0	0	0	0	0	1187	0	0	274	1215	1985	100	0	6	6	0	0	0
August	1784	0	197	103	1487	0	0	0	0	-4	5267	0	0	0	0	0	0	1547	0	0	274	1220	2230	100	0	4	4	0	0	0
September	2261	0	197	131	1898	0	0	25	0	10	5355	0	0	0	0	0	0	1499	0	0	274	1556	2027	100	0	2	2	0	0	0
October	2930	0	197	170	2403	0	0	173	0	-13	5616	0	0	0	0	0	0	2047	0	0	274	1971	1358	100	0	34	34	0	0	6
November	3566	0	197	207	2916	0	0	231	0	15	5981	0	0	0	0	0	0	2342	0	0	274	2391	998	100	0	26	26	0	0	4
December	4085	0	197	237	3123	0	0	519	0	9	5934	0	0	0	0	0	0	2061	0	0	274	2561	1065	100	0	27	27	0	0	3
Average	3123	0	197	181	2539	0	0	205	0	1	5578	0	0	0	0	0	0	1755	0	0	274	2082	1477	100	0	10	10	0	Average price (DKK/MWh)	
Maximum	7161	0	197	415	4085	0	0	3919	0	2932	8730	0	0	0	0	0	0	4968	0	0	274	3350	5578	100	0	1727	1727	0	244	187
Minimum	1673	0	197	97	549	0	0	0	0	-1361	0	0	0	0	0	0	0	1	0	0	274	450	0	100	0	0	0	0		
TWh/year	27.43	0.00	1.73	1.59	22.30	0.00	0.00	1.80	0.00	0.00	49.00	0.00	0.00	0.00	0.00	0.00	0.00	15.42	0.00	0.00	2.41	18.29	12.98		0.00	0.0	0.09	0.00	0	17

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.	Industry househ.	Industry Various	Total	Imp/Exp	Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	26.40	0.25	0.25	28.84	-	-	-	-	-	-	-	-	-	-	-	-	0.01	3.37	59.11	-0.20	58.91	20.22	20.15
Oil	1.77	-	-	0.25	0.25	-	-	-	-	-	-	-	-	-	-	-	-	69.20	4.20	26.92	102.59	0.00	102.59	27.33	27.33
N.Gas	-	18.21	-	0.25	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	5.66	18.19	42.56	0.00	42.56	8.69	8.69
Biomass	-	-	-	0.25	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	4.55	5.18	10.23	0.00	10.23	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
Total	1.77	18.21	26.40	0.99	1.01	28.84	-	-	-	-	-	-	3.93	11.49	-	-	-	69.20	14.42	53.66	229.91	0.20	229.71	56.23	56.16

Read the results of question 2.3.2:
The Primary energy supply has decreased from 231.11 to 229.91 TWh/year.
The CO_2 emission has decreased from 56.66 to 56.23 Mt/year.
Critical Excess Electricity Production (CEEP) is reduced from 1.22 to 0.09 TWh/year

Exercise 2.4: Implement electricity-saving measures

Decrease the electricity demand by 30% from 49 to 34.3 TWh/year.

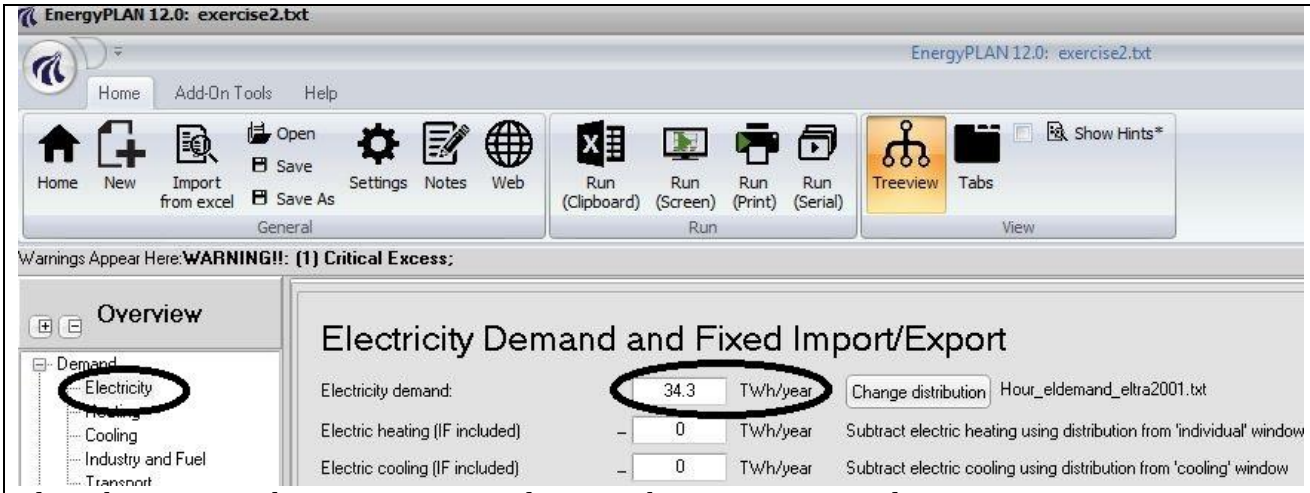
Question 2.4.1: What is 1) the excess electricity production, 2) the primary energy supply and 3) the CO_2 emission of the system if the CHP units are regulated solely according to the heat demand?

Question 2.4.2: What is the answer if the CHP units are regulated according to both the heat and the electricity demands?

How to do exercise 2.4: Use input data file from exercise 2.3.

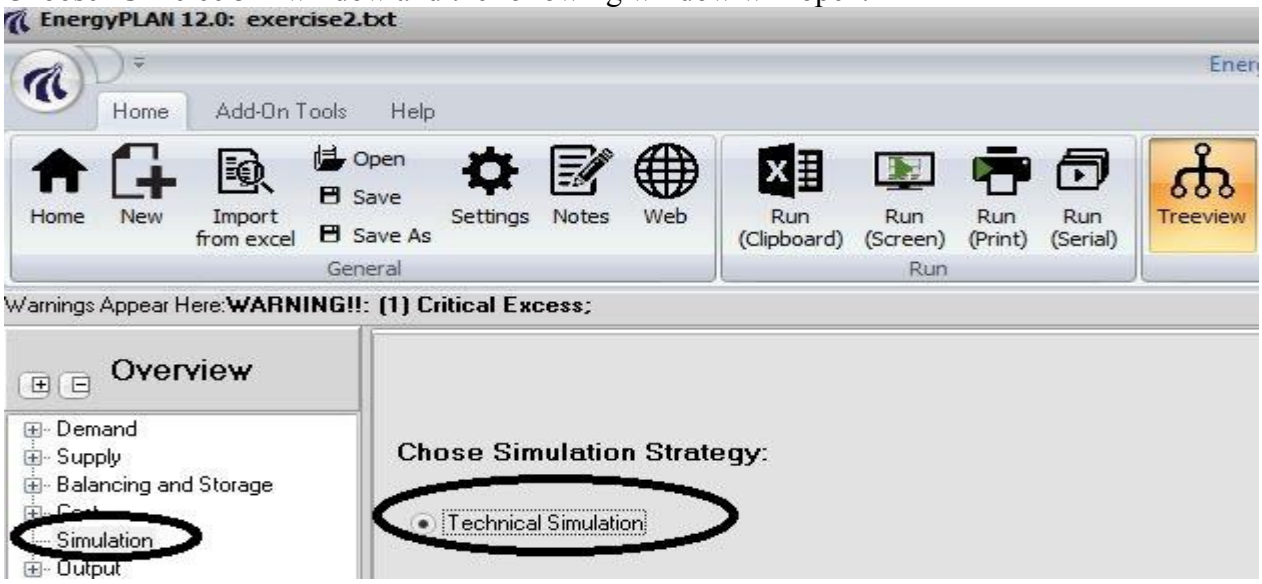
Step 1: Change electricity demand

Choose "Electricity" window under the "Demand" section and the following window will open:



Place the cursor in the input squares and type in the various input values.

Choose "Simulation" window and the following window will open:



Make sure that the Technical Simulation is on. Change the Technical Simulation Strategy to '1 Balancing heat demands'

Step 2: Calculate and see result in print output (or clipboard)

Activate the 

button and look at the following print output:

Input exercise2.txt — The EnergyPLAN model 12.0

Electricity demand (TWh/year):		Flexible demand	0.00		
Fixed demand	34.30	Fixed imp/exp.	0.00		
Electric heating + HP	0.00	Transportation	0.00		
Electric cooling	0.00	Total	34.30		

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	1.59	10.00	15.84	27.43
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	1.73	1.73
Demand after solar and CSHP	1.59	10.00	14.11	25.70

Wind	2000 MW	3.93	TWh/year	0.00	Grid
Offshore Wind	3000 MW	11.49	TWh/year	0.00	stabili-
Wave Power	0 MW	0	TWh/year	0.00	sation
River Hydro	0 MW	0	TWh/year	0.00	share
Hydro Power	0 MW	0	TWh/year		
Geothermal/Nuclear	0 MW	0	TWh/year		

	Capacities MW-e	MJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	1350	1646	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Group 3:					
CHP	2000	2439	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Condensing	2000		0.45		

Heatstorage:	gr.2:10	GWh	gr.10	GWh
Fixed Boiler:	gr.2:0.0	Per cent	gr.0.0	Per cent

Electricity prod. from	CSHP	Waste	(TWh/year)
Gr.1:	0.00	0.00	
Gr.2:	0.00	0.00	
Gr.3:	2.41	0.00	

Regulation Strate	Technical regulation no. 1
KEOL regulation	00000000
Minimum Stabilisation share	0.00
Stabilisation share of CHP	0.00
Minimum CHP gr 3 load	450 MW
Minimum PP	0 MW
Heat Pump maximum share	0.50
Maximum import/export	0 MW

Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	DKK/MWh
Multiplication factor	2.00	
Dependency factor	0.00	DKK/MWh pr. MW
Average Market Price	227	DKK/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level: Basic

	Capacities MW-e	Storage GWh	Efficien elec.	The
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:	0.000			

(TWh/year)	Coal	Oil	Ngas	Biomas
Transport	0.00	69.20	0.00	0.00
Household	0.01	4.20	5.66	4.55
Industry	3.37	26.92	18.19	5.18
Various	0.00	0.00	0.00	0.00

Output WARNING!!: (1) Critical Excess;

	District Heating: Demand: Distr. heating MW	Production: Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance MW	Electricity: Consumption: Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	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	Exchange: Payment Imp Million DKK	Exp
January	4481	0	197	260	3839	0	0	192	0	-7	4348	0	0	0	0	0	0	2344	0	0	274	3148	130	100	0	1549	1549	0	0	265
February	4564	0	197	265	3845	0	0	250	0	8	4349	0	0	0	0	0	0	1495	0	0	274	3153	186	100	0	760	760	0	0	99
March	4021	0	197	233	3553	0	0	48	0	-10	4242	0	0	0	0	0	0	1705	0	0	274	2913	217	100	0	868	868	0	0	127
April	3399	0	197	197	2986	0	0	2	0	17	3819	0	0	0	0	0	0	2009	0	0	274	2449	86	100	0	998	998	0	0	171
May	2859	0	197	166	2523	0	0	0	0	-26	3609	0	0	0	0	0	0	1285	0	0	274	2068	327	100	0	345	345	0	0	51
June	1784	0	197	103	1465	0	0	0	0	18	3543	0	0	0	0	0	0	1533	0	0	274	1202	763	100	0	229	229	0	0	32
July	1784	0	197	103	1495	0	0	0	0	-12	3259	0	0	0	0	0	0	1187	0	0	274	1226	677	100	0	105	105	0	0	9
August	1784	0	197	103	1489	0	0	0	0	-6	3687	0	0	0	0	0	0	1547	0	0	274	1221	800	100	0	156	156	0	0	24
September	2261	0	197	131	1930	0	0	0	0	2	3748	0	0	0	0	0	0	1499	0	0	274	1583	623	100	0	231	231	0	0	40
October	2930	0	197	170	2541	0	0	0	0	22	3931	0	0	0	0	0	0	2047	0	0	274	2084	292	100	0	766	766	0	0	136
November	3566	0	197	207	3153	0	0	8	0	1	4186	0	0	0	0	0	0	2342	0	0	274	2586	165	100	0	1181	1181	0	0	190
December	4085	0	197	237	3559	0	0	98	0	-6	4154	0	0	0	0	0	0	2081	0	0	274	2918	125	100	0	1225	1225	0	0	193
Average	3123	0	197	181	2895	0	0	49	0	0	3905	0	0	0	0	0	0	1755	0	0	274	2210	366	100	0	701	701	0	Average price	
Maximum	7161	0	197	415	4085	0	0	2463	0	1881	6111	0	0	0	0	0	0	4968	0	0	274	3350	3299	100	0	5657	5657	0	(DKK/MWh)	
Minimum	1673	0	197	97	549	0	0	0	0	-1845	0	0	0	0	0	0	0	1	0	0	274	450	0	100	0	[illegible]	0	0	267	217
TWh/year	27.43	0.00	1.73	1.59	23.68	0.00	0.00	0.43	0.00	0.00	34.30	0.00	0.00	0.00	0.00	0.00	0.00	15.42	0.00	0.00	2.41	19.42	3.22		0.00	6.16	[illegible]16	0.00	0	1337

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	Industry Transp.	household	Various	Total	Imp/Exp	Corrected Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	27.71	0.05	0.07	7.15	-	-	-	-	-	-	-	-	-	-	-	0.01	3.37	38.36	-13.69	24.68	13.12	8.44
Oil	1.77	-	-	0.05	0.07	-	-	-	-	-	-	-	-	-	-	-	69.20	4.20	26.92	102.21	0.00	102.21	27.23	27.23
N.Gas	-	19.64	-	0.05	0.07	-	-	-	-	-	-	-	-	-	-	-	-	5.66	18.19	43.61	0.00	43.61	8.90	8.90
Biomass	-	-	-	0.05	0.07	-	-	-	-	-	-	-	-	-	-	-	-	4.55	5.18	9.85	0.00	9.85	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	0.00	0.00	0.00	0.00
Total	1.77	19.64	27.71	0.20	0.28	7.15	-	-	-	-	-	-	3.93	11.49	-	-	69.20	14.42	53.66	209.45	-13.69	195.76	49.25	[illegible]57

Read the results of question 2.4.1:
The Primary energy supply has been reduced from 229.91 to 209.45 TWh/year.
The CO2 emission has been reduced from 56.23 to 49.25 Mt/year.
Critical Excess Electricity Production (CEEP) is raised from 0.09 to 6.16 TWh/year

Step 3: Change regulation strategy, calculate and read results.

Repeat steps 1 and 2.
Change the Technical Simulation strategy to '2 Balancing both heat and electricity demands' under the "Simulation" tab in the tree view.

Activate the Run (Print) button and read the results of question 2.4.2 on the print:
The Primary energy supply has been decreased from 209.45 to 204.02 TWh/year.
The CO_2 emission has been decreased from 49.25 to 47.31 Mt/year.
Critical Excess Electricity Production (CEEP) is reduced from 6.16 to 1.13 TWh/year

Exercise 2.5: Add heat pump and heat storage capacity to CHP plants

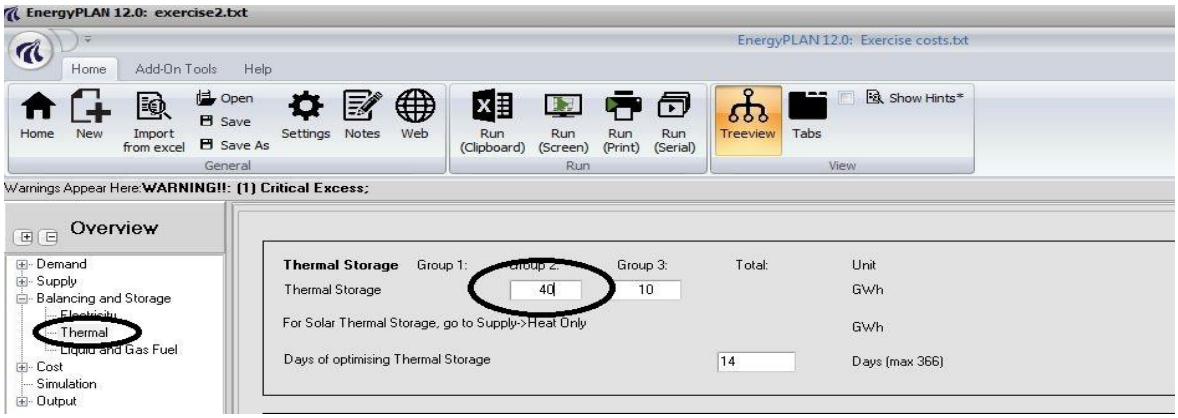
Add heat storage capacity of 40 GWh to gr 2 together with a 300 MW heat pump with a COP=3.

Question 2.5.1: What is 1) the excess electricity production, 2) the primary energy supply and 3) the CO2 emission of the system if the CHP units are regulated according to both the heat and the electricity demands?

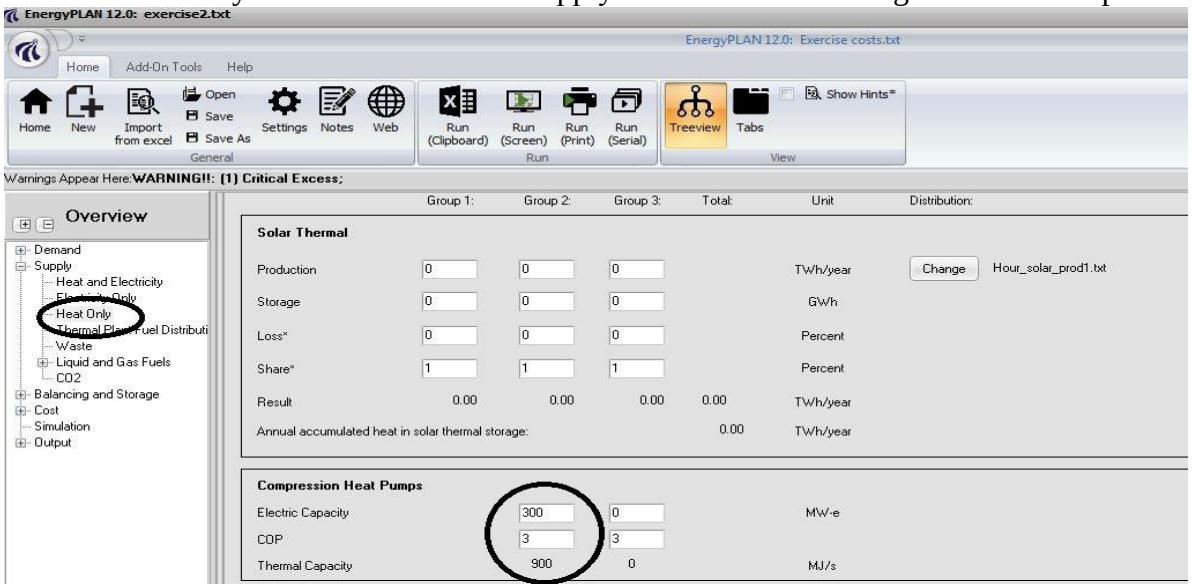
How to do exercise 2.5: Use input data file from exercise 2.4.

Step 1: Add heat pump and heat storage

Choose "Thermal" window under the "Balancing and Storage" tab and the following window will open:



Place the cursor in the input squares and type in the input value.
Choose "Heat only" window under the "Supply" tab and the following window will open:



Place the cursor in the input squares and type in input values for the heat pumps.

Step 2: Calculate and see result in print output (or clipboard)

Activate the 

button and look at the following print output:

Input exercise252.txt — The EnergyPLAN model 12.0

Electricity demand (TWh/year):		Flexible demand	0.00	
Fixed demand	34.30	Fixed imp/exp.	0.00	
Electric heating + HP	0.00	Transportation	0.00	
Electric cooling	0.00	Total	34.30	

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	1.59	10.00	15.84	27.43
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	1.73	1.73
Demand after solar and CSHP	1.59	10.00	14.11	25.70

Wind	2000	MW	3.93	TWh/year	0.00	Grid
Offshore Wind	3000	MW	11.49	TWh/year	0.00	stabil-
Wave Power	0	MW	0	TWh/year	0.00	sation
River Hydro	0	MW	0	TWh/year	0.00	share
Hydro Power	0	MW	0	TWh/year		
Geothermal/Nuclear	0	MW	0	TWh/year		

	Capacities MW-e	MJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	1350	1646	0.41	0.50	
Heat Pump	300	900			3.00
Boiler		5000		0.90	
Group 3:					
CHP	2000	2439	0.41	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Condensing	2000		0.45		

Heatstorage: gr.2: 40 GWh gr.3: 10 GWh
Fixed Boiler: gr.2: 0.0 Per cent gr.3: 0.0 Per cent

Electricity prod. from	CSHP	Waste	(TWh/year)
Gr.1:	0.00	0.00	
Gr.2:	0.00	0.00	
Gr.3:	2.41	0.00	

Regulation Strategy:	Technical regulation no. 2		
KEOL regulation	00000000		
Minimum Stabilisation share	0.00		
Stabilisation share of CHP	0.00		
Minimum CHP gr 3 load	450	MW	
Minimum PP	0	MW	
Heat Pump maximum share	0.50		
Maximum import/export	0	MW	
Distr. Name :	Hour_nordpool.txt		
Addition factor	0.00	DKK/MWh	
Multiplication factor	2.00		
Dependency factor	0.00	DKK/MWh pr. MW	
Average Market Price	227	DKK/MWh	
Gas Storage	0	GWh	
Syngas capacity	0	MW	
Biogas max to grid	0	MW	

Fuel Price level: Basic

	Capacities MW-e	Storage GWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:		0.000		

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	69.20	0.00	0.00
Household	0.01	4.20	5.66	4.55
Industry	3.37	25.92	18.19	5.18
Various	0.00	0.00	0.00	0.00

Output WARNING!! (1) Critical Excess;

	District Heating										Electricity														Exchange	
	Demand	Production									Consumption						Production							Balance				
	Distr. heating	Solar	Waste+ CSHP	DHP	CHP	HP	ELT	Boiler	EH	Balance	Elec. demand	Flex.& Transp.	HP	Elec-trolyser	EH	Hydro Pump	Tur-bine	RES	Hy-dro	Geo-thermal	Waste+ CSHP	CHP	PP	Stab-Load	Imp	Exp	CEEP	EEP	Payment Imp	Payment 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	Million DKK	Million DKK
January	4481	0	197	260	2285	657	0	1088	0	-6	4348	0	219	0	0	0	0	2344	0	0	274	1874	142	100	0	67	67	0	0	9
February	4564	0	197	265	3113	490	0	492	0	8	4349	0	163	0	0	0	0	1495	0	0	274	2552	204	100	0	14	14	0	0	2
March	4021	0	197	233	2710	418	0	475	0	-12	4242	0	139	0	0	0	0	1705	0	0	274	2222	218	100	0	39	39	0	0	6
April	3399	0	197	197	2064	459	0	484	0	-1	3819	0	153	0	0	0	0	2009	0	0	274	1692	73	100	0	76	76	0	0	11
May	2859	0	197	166	2174	217	0	101	0	4	3609	0	72	0	0	0	0	1285	0	0	274	1783	382	100	0	42	42	0	0	6
June	1784	0	197	103	1305	168	0	10	0	0	3543	0	56	0	0	0	0	1533	0	0	274	1070	839	100	0	117	117	0	0	15
July	1784	0	197	103	1375	107	0	2	0	0	3259	0	36	0	0	0	0	1187	0	0	274	1127	758	100	0	52	52	0	0	4
August	1784	0	197	103	1356	135	0	4	0	-13	3687	0	45	0	0	0	0	1547	0	0	274	1112	865	100	0	67	67	0	0	10
September	2261	0	197	131	1685	200	0	43	0	5	3748	0	67	0	0	0	0	1499	0	0	274	1382	713	100	0	54	54	0	0	9
October	2930	0	197	170	1961	344	0	262	0	-4	3931	0	115	0	0	0	0	2047	0	0	274	1608	288	100	0	171	171	0	0	30
November	3566	0	197	207	2132	492	0	534	0	4	4186	0	164	0	0	0	0	2342	0	0	274	1749	150	100	0	165	165	0	0	27
December	4085	0	197	237	2416	510	0	712	0	13	4154	0	170	0	0	0	0	2061	0	0	274	1981	131	100	0	124	124	0	0	16
Average	3123	0	197	181	2045	349	0	351	0	0	3905	0	116	0	0	0	0	1755	0	0	274	1677	398	100	0	83	83	0	Average price	
Maximum	7161	0	197	415	4085	900	0	3933	0	1459	6111	0	300	0	0	0	0	4968	0	0	274	3350	3298	100	0	2526	2526	0	(DKK/MWh)	
Minimum	1673	0	197	97	549	0	0	0	0	-1593	0	0	0	0	0	0	0	1	0	0	274	450	0	100	0	0	0	0	256	200
TWh/year	27.43	0.00	1.73	1.59	17.96	3.07	0.00	3.08	0.00	0.00	34.30	0.00	1.02	0.00	0.00	0.00	0.00	15.42	0.00	0.00	2.41	14.73	3.49		0.00	0.72	0.72	0.00	0	145

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 Imp/Exp	Corrected Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	23.46	0.19	0.66	7.76	-	-	-	-	-	-	-	-	-	-	-	-	0.01	3.37	35.45	-1.61	33.84	12.12	11.57
Oil	1.77	-	-	0.19	0.66	-	-	-	-	-	-	-	-	-	-	-	-	69.20	4.20	26.92	102.94	0.00	102.94	27.42	27.42
N.Gas	-	12.47	-	0.19	0.66	-	-	-	-	-	-	-	-	-	-	-	-	-	5.66	18.19	37.18	0.00	37.18	7.59	7.59
Biomass	-	-	-	0.19	0.66	-	-	-	-	-	-	-	-	-	-	-	-	-	4.55	5.18	10.59	0.00	10.59	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	1.77	12.47	23.46	0.77	2.65	7.76	-	-	-	-	-	-	3.93	11.49	-	-	-	69.20	14.42	53.66	201.57	-1.61	199.96	47.14	46.59

Read the results of question 2.5.1:

The Primary energy supply has been reduced from 204.02 to 201.57 TWh/year.
The CO_2 emission has been reduced from 47.31 to 47.14 Mt/year.
Critical Excess Electricity Production (CEEP) is reduced from 1.13 to 0.72 TWh/year

REMEMBER to save exercise 2. You will need it when doing exercise 3.