Henrik Lund, Aalborg University, January 2012/July 2022

# Guideline to EnergyPLAN Exercise 1: Define and calculate a simple national energy system.

## Exercise 1.1: Define an electricity demand

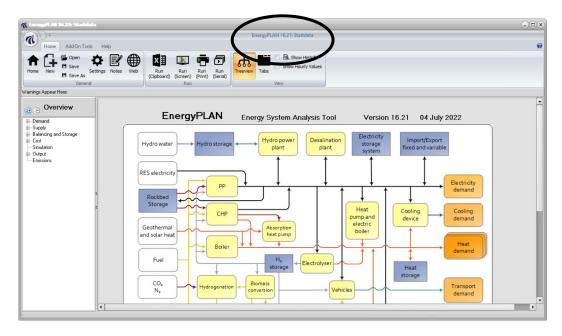
Open the EnergyPLAN model. Initialise data and define a simple national/regional energy system with an electricity demand of 49 TWh/year. Use the hour-distribution file of "hour-eldemand-eltra-2001" (The distribution of the western Danish region in 2001).

*Question 1.1.1: What is the peak hour electricity demand?* 

Question 1.1.2: What is the peak hour electricity demand for 40 TWh/year and distribution data file "Hour electricity.txt"?

#### How to do exercise 1.1:

Step 1: Open the EnergyPLAN model. You will see the following front page (version 16.21):



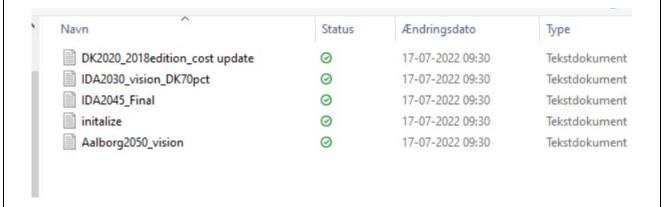
Look at the top: The EnergyPLAN model is loaded with "Startdata"

Step 2: Reset data by pressing "New" in the top bar.



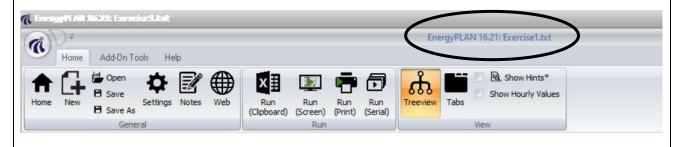
#### Step 3: Save Data

Activate "save as" in the top left-hand corner and the following window will open:



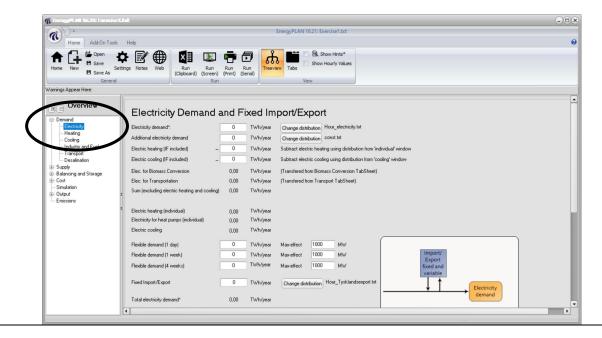
Give your file a name, e.g. "Exercise1" and press save.

Look at the top of the bar: The EnergyPLAN model is loaded with "Exercise 1" data.

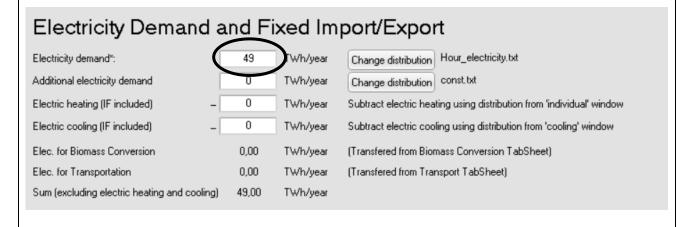


Step 4: Write input-data electricity demand 49 TWh/year.

To the left chose "Demand" and then "Electricity" and the following window will open:

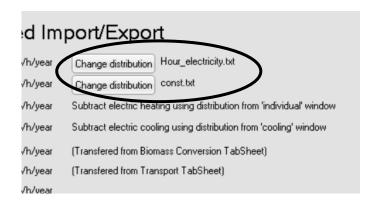


Place the cursor in the electricity input square and type in 49.



Step 5: Change hour-distribution to "hour-eldemand-eltra-2001"

Look at the "Demand > Electricity" input window: The model is loaded with "Hour-electricity" distribution data.



Activate the Change distribution button and the following window will open:



Choose "DK 2013 Electricity demand" and activate the Open/Åbn button.

Look at the Demand > Electricity input window:

The model is now loaded with "DK 2013 Electricity demand" distribution data:

Electricity Demand	and F	ixed Im	port/Export
Electricity demand*:	49	TWh/year	Change distribution DK 2013 Electricity demand.txt
Additional electricity demand	0	TWh/year	Change distribution const.tut
Electric heating (IF included)	_ 0	TWh/year	Subtract electric heating using distribution from 'individual' window
Electric cooling (IF included)	_ 0	TWh/year	Subtract electric cooling using distribution from 'cooling' window

Step 6: Save data:

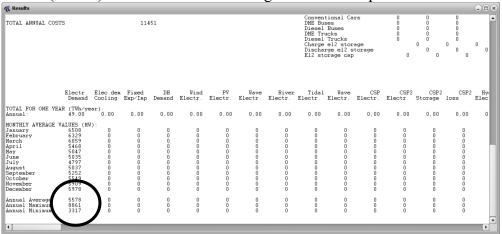


Activate the Save button.

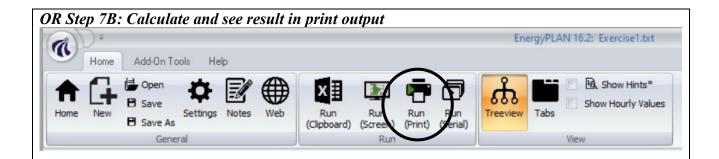
## EITHER Step 7A: Calculate and see result in clipboard



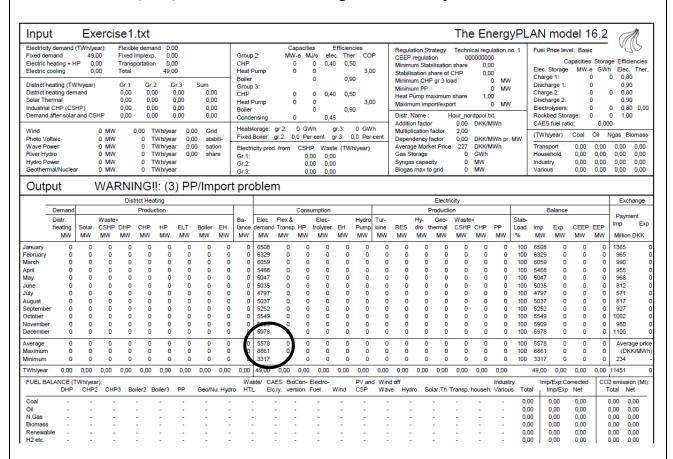
Activate the "Run (Screen)" button and the following window will open:



Read the result: 8861 MW



Activate the "Run (Print)" button and the following window will open:



Read the result: 8861 MW

Step 8: Repeat steps 4 to 7 using 40 TWh/year and "Hour\_electricity.txt". The result is 7023 MW

## Exercise 1.2: Define wind power and a power plant

Use the same electricity data as in exercise 1.1: Electricity demand of 49 TWh/year and "DK 2013 electricity demand". Define a wind power input of 2000 MW using "Hour\_wind\_1" and a condensing power plant of 9000 MW burning coal.

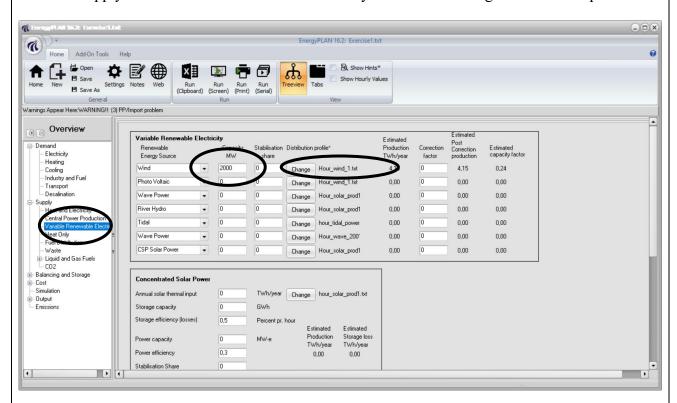
Question 1.2.1: What are the annual wind power and condensing power plant productions? What is the annual coal consumption? What is the annual CO2 emission?

Question 1.2.2: What are the annual wind power and condensing power plant productions, if the installed wind power capacity is raised to 6000 MW? What are the annual coal consumption and the CO2 emission?

#### **How to do exercise 1.2:** Use input data file from exercise1.1.

#### Step 1: Define wind power

Choose "Supply" and "Variable Renewable Electricity" and the following window will open:



Place cursor at the first RES Capacity input square and write 2000.

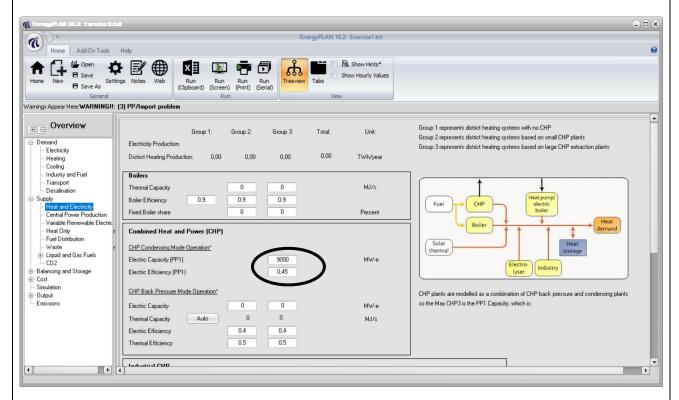
#### Step 2: Change hour distribution file

The Distribution profile is "Hour wind1".

Activate the button and change to "DK 2013 Wind onshore" as shown in exercise 1.1, step 5.

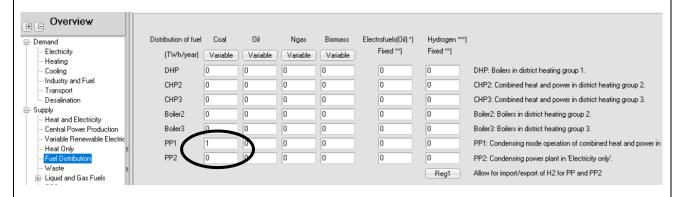
#### Step 3: Define condensing Power plant

Choose the "Supply > Heat and Electricity" window:

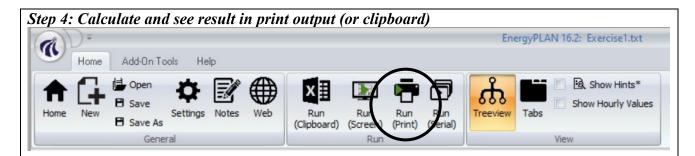


Place the cursor at the condensing Capacity input square and type in 9000. Place the cursor at the condensing Efficiency input square and type in 0.45.

Choose the "Supply > Fuel Distribution" window:



Place the cursor at the PP1 coal input square and type in 1 (Any number will do, they are all relative to the other fuel input squares)



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

Input		Ex	ercis	se1.	.txt																The	e Er	nerg	yPL/	AΝ	mod	lel 1	6.2	A			
Electricity demand (TWh/year): Flexible demand 0.00										Group 2: MV-e MJ/s elec. Ther COP CHP								Regulation Strategy: Technical regulation no. 1 CEEP regulation 000000000 Minimum Stabilisation share 0.00 Minimum Stabilisation share 0.00 Minimum CHP gr 3 load 0 MW Minimum PP 0 MW Heat Pump maximum share 1.00 Maximum import/export 0 MW Distr. Name: Hour_nordpool.txt Addition factor 0.00 DKK/MWh								Fuel Price level: Basic  Capacities Storag Elec. Storage MW-e GW! Charge 1: 0 Discharge 1: 0 Charge 2: 0 Discharge 2: 0 Electrolysers: 0 Rockbed Storage: 0 CAES fuel ratio: 0.00						
District heating (TWIN)war)         Gr.1         Gr.2         Gr.3         Sum           District heating demand         0.00         0.00         0.00         0.00           Solar Thermal         0.00         0.00         0.00         0.00           Industrial CHP (CSHP)         0.00         0.00         0.00         0.00           Demand after solar and CSHP         0.00         0.00         0.00         0.00           Wind         2000 MW         4,15         TWhyear         0.00         Grid																																
											orage: Boiler:	gr.2: gr.2: 0,	0 GWh 0 Perc		r.3: r.3: (	0 GW 0,0 Per		Multipl Depen			2,00 0,00	DKK/N	MWh pr.	MW	(TWh/	lgas Biom						
Wave Power         0 MW         0 TWhlyear         0.00 sation           River Hydro         0 MW         0 TWhlyear         0.00 share           Hydro Power         0 MW         0 TWhlyear         0 MW share           Geothermal/Nuclear         0 MW         0 TWhlyear         0 TWhlyear									Electricity prod. from CSHP Waste (TWh/year) Gr.1: 0,00 0,00 Gr.2: 0,00 0,00 Gr.3: 0,00 0,00								Average Market Price         227         DKK/MWh           Gas Storage         0         GWh           Syngas capacity         0         MW           Biogas max to grid         0         MW							House Indust Variou	00,00 00,00 00,00 00,00	0,00 0, 0,00 0, 0,00 0, 0,00 0,						
Outpu	ut																															
				Dist	rict Hea															Electric							Exchan					
	Demand Distr. heating	Solar		DHP	CHP	HP	ELT	Boiler	EH			Flex.& Transp.	HP tr	Elec- olyser	EH	Hydro Pump	Tur- bine	RES	Hy- dro t	Geo- hermal	Waste	CHP	PP	Stab- Load	Imp	Exp	CEEP		Payment Imp			
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oril av	0	0	0	0	0	0	0	0	0	0	5468 5047	0	0	0	0	0	0	445 438	0	0	0	0	5023 4609	100	0	0	0	0	0			
ne	0	0	0	0	0		0	0	0	0	5035 4797	0	0	0	0	0	0	379 288	0	0	0	ō	4656 4509	100	0	0	0	0	0			
y gust	0	0	0	0	0	0	0	0	0	0	5037 5252	0	0	0	0	0	0	331 424	0	0	0	0	4705	100	0	0	0	0	0			
ptember tober	0	0	ō	0	0	0	0	0	0	0	5549	ō	0	0	0	0	0	422	ō	0	0	0	4828 5127	100 100	ō	0	0	o	0			
wember cember	0	0	0	0	0	0		0	0	0	5909 5978	0	0	0	0	0	0	603 641	0	0	0	0	5307 5338	100 100	0	0	0	0	0			
erage aximum nimum	0	0	0	0	0	0	0	0	0	0	5578 8861 3317	0	0	0	0	0	0	472 1980 0	0	0	0	0	5106 8677 2157	100 100 100	0	0	0	0	Average (DKK/I			
Vh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	49,00	0,00	0,00	0,00	0,00	0,00	0,00	4,15	0,0	0,00	0,00	0,00	44,85	_	0,00	0,00	0,00	0,00	0			
UEL BAL	ANCE (T	Wh/yea		3 Boi	iler2 E	Boiler3	PP	Geo/N	u. Hydn	Wa HTI			Con- Ele ion Fu		Vind	PV an	d Wind	off Hun	s s	olar.Th. T	ransp.	houseb	Indust	ry 5 Tota		/Exp Co np/Exp	rrected Net		emission otal Net			
oal	-	-	-		-	-	99,67	-	-	-				-	-	-	-	-		-	-	-	7.	99,67		0,00	99,67		,09 34,09 0.00 0.00			
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Nuclear/C0	os -	-	-		-	-	-	-	-					-	-	-	-	-		-	-	-	-	0,0	) (	0,00	0.00	0	0,00			
otal	-	-	-		-	-	99,67	-	-			-		- 4	4,15	-	-	-		-	-	-	-	103,8	2   1	0,00	103332	34	,09 34,09			

#### Read results:

Wind power production = 4.15 TWh/year.

Condensing Power production = 44.85 TWh/year.

Coal consumption = 99,67 TWh/year.

CO2 emissions = 34.09 Mt.

## Step 5: Change installed wind power capacity

Repeat step 1 for 6000 MW wind power. The results are now:

Wind power production = 12.45 TWh/year.

Excess production (export) = 0.07 TWh/year.

Condensing Power production = 36.62 TWh/year.

Coal consumption = 81.38 TWh/year.

CO2 emission = 27,83 Mt

## Exercise 1.3: Define district heating and individual house heating

Use the data from exercise 1.2:

- Electricity demand of 49 TWh/year and "DK 2013 electricity demand"
- Condensing power plant: 9000 MW coal –fired
- 2000 MW wind power using "DK 2013 Wind onshore"

Define 1) an annual district heating demand of 39.18 TWh (distribution "hour\_distr\_heat") of oil boilers and 2) a 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. Use the efficiencies already used in the model.

Question 1.3.1: What is the net annual heat demand for individual houses?

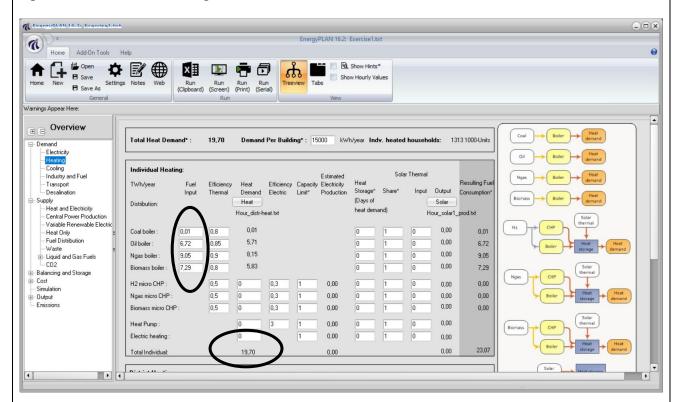
Question 1.3.2: What is the peak hour district heating demand?

Question 1.3.3: What is the annual primary energy supply of the system? And what is the annual CO2 emission?

## **How to do exercise 1.3:** Use input data file from exercise1.2.

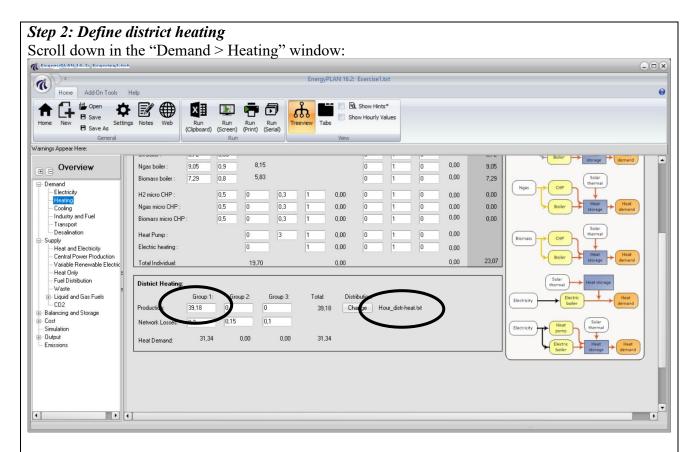
#### Step 1: Define individual house heating

Open the "Demand > Heating" window:

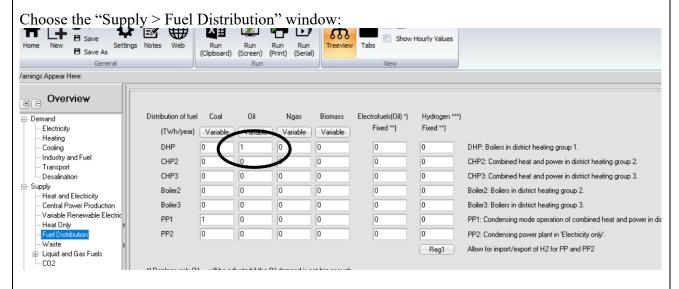


Place the cursor in the input squares of coal, oil, Ngas and Biomass boilers and type in the fuel demands.

Read the answer of question 1.3.1: The annual house heat demand is 19.70 TWh.



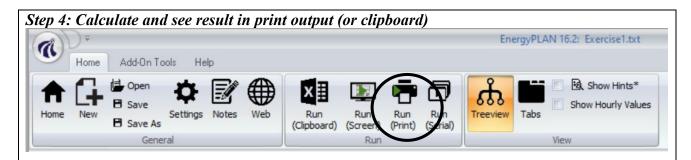
Place the cursor in the district heating group I input square and type in 39.18. Make sure that the distribution is already "hour-distr-heat"



Place the cursor in the DHP oil input square and type in 1 (Any number will do, they are all relative to the other fuel input squares)

#### Step 3: Calculate and see result in clipboard

The district heating peak hour load demand is 7932 MW (Question 1.3.2)



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

Input		Exe	ercise	1.txt																The	En	ergy	/PL/	١N	mod	lel 1	6.2		1
Electricity demand (TWh/year):   Flexible demand   0.00										Capacities Efficiencies Group 2: MW-e MJ/s elec. Ther COP CHP 0 0 0,40 0,50 Heat Pump 0 0 3,00									Regulation Strategy: Technical regulation no. 1 CEEP regulation 000000000 Minimum Stabilisation share 0,00 Stabilisation share of CHP 0,00								Storage GWH	ge Efficien Elec.	The
District heating (TWh/year)   Gr.1   Gr.2   Gr.3   Sum									Boiler 0 0,90 (Froup 5: CHP 0 0 0,40 0,50   Heat Pump 0 0 3,00   Boiler 0 0,90								Minimum CHP gr 3 load								e 1: arge 1: e 2: arge 2: olysers: ed Stora	0 0 0	0,90 0,80 0,90 0,90 0,80 0,1,00	0,0	
Wind 2000 MW 4,15 TWh/year 0,00 Grid									Heats	torage:		0 GWh		gr.3:	0 GW		Additio	n factor ication f			DKK/N				fuel rati		00,00 1 IiO		
Photo Voltaic								n	Fixed Boiler: gr.2: 0,0 Per cent   gr.3: 0,0 Per cent								Dependency factor						NIVV	Transp House Industr Variou	oort hold ry	0,00 0,01 0,00 0,00	0,00 6,72 0,00 0,00	0,00 9,05 0,00	0,00 7,29 0,00 0,00
Outp	ut																												
_	Demand		- 1	District He	eating uction							Consum						D	Electric						lalance		Excha	ange	
_	Demand Distr.		Waste+						Ba-	Elec.	Flex.&		Elec-		Hydro	Tur-		Hy-	Geo-	Waste			Stab-	В	alance			Payme Imp	ent E:
1	heating MW	Solar MW	MW M		HP MW	MW	Boiler MW	EH MW	lance MW	demand MW	Transp. MW	HP tr	olyser MW	EH MW	Pump MW	bine MW	RES MW	dro th MW	ermal MW	CSHP MW	MW	PP MW	Load %	lmp MW	Exp MW	MW	MW	Million I	
January	7553	0	0 75			0	0	0	0	6508	0	0	0	0	0	0	629	0	0	0	0	5879	100	0	0	0	0	0	
February March	7139 6151	0	0 71	-	_	0	0	0	0	6329 6059	0	0	0	0	0	0	600 475	0	0	0	0	5729 5584	100 100	0	0	0	0	0	
April	4595	0	0 45			0	0	0	0	5468	0	0	0	0	0	0	445	0	0	0	0	5023	100	0	0	0	0	0	
May	3012	0	0 30		_	0	0	0	0	5047	0	0	0	0	0	0	438	0	0	0	0	4609	100	0	0	0	0	0	
June	2202	0	0 22	-	_	0	0	0	0	5035	0	0	0	0	0	0	379	0	0	0	0	4656	100	0	0	0	0	0	
July	1788 1853	0	0 17			0	0	0	0	4797 5037	0	0	0	0	0	0	288 331	0	0	0	0	4509 4705	100	0	0	0	0	0	
August September	2611	0	0 26	-	_	0	0	0	0	5252	0	0	0	0	0	0	424	0	0	0	0	4828	100	0	0	0	0	0	
October	4058	ō	0 40	-	0	0	0	0	0	5549	0	0	0	ō	ō	0	422	ō	0	0	ō	5127	100	0	ō	o	ō	0	
November	5727	ō	0 57	-	0	ō	ō	ō	ō	5909	ō	ō	ō	ō	ō	ō	603	ō	ō	ō	ō	5307	100	ō	ō	ō	0	ō	
December	6921	0	0 693	21 0	0	0	0	0	0	5978	0	0	0	0	0	0	641	0	0	0	0	5338	100	0	0	0	0	0	
Average	4460	0	0 44	30 0	0	0	0	0	0	5578	0	0	0	0	0	0	472	0	0	0	0	5106	100	0	0	0	0	Averag	je p
Maximum	7932	0	0 79	32 0	0	0	0	0	0	8861	0	0	0	0	0	0	1980	0	0	0	0	8677	100	0	0	0	0	(DKK	
Minimum	1607	0	0 16	07 0	0	0	0	0	0	3317	0	0	0	0	0	0	0	0	0	0	0	2157	100	0	0	0	0	-	
TWh/year	39,18	0,00	0,00 39,	18 0,00	0,00	0,00	0,00	0,00	0,00	49,00	0,00	0,00	0,00	0,00	0,00	0,00	4,15	0,00	0,00	0,00	0,00	44,85		0,00	0,00	0,00	0,00	0	
FUEL BAL	ANCE (T	Wh/year CHP2		Boiler2	Boiler3	PP	Geo/N	u. Hydr				Con- Ele ion Fu		Vind	PV and CSP	Wind Wave		ro Sol	ar.Th. T	ransp. h	nouseh.	Industry Various			/Exp Co np/Exp			emission otal Net	
Coal	-	-	-	-	-	99,67	-						-	-	-	-	-		-	-	0,01	-	99,68		0,00	99,68	34	,09 34,0	09
Oil	43,53	-	-	-	-	-	-	-					-	-	-	-	-		-	-	6,72	-	50,25		0,00	50,25	13	,39 13,3	
N.Gas	-	-	-	-	-	-	-	-					-	-	-	-	-		-		9,05	-	9,05		0,00	9,05		,85 1,8	
Biomass	-	-	-	-	-	-	-	-					-		-	-	-		-	-	7,29	-	7,29		0,00	7,29		0,00 0,0	
Renewable H2 etc.	е -	-	-	-	-	-	-	-					- '	4,15	-	-	-		-	-	-		4,15		0,00	4,15		0,00 0,0	
H2 etc. Biofuel	- 1			-				-					-				-						0,00		0,00	0,00		0,00 0,0	00
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Read the results of question 1.3.3:

Primary energy supply = 170.42 TWh/year.

CO2 emissions = 49.33 Mt.

### Exercise 1.4: Define industrial fuel demand and heat and electricity productions.

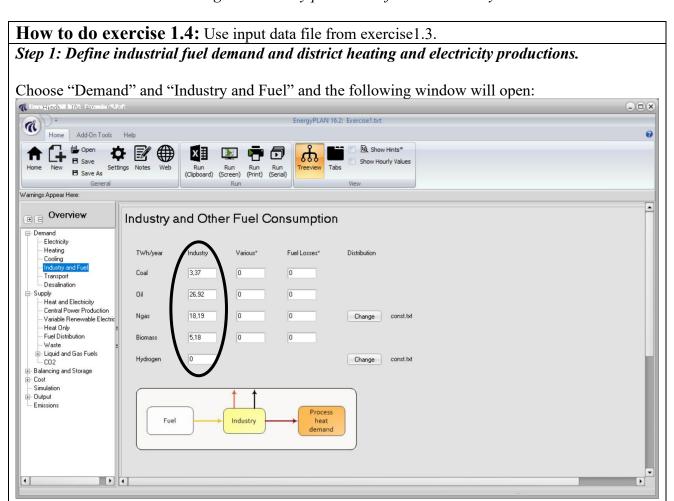
Use the data from exercise 1.3:

- Electricity demand of 49 TWh/year and "DK 2013 electricity demand"
- Condensing power plant: 9000 MW coal –fired
- 2000 MW wind power using "DK 2013 Wind onshore"
- 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.

Define an 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). Define an industrial district heating production of 1.73 TWh and an electricity production of 2.41 TWh. Use the hour distribution file "const".

Question 1.4.1: What is the annual primary energy supply of the system? And what is the annual CO2 emission?

Question 1.4.2: What are the annual primary energy supply of the system and the CO2 emission when there is no district heating or electricity production from the industry?



Place the cursor in the input squares of coal, oil, Ngas and Biomass and type in the fuel demands.

Choose "Supply" and "Heat and Electricity" and the following window will open: Characteristic farmings. \_) (D) (X EnergyPLAN 16.2: Exercise1.txt Home Add-On Tools Help Show Hints\* க் 🖺 **B** Save Run Run Run Run (Clipboard) (Screen) (Print) (Serial) Warnings Appear Here • Overview CHP Condensing Mode Operation\* Electric Capacity (PP1) 9000 MW-e 0,45 Electricity Electric Efficiency (PP1) Heating Cooling CHP Back Pressure Mode Operation\* CHP plants are modelled as a combination of CHP back pressure and conde Industry and Fuel so the Max CHP3 is the PP1 Capacity, which is: Transport Desalination Electric Capacity Supply

Heat and Electricity

Central Power Production

Variable Renewable Electric Thermal Capacity MJ/s Electric Efficiency 0,4 Thermal Efficiency 0.5 0.5 Heat Only Fuel Distribution Industrial CHP -- Waste -- Liquid and Gas Fuels -- CO2 Balancing and Storage 2,41 0.00 CHP Heat Demand TWh/year Output
 Emissions 2.41 Distribution Hour cshpel.txt CHP Heat Delivered\* 0.00 0.00 TWh/year 0

Place the cursor in the input squares of group I DH prod and electricity production and type in 1.73 and 2.41.

The hour-distribution-file is "Hour\_cshpel".

Activate the Distribution button and change to "const" as shown in exercise 1.1, step 5.

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



Read the results of question 1.4.1:

Primary energy supply = 217.56 TWh/year.

CO2 emissions = 59.33 Mt.

## Step 3: Change district heating and electricity production

Repeat steps 1 and 2:



Place the cursor in the input squares of group I DH prod and electricity production and type in 0.

Read the results of question 1.4.2:

Primary energy supply = 224.08 TWh/year.

CO2 emissions = 61.36 Mt.

## **Exercise 1.5: Define fuel demand for transportation.**

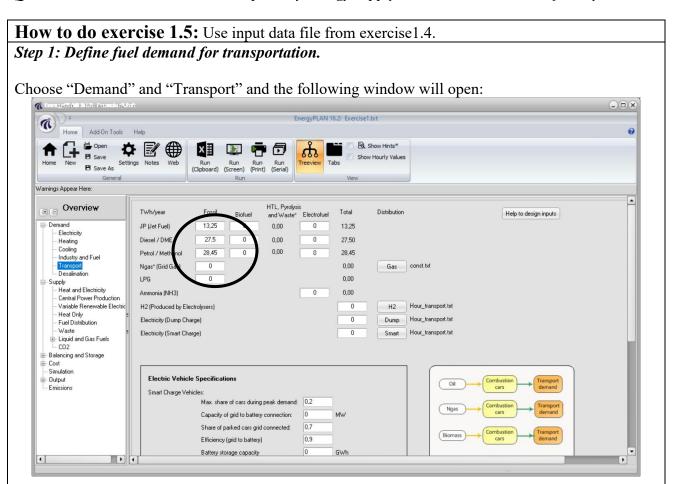
Use the data from exercise 1.4:

- Electricity demand of 49 TWh/year and "DK 2013 electricity demand"
- Condensing power plant: 9000 MW coal –fired
- 2000 MW wind power using "DK 2013 Wind onshore"
- 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".

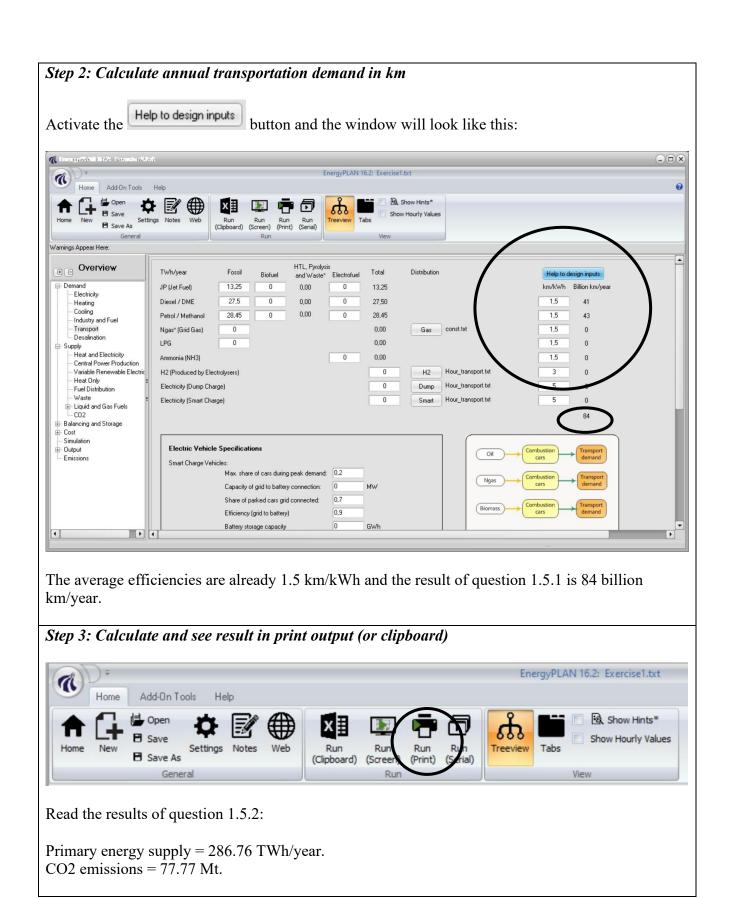
Add fuel demand for transportation: 13.25 TWh Jet Petrol, 27.50 TWh Diesel and 28.45 TWh Petrol.

Question 1.5.1: Assuming an average car efficiency of 1.5 km/kWh what is the transportation demand in km/year of the diesel and petrol supply?

Question 1.5.2: What are the annual primary energy supply and the CO2 emission of the system?



Place the cursor in the input squares of JP, Diesel and Petrol and type in the fuel demands.



REMEMBER to save exercise 1. You will need it when doing exercise 2.