# **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:





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	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	
😟 - Output	Elec. for Biomass Conversion 0.00 TWh/year (Transfered from Biomass Conversion TabSheet)	
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	Participation of the second	
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	Electric cooling 0.00 TWh/year	
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Step 5: Cha	ange hour-distribution to "hour-eldemand-eltra-2001"	
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#### **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 "houreldemand-eltra-2001". Define a wind power input of 2000 MW using "Hour\_wind\_eltra2001" 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?



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

Step 2: Change hour distribution file

Look at the "Intermittent Renewable Energy" window. The hour-distribution-file next to the "Wind" renewable energy source is "Hour\_wind1".

Activate the Change button and change to "hour-wind\_eltra2001" as shown in exercise 1.1, step 5.

#### Step 3: Define condensing Power plant

Look at the "Central Power Plants" part under the "Electricity Only" tab. Under the "Condensing PP2" capacity input square type in 9000.

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

Choose "Thermal Plant Fuel Distribution" in the tree view under the "Supply" tab and the following window will open:

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heating Solar CSHP DHP CHP HP ELT Boiler EH MW MW MW MW MW MW MW MW MW MW	lance MW	deman MW	dTransp HP MW MV	trolyser V MW	EH MW	Pump b MW 1	ine MW	RES	dro then MW N	mal C /IW I	SHP	MW	PP MW	Load %	Imp MW	Exp MW	CEEP I MW	MW	Million DKk
January         0 </td <td>000000000000000000000000000000000000000</td> <td>6211 6213 6060 5456 5155 5061 4656 5267 5355 5616 5981 5934</td> <td>000000000000000000000000000000000000000</td> <td></td> <td></td> <td></td> <td>000000000000000000000000000000000000000</td> <td>399 610 469 375 386 394 264 388 373 662 637 424</td> <td></td> <td>000000000000000000000000000000000000000</td> <td>000000000000000000000000000000000000000</td> <td>000000000000000000000000000000000000000</td> <td>5813 5593 5593 5081 4769 4887 4392 4880 4982 4954 5343 5511</td> <td>100 100 100 100 100 100 100 100 100 100</td> <td>0 0 0 0 0 0 0 0 0 0 0 0</td> <td>001000000000000000000000000000000000000</td> <td>0 0 1 0 0 0 0 0 0 0 0 0</td> <td>000000000000000000000000000000000000000</td> <td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>	000000000000000000000000000000000000000	6211 6213 6060 5456 5155 5061 4656 5267 5355 5616 5981 5934	000000000000000000000000000000000000000				000000000000000000000000000000000000000	399 610 469 375 386 394 264 388 373 662 637 424		000000000000000000000000000000000000000	000000000000000000000000000000000000000	000000000000000000000000000000000000000	5813 5593 5593 5081 4769 4887 4392 4880 4982 4954 5343 5511	100 100 100 100 100 100 100 100 100 100	0 0 0 0 0 0 0 0 0 0 0 0	001000000000000000000000000000000000000	0 0 1 0 0 0 0 0 0 0 0 0	000000000000000000000000000000000000000	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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Minimum 0 0 0 0 0 0 0 0 0 0	0.00	0	0 0.00	0 0	0	0	0	2.02	0	0	0	0	5.07	100	0	0	0	0	- 1
FUEL BALANCE (TWh/year):	0.00	49.00 CA	AES BioCor	-Synthetic	0.00	0.00 0	T	3.83	)	.00 0	100		ladus	L	imi	o/Exp C	orrected	CO2	emission (N
Coal 100.18 100.18	ro Wa	aste Ek -	.ly. version	Fuel V	Vind	PV .	Wave -		fo Solar	Th Tra	ansp.h	ouseh -	Varia	100.1	8	mp/Exp	00.18	34	25 34.25
Oil	34 1 1 1 1 1	20 8 57 8		-	2		2					2	-	0.0		00.00	0.00	0	00 0.00 .00 0.00
Biomass	34 1 1 1 1	-01 0 12 8		- 3	.93		2					2	-	0.0	0 0 3 0	0.00 0.00	0.00	0	00 0.00 .00 0.00
H2 etc	1 8 1 97	20 8 51 8		-	20 73		- 22	2				2 3	-	0.0		00.00	0.00	0	00 0.00 00 0.00
Nuclear/CCS		- S - S 25 - 5		- 3	-	2	2	2			-	2		0.0	0 0	0.00	0.00	34	25 31 25
ad results.														101.0	- I	9			
ind power production = 3.93 TW	/h/	vea	r.																
ondensing Power production $= 43$	5.0	7 T	Wh/y	ear.															
al consumption = $100.16 \text{ TWh/s}$	yea	r.																	
D2  emissions = 34.25  Mt.																			
ep 5: Change installed wind nov	ver	can	nacit	v															
		1		,															
peat step 1 for 6000 MW wind p	pov	ver.																	
e results are now:																			
ind power production $= 11.79$ T	Wh	/ve	ar.																
cess production (export) = $0.06$	T٧	Vh/v	vear																
$\frac{1}{2}$ ondensing Power production = 3'	7.2	8 Т	Wh/x	vear															
had consumption $-82.83$ TW/h/w	,.2 29r	01	,, 11/ J	cui.															
2  amission = 28.22  Mt	Jai	•																	
72 CHIISSIUH – 20.33 IVII																			

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

Use the data from exercise 1.2:

- 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"

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 (part of the initialize data set).

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?* 



Place the cursor in the input squares of Coal boiler, Oil boiler, Ngas boiler and Biomass boiler and type in the fuel demands.

Read the answer of question 1.3.1: The annual house heat demand is 19.7 TWh.

#### Step 2: Define district heating

In the same window, in the District Heating part, place the cursor in the Production group 1 input square and type in 39.18.

Make sure that the distribution is already "hour-distr-heat"

Choose "Thermal Plant Fuel Distribution" in the tree view under the "Supply" tab and the following window will open:

Home New Import from excel 🗗 Sa Gene	ve Settings Notes ve As ral	Web	Run (Clipboard)	Run F (Screen) (P Run	tun Run rint) (Serial)	Treev
Overview						
⊡ ⊡ ⊞-Demand	Distribution of fuel	Coal	0il	Ngas	Biomass	
∃- Supply	(T\u/h/uear)	Variable	Variable	Variable	Variable	
- Heat and Electricity Electricity Only	DHP	0	1		0	
- Heat Only	CHP2	0		0	0	
Vaste		0	0	0	0	
E Liquid and Gas Fuels	Boiler2	0	0	0	0	
Balancing and Storage	Boiler3	0	0	0	0	
E- Cost	PP1	0	0	0	0	
Simulation ⊕ Output	PP2	1	0	0	0	
Simulation Output	PP1 PP2	0	0	0	0	
lace the cursor in the DHP of	il input square and	l type in 1	1 (Any nu	mber will	do, they are	e all

		EnergyPLAN 12.0: exer	cise1.txt
Settings Notes Web	Run (Screen) (Frint) (Serial)	reeview Tabs	now Hints*
The district heating peak hour load	demand is 7932 MW (	Question 1.3.2)	
Step 4: Calculate and see result in	n print output (or clipbo	ard)	
C EnergyPLAN 12.0: exercise1.txt			
Home Add-On Tools Help		$\sim$	
Home New Import From excel B Save General	Settings Notes Web (c	Run Run (Screen) Run (Screen) Run (Print)	Run Serial)
Input exercise1.txt		The EnergyPl	LAN model 12.0
Electricity demand (TWh/year): Flexible demand0.00 Fixed demand 40.00 Fixed implexp. 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	Capacities         Efficiencies           Group 2:         MIV-e         MJ/s         elec. Ther COF           CHP         0         0.40         0.50           Heat Pump         0         3.00           Bolier         0         0.90	Regulation Strate(Technical regulation no. 1 KEDL regulation 00000000 Minimum Stabilisation share 0.00 Stabilisation share of CHP 0.00 Minimum CHP gr 3 load 0 MW	Fuel Price level: Basic Capacities Storage Efficiencie MW-e GWh elec. Ther. Hydro Pump: 0 0 0.80 Hydro Turbine: 0 0.90
District heating demand         39.18         0.00         0.00         39.18           Solar Thermal         0.00         0.00         0.00         0.00         1.00           Industrial CHP (CSHP)         0.00         0.00         0.00         0.00         0.00         0.00           Demand after solar and CSHP 39.18         0.00         0.00         39.18         0.00         39.18	CHP         0         0.40         0.50           Heat Pump         0         0         3.00           Boiler         0         0.90         .           Condensing         0         0.45         .	Heat Pump maximum share 0.50 Maximum import/export 0 MW Distr. Name : Hour_nordpool.bdt Addition factor 0.00 DKK/MWh	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
Wind         2000 MW         3.83         TWh/year         0.00         Grid           Photo Voltaic         0 MW         0         TWh/year         0.00         Stabili-           Wave Power         0 MW         0         TWh/year         0.00         stabili-           Wave Power         0 MW         0         TWh/year         0.00         stabili-           River Hydro         0 MW         0         TWh/year         0.00         share           Hydro Power         0         MW         0         TWh/year         share           Geothermal/Nuclear         0         MW         0         TWh/year	Heatstorage:         gr.2:0         GWh         gr.3:0         GWh           Fixed Boiler:         gr.2:0.0         Per cent         gr.0:0         Per cent           Electricity prod. from         CSHP         Waste         (TWhyser)           Gr.1:         0.00         0.00         0.00           Gr.3:         0.00         0.00         0.00	Multiplication factor 2.00 Dependency factor 0.00 DKK/MWh pr. MW Average Marker Price227 DKK/MWh Gas Storage 0 GWh Syngas capacity 0 MW Biogas max to grid 0 MW	(TWh/year)         Coal         Oil         Ngas         Biomass           Transport         0.00         0.00         0.00         0.00           Household         0.01         6.72         9.05         7.29           Industry         0.00         0.00         0.00         0.00           Various         0.00         0.00         0.00         0.00
Output WARNING!!: (1) Critica	l Excess;		
District Heating Demand Production	Consumption	Electricity Production	Exchange Balance
Distr. Waste heating Solar CSHP DHP CHP HP ELT Boiler EH	Ba- Elec. Flex.& Elec- Hydro Tur- lancedemandTransp HP trolyser EH Pump bine	Hy- Geo- Waste- Stab- RES dro thermal CSHP CHP PP Load	Imp Exp CEEP EEP
January         7553         0         0         7553         0         <	NO         NO<	Mrd         Mrd         Mrd         Mrd         Mrd         Mrd         R           399         0         0         0         5813         100           400         0         0         0         5613         100           399         0         0         0         5693         100           375         0         0         0         5693         100           384         0         0         0         4769         100           384         0         0         0         4480         100           384         0         0         0         4480         100           384         0         0         0         4480         100           384         0         0         0         4480         100           373         0         0         0         4842         100           382         0         0         0         4842         100           373         0         0         0         4842         100           682         0         0         0         54343         100      424         0         0	Mot         Mot         Mot         Mot         Multiple Dock           0         0         0         0         0         0         0           0         1         1         0         0         0         0         0           0         0         0         0         0         0         0         0           0         0         0         0         0         0         0         0         0           0
Average         4480         0         0         4480         <	0 5578 0 0 0 0 0 0 0 8730 0 0 0 0 0 0 0	447         0         0         0         0         5131         100           2000         0         0         0         0         8585         100	0 0 0 0 Average price 0 614 614 0 (DKK/MWh)
TWh/year 39.18 0.00 0.00 39.18 0.00 0.00 0.00 0.00		0 0 0 0 0 100 3.93 0.00 0.00 0.00 0.00 45.07	0.00 0.00 0.00 0.00 0 0
FUEL BALANCE (TWh/year): DHP CHP2 CHP3 Boiler2 Boiler3 PP Geo/NuHyd	CAES BioCon-Synthetic ro Waste Elc.ly. version Fuel Wind PV War	industry ve Hydro Solar.Tr Transp.househ.Various Tota	Imp/Exp Corrected CO2 emission (Mt): Imp/Exp Netto Total Netto
Coal         -         -         100.16         -		0.01 - 100.1 6.72 - 60.2 0.05 - 0.0 7.29 - 7.2 3.0 0.0 0.0 0.0 0.0 0.0	7         0.00         100.17         34.26         34.26           5         0.00         60.25         13.39         13.39           5         0.00         0.05         1.85         1.85           6         0.00         7.29         0.00         0.00           0         0.00         3.93         0.00         0.00           0         0.00         3.93         0.00         0.00           0         0.00         0.00         0.00         0.00           0         0.00         0.00         0.00         0.00           0         0.00         0.00         0.00         0.00           0         0.00         1.00         0.00         0.00           0         0.00         1.00         0.00         0.00           0         0.00         1.00         0.00         0.00           0         0.00         1.00         0.00         0.00           0         0.00         170.89         49.49         49
Read the results of question 1.3.3: Primary energy supply = 170.69 T CO2 emissions = 49.49 Mt.	Wh/year.		

## 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 "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.

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?

How to do exercise 1.4: Use input data file from exercise1.3. Step 1: Define industrial fuel demand and district heating and electricity productions. Choose "Industry and Fuel" window under the "Demand" tab and the following window will open: C EnergyPLAN 12.0: exercise1.txt a Home Add-On Tools Help Dpen Đ. Q -X≣ **A** P 6 E Save Import Settings Notes Run Run Run Run (Clipboard) (Screen) (Print) (Serial) Home Web Run Warnings Appear Here: WARNING!!: (1) Critical Excess; **Overview** Industry and Other Fuel Consumption - Demand Electricity Heating TWh/yea Various\* Fuel Losses\* Coal 3 37 In 0 Iransport Wate 🗄 - Supply Oil 26.92 0 0 🗄 Balancing and Storage E- Cost 18.19 0 0 Ngas - Simulation . . Output 0 5.18 0 Biomass Place the cursor in the input squares of Coal, Oil, Ngas and Biomass and type in the fuel demands. Choose "Heat and Electricity" window under the "Supply" tab and the following window will open:

Home Add-On Tools	Help an 🏠 📝 🌐 🚺 💽	EnergyPLA	N 12.0: exercise1.txt
from excel B Sav Gener Varnings Appear Here: WARNING!!: (	e As (Clipboard) (Screen al (Clipboard) (Screen Ru 1) Critical Excess;	(Print) (Serial)	View
Overview     Overview     Overview     Supplement	Thermal Capacity     0       Boiler Efficiency     0.9       Fixed Boiler share     0	0 0.9 0	MJ/s Percent Percent
Heat and Electricity     Heat Only     Heat Only     Heat Only     Thermal Plant Fuel Distributi     Waste     Liquid and Gas Fuels     CO2	Combined Heat and Power (CHP) <u>CHP Condensing Mode Operation*</u> Electric Capacity (PP1) Electric Efficiency (PP1)	0	Solar thermal
∰ Balancing and Storage ⊕ Cost → Simulation ⊕ Output	CHP Back Pressure Mode Operation*         Electric Capacity       0         Thermal Capacity       Auto       0         Electric Efficiency       0.4         Thermal Efficiency       0.5	0 0 0.4 0.5	MW-e So the Max CHP3 is the PP1 Capa MJ/s Percent Percent
	Industrial CHP       CHP Electricity       CHP Heat Produced       CHP Heat Own Use       CHP Heat Delivered*	0 2.41 0 1.73 0 0.00 0.00 1.73	TWh/year TWh/year TWh/year TWh/year
Place the cursor in t n 2.41 and 1.73.	he input squares of group 1 C	CHP Electricity and	CHP Heat Production and typ
The hour-distribution	on-file is "Hour_cshpel".	to "const" as shown	in evercise 1.1 step 5



Home Add-On Tools	Help				Energy	PLAN 12.0: exercis	el.txt
Home New Import from excel B Sav Genera	en 🏠 📝 🤀 e As settings Notes Wi	eb Run (Clipboa	Run (Screen) Run	Run Run (Print) (Serial)	Treeview	Tabs View	v Hints*
rnings Appear Here: <b>WARNING!!: (</b>	1) Critical Excess;						1.(
Overview	Thermal Capacity		0	0		MJ/s	
- Demand	Boiler Efficiency	0.9	0.9	0.9		Percent	Fuel
Supply	Fixed Boller share		U	0		Percent	
Heat Only     Thermal Plant Fuel Distributi     Waste     Co2     Balancing and Storage     Simulation	<u>CHP Condensing Mode 0</u> Electric Capacity (PP1) Electric Efficiency (PP1) <u>CHP Back Pressure Mode</u>	peration* • Operation*		0		Mu/a	CHP plant so the Mar
- Output	Thermal Canacity	Auto	0	0		MW-e	
	Electric Efficiency		0.4	0.4		Percent	
	Thermal Efficiency		0.5	0.5		Percent	
	Industrial CHP						
	CHP Electricity	0	0	0	0.00	TWh/year	
	CHP Heat Produced	a /	0	0	0.00	TWh/year	
	CHP Heat Own Use		0	0	0.00	TWh/year	
		0.00	0.00	0.00	0.00	T\u/b/uear	Distribution COD

Read the results of question 1.4.2: Primary energy supply = 224.35 TWh/year. CO2 emissions = 61.53 Mt.

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

Use the data from <u>exercise 1.4</u>:

- 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".

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?



T EnergyPLAN 12.0: exercise1.bct	
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G Warnings Appear Here:	eneral Run View
wanings Appear Here.	
<b>Overview</b>	TWh/year Fossil Biofuel Waste* Synthetic Fuel Total Distribution
⊡- Demand	JP (Jet Fuel) 13.25 0 0 13.25 km/kW/h Billion km/year
- Electricity	Diesel 27.5 0 0.00 0 27.50 1.5 41
Cooling	Petrol 28.45 0 0 28.45 15 42
- Industry and Fuel	
Water	
⊕- Supply     ⊕- Balancing and Storage	LPG 0 0.00 1.3 0
⊕- Cost	
- Simulation	Electricity (Dump Charge)
	Electricity (Smart Charge) U Smart Provi_transport.cxt 5 U
	84
Step 3: Calcula	te and see result in print output (or cliphoard)
C EnergyPLAN 12	.0: exercise1.txt
(A))=	
() Hama	Add Op Tools Holp
Home	
nome New fi	rom excel 🗄 Save As (Clipboard) (Screen, (Print) Serial)
	General Run
Activate the (Print) button and look at the following print output:	
Read the results	of question 1.5.2:
Primary energy	supply = 286.27  TWh/year
CO2 omissions	$= 77.60 \text{ M}_{\odot}$
CO2 emissions	- //.02 IVIL.

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