# **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):



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:



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

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The CO<sub>2</sub> 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?



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	40.70	27.07		10	0.40	54.20	- 28	200			8 13 	8 8		02	125	55			80	20	14 42	53.8	242.2		1.01	242.22	C	4 42 64 42

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:

EnergyPLAN 12.0: exercise2.tx	t							
1)V*					EnergyPLA	V12.0: exe	rcise2.txt	
Home Add-On Tools	Help							
me New Import	en e Settings Notes Web	X ∄ Bun	Run		Treeview Tabs	🗖 🗟 s	how Hints*	
from excel 🖪 Sav	e As	(Clipboard)	(Screen)	(Print) (Serial)				
Genera	al		Run			View		
nings Appear Here: <b>WARNING!!:</b> (	I) Unitical Excess;							
Overview	Central Power Plants	Capacity MW-e	Efficiency Percent	Correction Factor: Percent	Annual produ TWh/yea	etion: D	)istributions	
Demand Electricity	PP1 (CHP3 Condensing Mod	e)* 2000.00			n/a*			
Cooling	Condensing PP2	9000	0.45		n/a*			
Industry and Fuel Transport	Nuclear	0	0	1	0.00	) (	Change Ho	ur_wind_1.t
Water	Geothermal	0	0	1	0.00	) (	Change Ho	ur_wind_1.t
- Heat and Electricity	Dammed Hydro Water supply	×			0	] (	Change Ho	ur_wind_1.1
- Heartoniy Heartoniy Waste Waste Urquid and Gas Fuels	Dammed Hydro Power	0	0.33		0.00	) (Estimated	d)×	
Balancing and Storage								
Electricity Thermal	Intermittent Renewable I Renewable	E <b>lectricity</b> Capacit	y: Stabili:	sation Distribution p	profile	Estimated Production	Correction	Estimated Post Correction
Cost	Energy Source	MW	sha	re		TWh/year	factor	productio
Simulation	Wind 🚽	2000	0	Change	hour_wind_eltra2	3.93	0	3.93
	Ulfshore Wind	6 3000		Change	OffshoreHornsRe	3.49	0	11.49
	Wave Power	Ō	0	Change	Hour_solar_prod1	0.00	0	0.00
	River Hudro	0	0	Change	Hour solar prod1	0.00	0	0.00

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:

a)V*		EnergyPLAN 12.0: exercise	
Home Add-On Tools Help			
Naw Treport Save Setting Nate Wal			
from excel 🔁 Save As General	(Clipboard) (Screen) (Print) (Serial)	View	
nings Appear Here:WARNING!!: (1) Critical Excess;	A		
Chose Simulation Str	ategy:		
Demand Electricity  • Technical Simulation			
Heating			
Industry and Fuel     Transport     Transport	ds		
- Supply	ad al-onicity demands	المراجع والمراجع	
Heat and Electricity     Electricity     A Balancing bett neat an     A Balancing heat deman	ds using tripple tariff	nny needed for gird stabilisation)	
	ation		
Waste  Individual Heat Pumps Curve Control of Control	and Electric Boilers seek to utilise only Critical Excess and Electric Boilers seek to utilise all electricity evont	s Production	
Balancing and Storage		ð	
- Electricity - Thermal			
- Cost			
[also sure that the technical re	gulation stratagy is 1		
take sure that the teenmean re		1:1	
tep 2: Calculate and see resu	it in print output (or cl	upboara)	
ctivate the Run button and lo	ok at the following prin	nt output.	
Input exercise2.txt		The EnergyF	LAN model 12.0
Electricity demand (TWh/year): Flexible demand0.00 Fixed demand 49.00 Fixed imp/exp. 0.00	Capacities Efficiencies Group 2: MW-e MJ/s elec. Ther CO	Regulation Strate(Technical regulation no. 1	Fuel Price level: Basic V.U.S
Electric heating + HP 0.00 Transportation 0.00 Electric cooling 0.00 Total 49.00	CHP 1350 1646 0.41 0.50 Heat Pump 0 0 3.00	Minimum Stabilisation share 0.00 Stabilisation share of CHP 0.00	Capacities Storage Efficier MW-e GWh elec. The
District heating (TWh/year) Gr.1 Gr.2 Gr.3 Sur	Boller 5000 0.90 n Group 3:	Minimum CHP gr 3 load 450 MW Minimum PP 0 MW	Hydro Pump: 0 0 0.80 Hydro Turbine: 0 0.90
District nearing demand         1.59         10.00         15.64         27.43           Solar Thermal         0.00         0.00         0.00         0.00         0.00           Induction CHD (CDER)         0.00         0.00         0.00         0.00         0.00	CHP 2000 2439 0.41 0.50 Heat Pump 0 0 3.00	Heat Pump maximum share 0.50 Maximum import/export 0 MW	Electrol. Gr.2: 0 0 0.80 0.10 Electrol. Gr.3: 0 0 0.80 0.10 Electrol. trans: 0 0 0.80 0.10
Demand after solar and CSHP 1.59 10.00 14.11 25.70	Boller 5000 0.90 Condensing 2000 0.45	Distr. Name : Hour_nordpool.txt	Ely, MicroCHP: 0 0 0.80
Wind 2000 MW 3.93 TWh/year 0.00 Grid Offshore Wind 3000 MW 11.49 TWh/year 0.00 stabili-	Heatstorage: gr.2:10 GWh gr.10 GWh Fixed Boller: gr.2:0.0 Per cent gr.0.0 Per cen	Multiplication factor 2.00 tt Dependency factor 0.00 DKK/MWh pr. MW	(TWh/year) Coal Oll Ngas Bloma
Wave Power 0 MW 0 TWh/year 0.00 sation River Hydro 0 MW 0 TWh/year 0.00 share	Electricity prod. from CSHP Waste (TWh/year)	Average Market Price227 DKK/MWh Gas Storage 0 GWh	Transport 0.00 69.20 0.00 0.00 Household 0.01 4.20 5.66 4.55
Hydro Power D MW D TWh/year Geothermaii/Nuclear D MW D TWh/year	Gr.1: 0.00 0.00 Gr.2: 0.00 0.00 Gr.3: 2.41 0.00	Syngas capacity 0 MW Blogas max to grid 0 MW	Industry 3.37 26.92 18.19 5.18 Various 0.00 0.00 0.00 0.00
Output WARNINGII: (1) Critic	al Excess:		-common encodermentation (2010)
District Heating	ui Ex0033,	Electricity	Exchange
Demand Production	Consumption	Production	Balance Payment
heating Solar CSHP DHP CHP HP ELT Boller EH	I lance demandTransp HP trolyser EH Pump bin	e RES dro thermal CSHP CHP PP Load	Imp Exp CEEP EEP
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
Peorolary 4554 0 197 255 3549 0 0 249 March 4021 0 197 233 3566 0 0 25		0 1705 0 0 274 3157 1357 100 0 1705 0 0 274 2924 1301 100	
April 3399 0 197 197 3015 0 0 2 May 2859 0 197 166 2492 0 0 0		0 2009 0 0 274 2472 859 100 0 1285 0 0 274 2043 1578 100	
June 1784 0 197 103 1495 0 0 0 July 1784 0 197 103 1483 0 0 0	0 -12 5051 0 0 0 0 0 0 0 0 4656 0 0 0 0 0 0	0 1833 0 0 274 1226 2060 100 0 1187 0 0 274 1216 1986 100	0 32 32 0 0 4
August 1784 0 197 103 1489 0 0 0 September 2261 0 197 131 1923 0 0 0	0 -6 5267 0 0 0 0 0 0 0 0 9 5355 0 0 0 0 0 0	0 154/ 0 0 2/4 1221 2228 100 0 1499 0 0 274 1577 2025 100	0 21 21 0 0 3
November 2556 0 197 176 2576 0 0 0 November 3566 0 197 207 3139 0 0 7	0 -12 5010 0 0 0 0 0 0 0 0 16 5981 0 0 0 0 0 0	0 204/ 0 0 2/4 2112 1351 100 0 2342 0 0 274 2574 996 100	
Average 3123 0 197 181 2698 0 0 47	0 1 5578 0 0 0 0 0 0	0 1755 0 0 274 2912 1002 100 0 1755 0 0 274 2212 1475 100	0 138 138 0 Average price
Maximum 7161 0 197 415 4085 0 0 2463 Minimum 1673 0 197 97 549 0 0 0	0 2698 8730 0 0 0 0 0 0 -1535 0 0 0 0 0 0	0 4968 0 0 274 3350 5529 100 0 1 0 0 274 450 0 100	0 4473 4473 0 (DKK/MWh) 0 0 0 0 0 242 199
TWh/year 27.43 0.00 1.73 1.59 23.70 0.00 0.00 0.41 0.0	0 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 1.2 1.22 0.00 0 242
FUEL BALANCE (TWh/year): DHP CHP2 CHP3 Boller2 Boller3 PP Geo/Nu.H	CAES BloCon-Synthetic ydro Waste Elc.ly. version Fuel Wind Offsh. W	industry /ave Hydro Solar.Tr Transp.househ.Various To	Imp/Exp Concerto CO2 emission (Mt) Ital Imp/Exp Netto Total Netto
Coal - 27.74 0.05 0.07 28.80 -		0.01 3.37 60. 69.20 4.20 26.92 102	03 -2.70 57.33 20.53 19.61 20 0.00 102.20 27.23 27.23
N.Gas - 19.65 - 0.05 0.07 Blomass 0.05 0.07		5.66 18.19 43. 4.55 5.18 9	61 0.00 43.61 8.90 8.90 84 0.00 9.84 0.00 0.00
Renewable 0.00 0.00 0.00 -	3.93 11.49	· · · · · · · · · · · · · · · · · · ·	42 0.00 15.42 0.00 0.00 00 0.00 0.00 0.00 0.00
Blofuel			00 0.00 0.00 0.00 0.00

1.77 19.65 27.74 0.19 0.27 28.80 Read the results of question 2.3.1:

Total

11.49

3.93

69.20 14.42 53.6

231.11

0.00

74

228.41



Electricity of Fixed dema Electric hea Electric coo	lemand and ating + H bling	(TWh/ye 49.0 IP 0.0 0.0	ar):   0   0   0	Flexible Fixed in Transpo Total	e deman np/exp ortation	nd 0.0 0.0 0.0 49.0				Group CHP Heat P Boller	2: <sup>J</sup> ump	Ca MW 1350 0	pacities (-e MJ ) 1646 ) ( 5000	s ele 5 0.41	Efficien c. The i 0.5 0.9	cles r CO 0 3.0 0	0	Regul KEOL Minim Stabili	ation St regulati um Stat sation s	rategy: on bilisation hare of (	Techr share CHP	lical regi 0000000 0.0 0.0	lation n 0 0 0	0.2	Fuel P	rice lev Pump:	el: Basic Capaci MW-e O	ties Sto GWI	V(() prage Effi n elec. 0 0.80	clencies Ther.
District hea District hea Solar Therr Industrial C Demand af	ting (TW ting den nal :HP (CS ter solar	/h/year) hand HP) and CSI	1P	Gr.1 1.59 0.00 0.00 1.59	Gr.2 10.0 0.0 0.0	: G D 1 D 1 D 1 D 1	97.3 5.84 0.00 1.73 4.11	Sum 27.4 0.0 1.7 25.7	3 0 3 0	Group CHP Heat P Boller Conde	3: Pump ensing	2000 0 2000	) 2439 ) ( 500( )	0.41	0.5	0 3.0 0		Minim Heat P Maxim Distr. I Additio	um PP Pump m num Imp Name : on facto	aximum ort/expo H	share int lour_no 0.00	D.5 Indpool.t	D MW D D MW d Wh		Hydro Electro Electro Electro Ely. M CAES	Turbine ol. Gr.2: ol. Gr.3: ol. trans loroCHF fuel rat	8: 0 0 1: 0 2: 0	) ) ) 0.00	0.90 0.80 0.80 0.80 0.80 0.80 0	0.10
Wind Offshore W Wave Pow River Hydro Hydro Pow Geotherma	lind er o er i/Nuclea	200 300	0 MW 0 MW 0 MW 0 MW 0 MW 0 MW	3.	93 T 49 T 0 T 0 T 0 T 0 T	Wh/yea Wh/yea Wh/yea Wh/yea Wh/yea	er D.C er D.C er D.C er D.C er er	0 Grid 10 stab 10 satic 10 shar	10- n e	Heats Fixed Gr.1: Gr.2: Gr.3:	lorage: Boller: city proc	gr.2: 1 gr.2: 0 1. from	0 GWI 0 Per 0.00 0.00 2.4	n 9 pent 9 Wast 0 0.00 0 0.00	gr.3: <u>r.3: (</u> e (TW1 ) )	10 GW <u>).0 Per</u> Nyear)	h cent	Multip Deper Avera Gas S Synga Biogar	ilication f indency f ge Mark torage is capac s max to	factor actor et Price ity grid	2.00 0.00 227 0 0 0	DKK/N DKK/N GWh MW MW	/Wh pr. /Wh	MW	(TWh/ Transp House Indust Variou	year) oort hold ry is	Coal 0.00 0.01 3.37 0.00	OII N 69.20 4.20 26.92 0.00	Ngas Bio 0.00 5.66 18.19 0.00	mass 0.00 4.55 5.18 0.00
Outpu	ıt	1	NAF	NIN	<b>VG</b>	1: (1	) Cr	itica	I Ex	ces	S;																			
	hemand	0		Distri	Produc	ting				3 12			Concur	notion						Electri	city		3		-	ance			Excha	ange
C h	Distr. leating	Solar	Waster CSHP	DHP	CHP	HP	ELT MW	Boller	EH	Ba- lance	Elec. demand	Flex.& 1 Transp.	HP t	Elec- rolyser	EH	Hydro Pump MW	Tur- bine	RES	Hy- dro ti	Geo- nermal	Waste CSHF		PP MW	Stab- Load	Imp	Exp	CEEP	EEP	Payme Imp Million I	nt Exp DKK
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	JAN (
February March April	4564 4021 3399	0 0	197 197 197	265 233 197	3771 3388 2817	0	000	328 203 197	000	4 0 -8	6213 6060 5456	0	0 0	0	000	0 0 0	000	1495 1705 2009	0	000	274 274 274	3092 2778 2310	1351 1305 865	100 100 100	0	0 2 1	0 2 1	000	0 0 0	
Vlay June July	2859 1784 1784	0	197 197 197	166 103 103	2464 1472 1482	0	0	29 20 5	0 0	-10 -3	5155 5061 4656	0	0 0 0	000	000	000	0 0 0	1285 1533 1187	0	0 0 0	274 274 274	2021 1207 1215	1578 2064 1985	100 100 100	0	3 18 6	3 18 6	000	0	
Nugust September Dotober November	1784 2261 2930 3566	000	197 197 197 197	103 131 170 207	1487 1898 2403 2916	000	0000	25 173 231	0000	-4 10 -13 15	5267 5355 5616 5981	0	0000	0	0 0 0	000	0000	1547 1499 2047 2342	0000	0000	274 274 274 274	1220 1556 1971 2391	2230 2027 1358 998	100 100 100	0000	4 2 34 26	4 2 34 26	0000	0 0 0	
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	
Average Maximum Minimum	3123 7161 1673	0	197 197 197	181 415 97	2539 4085 549	0	0 0 0	205 3919 0	0	1 2932 -1361	5578 8730 0	000	0 0 0	0	0 0	0	000	1755 4968 1	000	000	274 274 274	2082 3350 450	1477 5578 0	100 100 100	0 0 0	10 1727 0	10 1727	0 0 0	Averag (DKK 244	je prici VMWh 187
rWh/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	00	0	17
FUEL BAL	ANCE (T DHP	Wh/year CHP2	): CHP3	Boll	er2 B	oller3	pp	Geo/N	u. Hydro	wa	C/A ste Ek	AES Blo s.ly. ven	Con- Sj slon Fi	inthetic Jel V	Vind	Offsh.	Wave	e Hyd	iro So	ilar.Th 1	Fransp.	househ	Industi Variou	ry s Tota	imp al li	/Exp Co np/Exp	Netto	CO2 T	2 emissio otal Ne	n (Mt): tto
Oli N.Gas Biomass	1.77	18.21	26.40	0.2 0.2 0.2	15 C 15 C 15 C	1.25 1.25 1.25 1.25	28.84		101					:	-	1	1.1.1			- 69 -	9.20	0.01 4.20 5.66 4.55	3.37 26.92 18.19 5.18	59.1 102.5 42.5 10.2	1 - 1 9 1 6 1 3 1	0.20 0.00 0.00 0.00	58.91 102.59 42.56 10.23	20 27 8 0	0.22 20. 7.33 27. 8.69 8. 0.00 0.	15 33 59 00
Renewable H2 etc. Blofuel Nuclear/CC	-	-	:	0.0	10 0	-	0.00			500				-	3.93	11.49				-	2	:	-	15.4 0.0 0.0	2 1	0.00 0.00 0.00 0.00	15.42 0.00 0.00 0.00	0	0.00 0.1 0.00 0.1 0.00 0.1 0.00 0.1	00 00 00 00
	1.77	18 21	25 40	0.0	0 1		00.04	192	- 197	8		a) [1]		3	3 03	11.49				- 60	9.20	14.42	53.64	220.0	N	1 20	220 71		123	16

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:



Input exercise2.txt		The EnergyPLAN model 12.0
Electricity demand (TWh/year):         Flexible demand 0.00           Fixed demand         34.30         Fixed implexp. 0.00           Electric heating + HP 0.00         Transportation         0.00           Electric cooling         0.00         Total         34.30           District heating + HP 0.00         Total         34.30         Statistic heating + HP 0.00           District heating (TWh/year)         Gr.1         Gr.2         Gr.3         Sum           District heating (TWh/year)         0.00         10.00         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 stabili           Wave Power         0 MW         0 TWh/year         0.00 stabili         MW P TWh/year         0.00 stabili         MW P TWh/year         0.00 share           Hydro	Capacities         Efficiencies         Regular           Group 2:         MW-e         MJ/se         elec. Ther COP         KEOL n           CHP         1350         1648         0.41         0.50         Minimu           Heat Pump         0         3.00         Stabilis         Minimu           Boiler         5000         0.90         Minimu           CHP         2000         2439         0.41         0.50           Heat Pump         0         3.00         Minimu           Boiler         5000         0.90         Maximu           Condensing         2000         0.45         Addition           Heatstorage:         gr.2:10         GWh         gr.10         Multiplik           Fixed Boiler:         gr.2:0.0         Per cent         gr.3         Addition           Gr.1:         0.00         0.00         Syngas         Syngas           Gr.2:         2.41         0.01         Bioas         Singas Str	In Strate(Technical regulation no. 1         Fuel Price level: Basic         VLV           agulation         00000000         Capacities Storage Efficien           m Stabilisation share 0.00         MW-e         GWh elec. The           m CHP gr 3 load         450         MW           mPP         0         MW           min praximum share 0.50         MW         Electrol. Gr.2:         0         0.80           min prodpool.txt         0         MW         Electrol. Gr.3:         0         0.80           ratoin factor 2.00         DKK/MWh         Electrol. Gr.3:         0         0.80         0.10           Electrol. Gr.2:         0         0         0.80         0.10         Electrol. Gr.3:         0         0.80         0.10           Electrol. Gr.2:         0         0         0.80         0.10         Electrol. Gr.3:         0         0.80         0.10           ame :         Hour prodpool.txt         Transport         0.00         0.20         CAES fuel ratio:         0.000           Grage         GWH         Transport         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
Output WARNING!!: (1) Critica	Excess;	
District Heating	Consumption	Electricity Exchange Exchange
Distr. Waste Distr. Waste heating Solar CSHP DHP CHP HP ELT Boiler EH MW MW MW MW MW MW MW MW MW	Ba- Elec. Flex.& Elec- Hydro Tur- H lancedemandTransp HP trolyser EH Pump bine RES of MW MW MW MW MW MW MW MW MW	Hy Geo-Waste- Stab- fro thermal CSHP CHP PP Load Imp Exp CEEP EEP Imp Exp MW MW MW MW MW % MW
Invo         Invo <th< td=""><td>Mite         Mite         <th< td=""><td>Nino         Nino         <th< td=""></th<></td></th<></td></th<>	Mite         Mite <th< td=""><td>Nino         Nino         <th< td=""></th<></td></th<>	Nino         Nino <th< td=""></th<>
Nuclear/CCS	· · · · 3.93 11.49 · ·	0.00 0.00 0.00 0.00 - 69.20 14.42 53.66 209.45 13.89 195.76 49.25 5.7
Read the results of question 2.4.1:		
The Primary energy supply has bee	n reduced from 229.91 to 209	9.45 TWh/year.
The CO2 emission has been reduce	d from 56.23 to 49.25 Mt/yea	ur.
Critical Excess Electricity Producti	on (CEEP) is raised from 0.09	9 to 6.16 TWh/year
Repeat steps 1 and 2. Change the Technical Simulation s he "Simulation" tab in the tree view Activate the Runner button and read the The Primary energy supply has been The CO <sub>2</sub> emission has been decreas	<i>calculate and read results.</i> rategy to '2 Balancing both h w. e results of question 2.4.2 on n decreased from 209.45 to 2 red from 49.25 to 47.31 Mt/ve	the print: 04.02 TWh/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:

Home Add-On Tools	Help				Energy	PLAN 12.0: Exercise costs.txt	
Home New Import from excel B s	ave ave As	Run (Clipboard) (Sc	Run Run reen) (Print)	Run (Serial)	Treeview	Tabs	
Gen	eral		Run			View	
+ Overview							
			-		<b>T</b>		
명··Demand 명··Supply 다·Balancing and Storage	Thermal Storage Gro Thermal Storage	up 1: 0000 2	Grou	р 3: 0	Total:	Unit GWh	
Belancing and Storage     Electricity     Thermal	Thermal Storage Gro Thermal Storage For Solar Thermal Storage,	up 1: 40 go to Supply->Heat	Grou Only	р3: 0	Total:	Unit GWh GWh	

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:

				EnergyPLAN	12.0: EXERCISE COSISIDAT		
s Settings Notes Web	Run (Clipboard)	Run (Screen) (Print) Run	Run (Serial)	Treeview Tabs	View		
Critical Excess;							
	Group 1:	Group 2:	Group 3:	Total:	Unit	Distribution:	
Solar Thermal							
Production	0	0	0		TWh/year	Change Ho	ur_solar_prod1.txt
Storage	0	0	0		GWh		
Loss*	0	0	0		Percent		
Share*	1	1	1		Percent		
Result	0.00	0.00	0.00	0.00	TWh/year		
Annual accumulated heat in	solar thermal st	orage:		0.00	TWh/year		
Compression Heat Pump	15						
Electric Capacity	(	300	0		MW-e		
Thermal Capacity	•	900	0		MJ/s		
	p  Settings Notes Web  Critical Excess;  Solar Thermal  Production  Storage  Loss* Share*  Result  Annual accumulated heat in  Compression Heat Pump; Electric Capacity  COP  Thermal Capacity	p Settings Notes Web Run Clipboard)	p         Settings Notes       Web       Image: Run (Run (Run ) Run (Clipboard) (Screen) (Print) Run (	Image: Settings Notes Web       Image: Settings Run	Image: settings       Notes       Web       Image: settings       Image: settings	Image: setting s Notes       I	Image: settings       Image: settings

Input	6	exe	ercis	se25	52.t	xt			- 32								33				Th	e Er	nerg	yPLA	N m	odel	12.0	6	A
Electricity of Fixed dem Electric he Electric co District hea Solar Them Industrial O	demand hand eating + H poling ating (TW ating dem mai CHP (CS)	(TWh/ye 34.: IP 0.( 0.( /h/year) nand HP)	ar): 30 30	Flexible Fixed in Transp Total Gr.1 1.59 0.00 0.00	e dema np/exp ortatio Gr. 10.0 0.0 0.0	and 0.0 0. 0.0 0. 0.0 34.3 2 G 10 1 10 10 1 10	0 0 0 97.3 5.84 0.00 1.73	Sum 27.4 0.0 1.7	3	Group CHP Heat F Boiler Group CHP Heat F Boiler	2: Pump 3: Pump	Ca MW 1351 300 2001	Apacitiei (-e MJ 0 164 0 90 500 0 243 0 500	s ele 6 0.4 0 9 0.4 0	Efficien c. The 1 0.5 0.9 1 0.5 0.9	cles er CO 3.0 0 3.0 0 3.0 0 0	р 0	Regula KEOL Minimu Stabilis Minimu Heat P Maxim	ation Str regulati um Stati sation s um CHF um PP fump m um Imp	ategy: on illisation hare of 0 gr 3 loc aximum ort/expo	Techr share CHP ad share rt	nical regi 0000000 0.0 0.0 45 0.5	ulation n 00 00 00 00 00 00 00 00 00 00 00 00 00	0.2	Fuel Price Hydro Pur Hydro Tur Electrol. G Electrol. If	level: Baa Capa MW Ip: Ine: r.2: r.3: ans.: ans.:	sic icities Sti e GWI 0 0 0 0	orage E n elec 0 0. 0 0. 0 0. 0 0.	. Ther. 80 90 80 0. 80 0.
Wind Offshore W Wave Pow River Hydr Hydro Pow Geotherma	Latter solar and CSHP         1.59         10.00         14.11           2000 MW         3.93         TWhysar         0.00           Wind         3000 MW         1.49         TWhysar         0.00           ower         0 MW         0 TWhysar         0.00         0.00           otro         0 MW         0 TWhysar         0.00         0.00           ower         0 MW         0 TWhysar         0.00         0.00           out         WARNING!!:         (1) Critt         District Heating									Heatst Fixed I Electri Gr.1: Gr.2: Gr.3:	orage: Boller: city prod	gr.2: 4 gr.2: 0	40 GW 1.0 Per CSHP 0.0 0.0 2.4	h cent ( Wast 0 0.0 0 0.0 1 0.0	gr.3: gr.3: te (TW 0 0 0	10 GW 0.0 Per h/year)	'h cent	Additio Multipi Depen Averaç Gas Si Synga Biogas	in factor lication f dency f ge Mark torage s capac max to	tactor actor et Price ity grid	0.00 2.00 0.00 227 0 0 0	DKK/I DKK/I DKK/I GWh MW MW	viWh viWh pr. viWh	MW	CÁES fuel (TWh/year Transport Household Industry Various	ratio: ) Coal 0.00 0.01 3.37 0.00	0.00 OII 1 69.20 4.20 26.92 0.00	0 Ngas 0.00 5.66 18.19 0.00	Biomase 0.00 4.55 5.18 0.00
Outpu	dro         0         MW         0         TWhylear         0.00         starse         Gr.1:         0.00         0.00         Syngas capacity         0         GWh           wer         0         MW         0         TWhylear         0         Gr.2:         0.00         0.00         Syngas capacity         0         MW           0         MW         0         TWhylear         0         Gr.3:         2.41         0.00         Blogas max to grid         0         MW           Dut         WARNINGII: (1) Critical Excess;         Image: Compare the second																												
				Distr	lot Hei	ating					8					3				Electri	city							Ex	change
	Demand		Ittente	1	Produ	ction					<b>5</b> 144		Consu	mption	_	i budes	Tree		P	roductio	n		3	Charle	Balar	ce	-	Pay	ment
	heating MW	Solar MW	CSHP	DHP	CHP	HP MW	ELT MW	Boller MW	EH MW	lance MW	demand MW	1 Transp MW	HP MW	trolyser MW	EH	Pump MW	bine MW	RES MW	dro ti MW	nermal MW	CSHF	P CHP MW	pp MW	Load I	Imp Ex MW M	CEER	P EEP MW	Imp Millo	Ex In DKK
January February Vlarch April May June	4481 4554 4021 3399 2859 1784	000000000000000000000000000000000000000	197 197 197 197 197 197	260 265 233 197 166 103	2285 3113 2710 2064 2174 1305	657 490 418 459 217 168	0 0 0 0 0 0 0	1088 492 475 484 101 10	000000	-6 8 -12 -1 4 0	4348 4349 4242 3819 3609 3543	000000	219 163 139 153 72 56	000000000000000000000000000000000000000	0 0 0 0 0 0	0000000	000000	2344 1495 1705 2009 1285 1533	000000	000000	274 274 274 274 274 274 274	1874 2552 2222 1692 1783 1070	142 204 218 73 382 839	100 100 100 100 100 100		57 67 14 14 39 39 76 76 42 42 17 117	000000	000000	
ury kugust September Sctober lovember Secember	1784 2261 2930 3566 4085	00000	197 197 197 197 197 197	103 103 131 170 207 237	1375 1356 1685 1961 2132 2416	135 200 344 492 510	00000	4 43 262 534 712	00000	13 5 4 4 13	3259 3687 3748 3931 4186 4154	00000	45 67 115 164 170	00000	00000		00000	1547 1499 2047 2342 2061	00000	000000	274 274 274 274 274 274	1112 1382 1608 1749 1981	756 865 713 288 150 131	100 100 100 100 100	0 0 0 1 0 1 0 1	52 52 57 67 54 54 71 171 55 165 24 124	000000	00000	
Average Maximum Minimum	3123 7161 1673	0	197 197 197	181 415 97	2045 4085 549	349 900 0	0 0 0	351 3933 0	0	0 1459 -1593	3905 6111 0	0	116 300 0	000	0	0 0 0	0 0 0	1755 4968 1	000	0	274 274 274	1677 3350 450	398 3298 0	100 100 100	0 0 25 0	83 83 26 2526 0 0	0	Ave (D 256	rage p KK/M
Wh/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.	0.72	00	0	
FUEL BAL	ANCE (T	Wh/yea CHP2	r): CHP	3 Bol	ler2 B	Boller3	PP	Geo/N	u. Hydr	o Wa	CA ste Ek	AES Blo a.ly. ver	Con-S	ynthetic uel	Wind	Offsh.	Wave	e Hyd	ro So	lar.Th T	Transp.	househ	Industr Variou	ry s Total	Imp/Exp Imp/E	Corrected xp Netto	CO. T	2 emisi otal	sion (N Netto
Coal	177	2	23.46	0.	19	0.66	7.76	5	50	3		3 3	3	10	5	0	5	5			-	0.01	3.37	35.45	-1.61	33.84	1	2.12 1	1.57
N.Gas	1.0	12.47	12	0.1	19	0.66	8	30	5	5		2	2	15	2	1	0	5		_ 0:	20	5.66	18.19	37.18	0.00	37.18	2	7.59	7.59
Blomass		-		0.	19	0.66	20	5						35	(5	3	10	2		53	<b>5</b> 2	4.55	5.18	10.59	0.00	10.59		0.00	0.00
Renewable	е -	-			0	-	1	3	-	-		3 6	5	13	3.93	11.49				-	63	-	- 2	15.42	0.00	15.42		0.00	0.00
H2 etc.		-		0.0	00	0.00	0.00	2	-			-	-	3 <b>-</b> -	12	-	-			-	-	-	<b>4</b> 0	0.00	0.00	0.00		0.00	0.00
HIGHLIGE		2			1	2	1	5	1	3		1	2		5	2	3			2	2	1		0.00	0.00	0.00		00.0	0.00
Nuclear/C/						1000	1072	573				<3 13	10	100	100	127				242	22	23	- 20	-	0.00	0.00		-	-

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.