

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

Exercise 1.1: Define an electricity demand

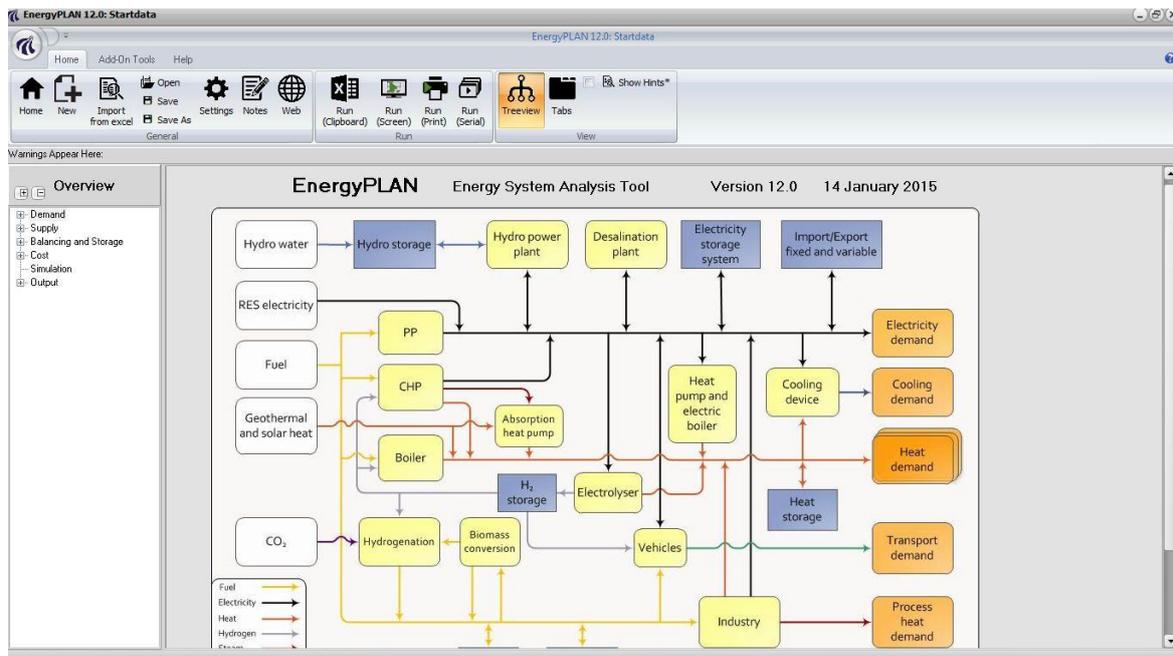
Open the EnergyPLAN model. Initialise data and define a simple national/regional energy system with an electricity demand of 49 TWh/year. Use the hour-distribution file of “hour-eldemand-eltra-2001” (The distribution of the western Danish region in 2001).

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 12):

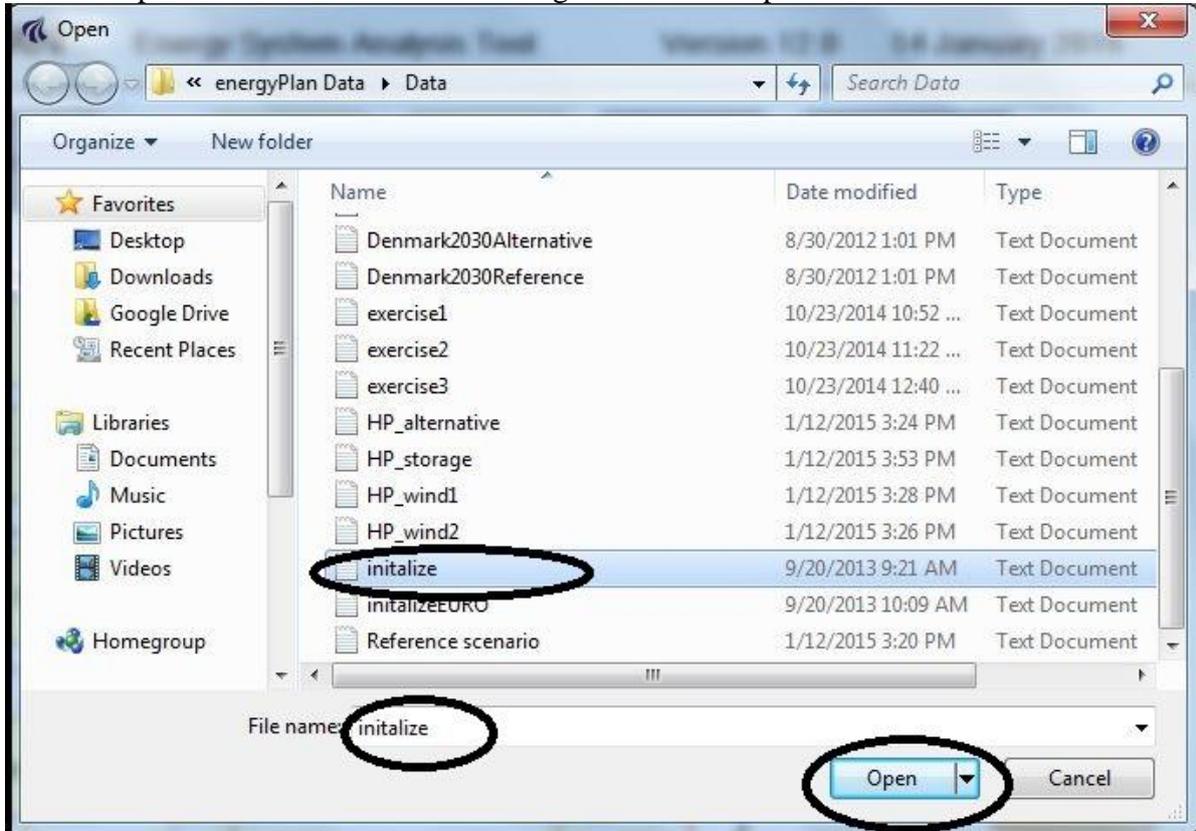


Look at the top left-hand corner: The EnergyPLAN model is loaded with “Startdata”



Step 2: Initialise the model by loaded “Initialize” data.

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



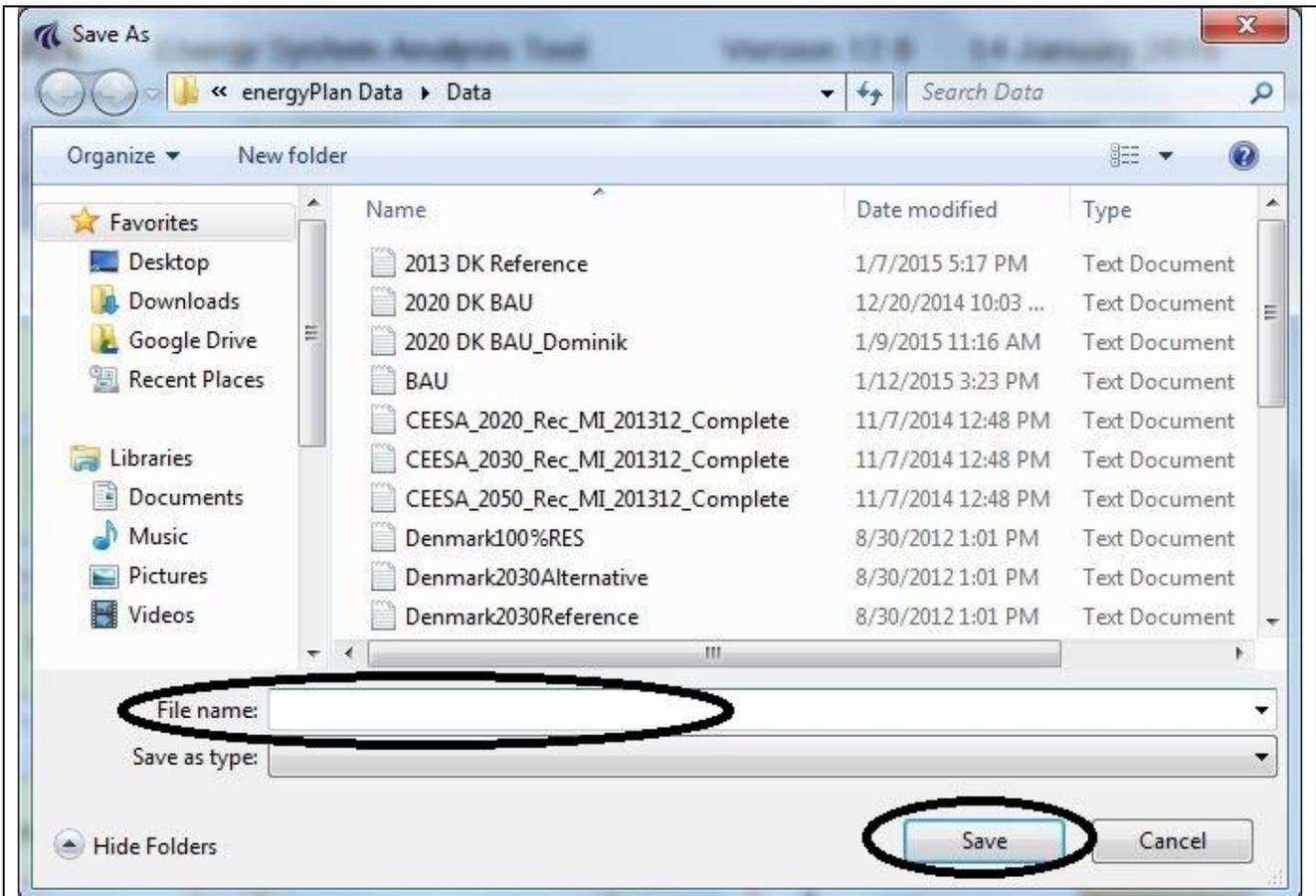
Choose “initialize.txt” and activate the Open button.

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



Step 3: Save Data

Press the “Save as” button at the top left-hand corner and the following window will open:



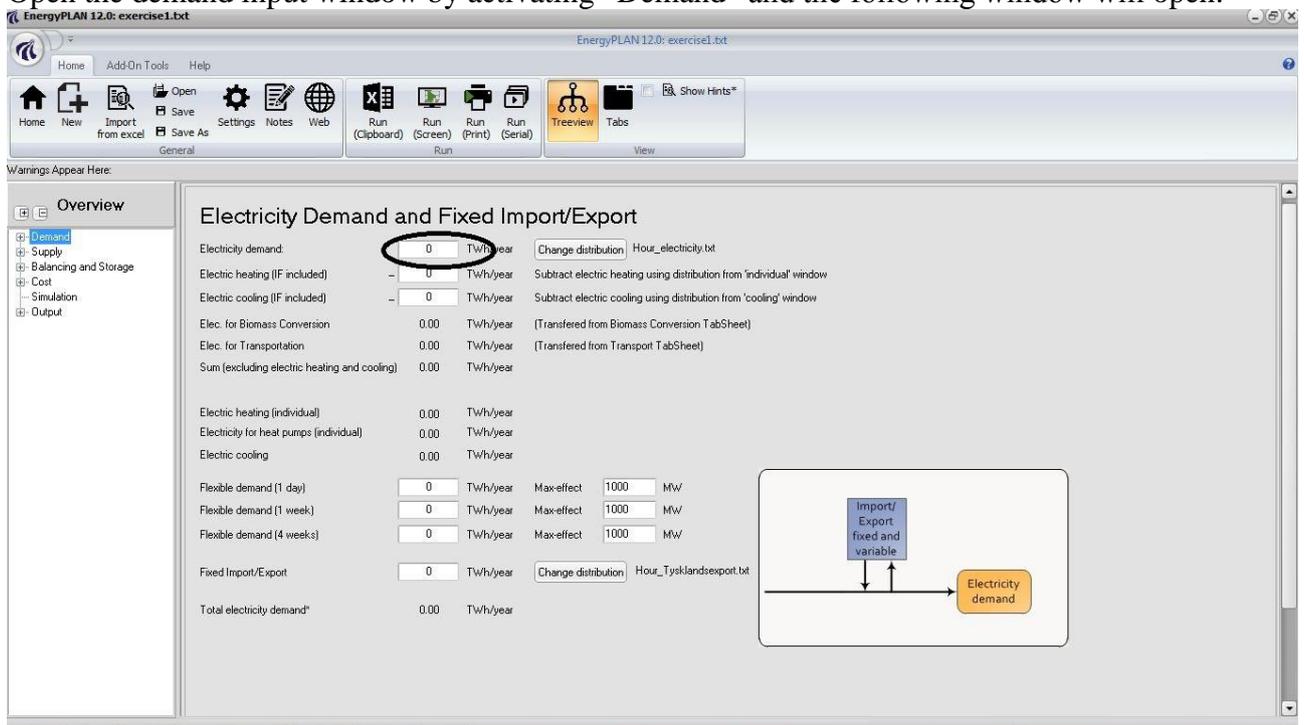
Choose a name and write the name, e.g.: “Exercise1” and activate the Save button.

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

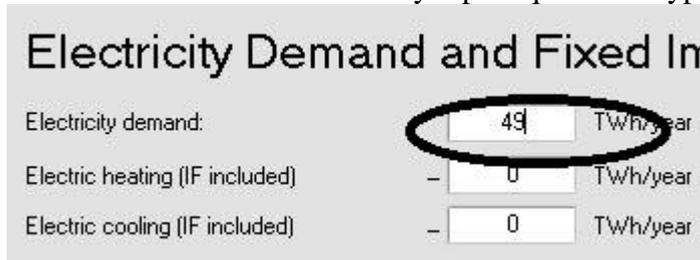


Step 4: Write input-data electricity demand 49 TWh/year.

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



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

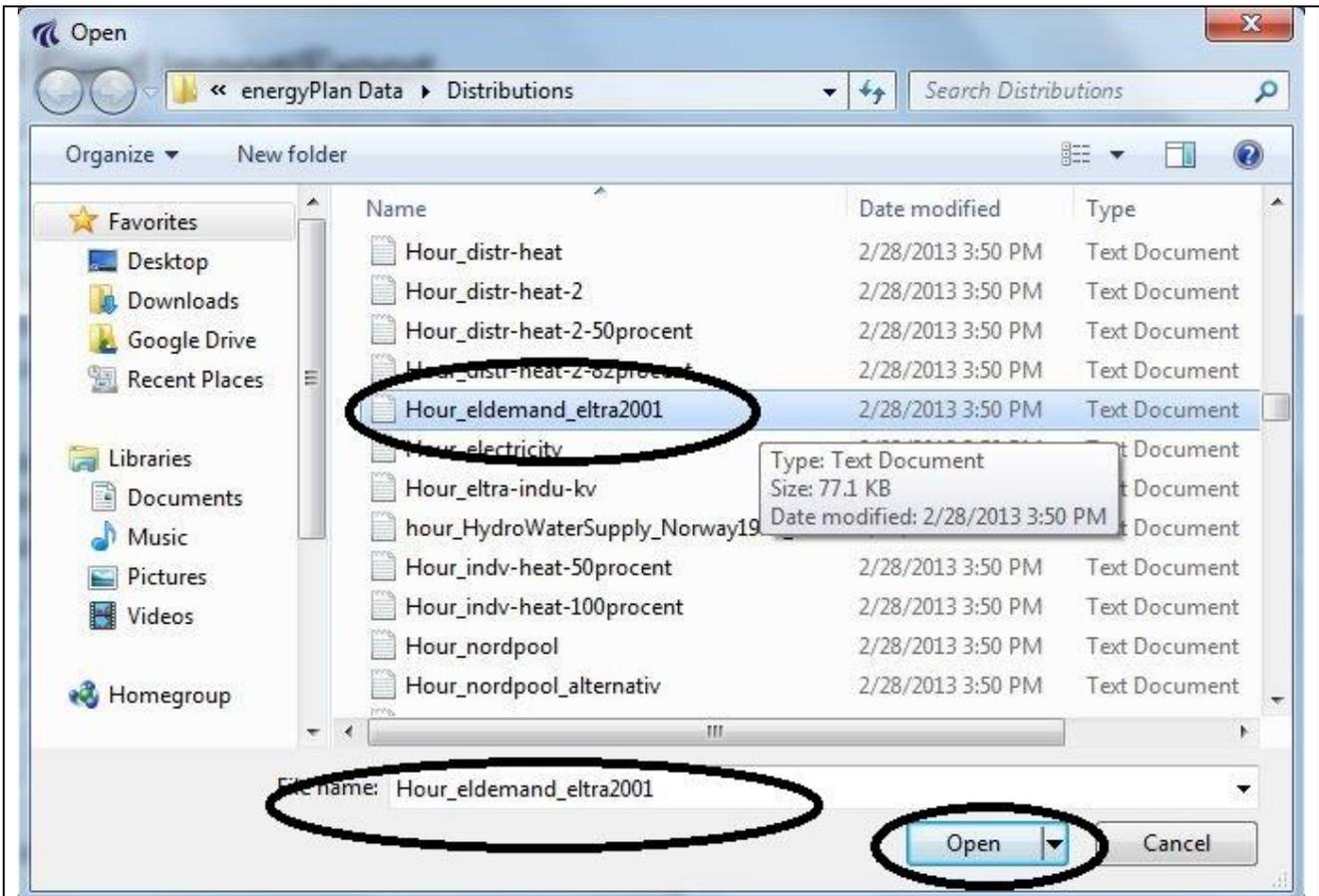


Step 5: Change hour-distribution to "hour-eldemand-eltra-2001"

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



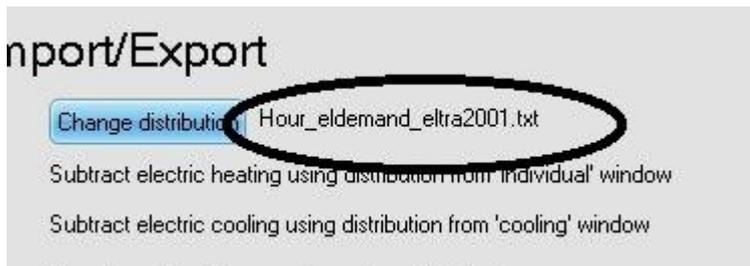
Activate the **Change distribution** button and the following window will open:



Choose “Hour_eldemand_eltra2001.txt” and activate the Open button.

Look at the Electricity Demand input window:

The model is now loaded with “Hour_eldemand_eltra2001.txt” distribution data:



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:

| | Electr. Demand | Elec.dem Cooling | Fixed Exp/Imp | DH Demand | Wind Electr. | PV Electr. | Wave Electr. | River Electr. | E |
|--------------------------------|----------------|------------------|---------------|-----------|--------------|------------|--------------|---------------|---|
| TOTAL ANNUAL COSTS | | 11599 | | | | | | | |
| TOTAL FOR ONE YEAR (TWh/year): | | | | | | | | | |
| Annual: | 49.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| MONTHLY AVERAGE VALUES (MW): | | | | | | | | | |
| January | 6211 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| February | 6213 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| March | 6060 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| April | 5456 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| May | 5155 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| June | 5061 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| July | 4656 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| August | 5267 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| September | 5355 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| October | 5616 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| November | 5981 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| December | 5934 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Annual Average | 5578 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Annual Maximum | 8730 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Annual Minimum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

Read the result : 8730 MW

OR Step 7B: Calculate and see result in print output



Activate the  button and the following window will open:

| Input | | | | | | | | | | exercise1.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 | | | | | | | | | | Group 2: Capacities Efficiencies MW-e MJ/s elec. Ther COP CHP 0 0 0.40 0.50 Heat Pump 0 0 0 3.00 Boiler 0 0 0.90 Group 3: CHP 0 0 0.40 0.50 Heat Pump 0 0 0 3.00 Boiler 0 0 0.90 Condensing 0 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 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 Storage Efficiency 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 | | | | | | | | | | | | | | | | | | | | | |
| District heating (TWh/year) 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 0 MW 0.00 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 | | | | | | | | | | 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: 0.00 0.00 Gr.2: 0.00 0.00 Gr.3: 0.00 0.00 | | | | | | | | | | (TWh/year) Coal Oil Ngas Biomass Transport 0.00 0.00 0.00 0.00 Household 0.00 0.00 0.00 0.00 Industry 0.00 0.00 0.00 0.00 Various 0.00 0.00 0.00 0.00 | | | | | | | | | | | | | | | | | | | | | |
| Output WARNING!!: (3) PP/Import problem | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Demand | | | | | | | | | | Production | | | | | | | | | | Consumption | | | | | | | | | | Production | | | | | | | | | | Balance | | | | | | | | | | Exchange | |
| Distr. heating | Solar | Waste | CSHP | DHP | CHP | HP | ELT | Boiler | EH | Ba-lance | 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 | ECP | Payment Imp | Exp | | | | | | | | | | | | | | | | | | | | |
| MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | Million DKK | | | | | | | | | | | | | | | | | | | | |
| January | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8211 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 8211 | 0 | 0 | 0 | 1313 | 0 | | | | | | | | | | | | | | | | | | | |
| February | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8213 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 8213 | 0 | 0 | 0 | 951 | 0 | | | | | | | | | | | | | | | | | | | |
| March | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8080 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 8080 | 0 | 0 | 0 | 1016 | 0 | | | | | | | | | | | | | | | | | | | |
| April | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5486 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5486 | 0 | 0 | 0 | 971 | 0 | | | | | | | | | | | | | | | | | | | |
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5155 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5155 | 0 | 0 | 0 | 1026 | 0 | | | | | | | | | | | | | | | | | | | |
| June | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5051 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5051 | 0 | 0 | 0 | 348 | 0 | | | | | | | | | | | | | | | | | | | |
| July | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4858 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 4858 | 0 | 0 | 0 | 588 | 0 | | | | | | | | | | | | | | | | | | | |
| August | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5287 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5287 | 0 | 0 | 0 | 859 | 0 | | | | | | | | | | | | | | | | | | | |
| September | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5355 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5355 | 0 | 0 | 0 | 945 | 0 | | | | | | | | | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5616 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5616 | 0 | 0 | 0 | 1013 | 0 | | | | | | | | | | | | | | | | | | | |
| November | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5981 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5981 | 0 | 0 | 0 | 990 | 0 | | | | | | | | | | | | | | | | | | | |
| December | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5925 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5934 | 0 | 0 | 0 | 1098 | 0 | | | | | | | | | | | | | | | | | | | |
| Average | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5578 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 5578 | 0 | 0 | 0 | Average price (DKK/MWh) | | | | | | | | | | | | | | | | | | | | |
| Maximum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8730 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 8730 | 0 | 0 | 0 | 8730 | 0 | | | | | | | | | | | | | | | | | | | |
| Minimum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 237 | 0 | | | | | | | | | | | | | | | | | | | | |
| TWh/year | | | | | | | | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11599 | 0 | | | | | | | | | | | | | | | |
| FUEL BALANCE (TWh/year): | | | | | | | | | | RES BioCon-Synthetic | | | | | | | | | | Industry | | | | | | | | | | Imp/Exp Corrected | | CO2 emission (Mt) | | | | | | | | | | | | | | | | | | | |
| DHP | CHP2 | CHP3 | Boiler2 | Boiler3 | PP | Geo/Nu | Hydro | Waste | Elecly. | version | Fuel | Wind | PV | Wave | Hydro | Solar.Th | Transp.househ. | Various | Total | Imp/Exp | Netto | Total | Netto | Total | Netto | Total | Netto | Total | Netto | Total | Netto | | | | | | | | | | | | | | | | | | | | |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | | | | | | | | | | | | | | |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | | | | | | | | | | | | | | |
| N.Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | | | | | | | | | | | | | | |

Read the result : 8730 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 “hour-eldemand-ultra-2001”. Define a wind power input of 2000 MW using “Hour_wind_ultra2001” 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 exercise 1.1.

Step 1: Define wind power

Choose “Electricity only” in the tree view under the “Supply” tab and the following window will open:

Warnings Appear Here: WARNING!!: (1) Critical Excess;

Overview

- Demand
- Supply
 - Heat and Electricity
 - Electricity Only**
 - Heat Only
 - Thermal Plant Fuel Distribution
 - Waste
 - Liquid and Gas Fuels
 - CO2
- Balancing and Storage
- Cost
- Simulation
- Output

Central Power Plants

| Central Power Plants | Capacity MW-e | Efficiency Percent | Correction Factor: Percent | Annual production: TWh/year | Distributions |
|------------------------------|------------------|-----------------------|-------------------------------|--------------------------------|------------------------|
| PP1 (CHP3 Condensing Model)* | 0.00 | | | n/a* | |
| Condensing PP2 | 9000 | 0.45 | | n/a* | |
| Nuclear | 0 | 0 | 1 | 0.00 | Change Hour_wind_1.txt |
| Geothermal | 0 | 0 | 1 | 0.00 | Change Hour_wind_1.txt |
| Dammed Hydro Water supply* | | | | 0 | Change Hour_wind_1.txt |
| Dammed Hydro Power | 0 | 0.33 | | 0.00 (Estimated)* | |

Intermittent Renewable Electricity

| Renewable Energy Source | Capacity: MW | Stabilisation share | Distribution profile | Estimated Production TWh/year | Correction factor | Estimated Post Correction production |
|-------------------------|-----------------|------------------------|-------------------------|-------------------------------------|----------------------|---|
| Wind | 2000 | 0 | Change hour_wind_ultra2 | 3.93 | 0 | 3.93 |
| Photo Voltaic | 0 | 0 | Change Hour_wind_1.txt | 0.00 | 0 | 0.00 |
| Wave Power | 0 | 0 | Change Hour_solar_prod1 | 0.00 | 0 | 0.00 |
| River Hydro | 0 | 0 | Change Hour_solar_prod1 | 0.00 | 0 | 0.00 |
| Tidal | 0 | 0 | Change hour_tidal_power | 0.00 | 0 | 0.00 |
| Wave Power | 0 | 0 | Change Hour_wave_200 | 0.00 | 0 | 0.00 |

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_ultra2001” 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:

EnergyPLAN 12.0: exercise1.txt

Home Add-On Tools Help

Home New Import from excel Open Save Save As Settings Notes Web Run (Clipboard) Run (Screen) Run (Print) Run (Serial) Treeview

Warnings Appear Here: **WARNING!!: (1) Critical Excess:**

Overview

Demand

Supply

Heat and Electricity

Electricity Only

Heat Only

Thermal Plant Fuel Distribution

Wood

Liquid and Gas Fuels

CO2

Balancing and Storage

Cost

Simulation

Output

| Distribution of fuel | Coal | Oil | Ngas | Biomass |
|----------------------|----------|----------|----------|----------|
| (TWh/year) | Variable | Variable | Variable | Variable |
| DHP | 0 | 0 | 0 | 0 |
| CHP2 | 0 | 0 | 0 | 0 |
| CHP3 | 0 | 0 | 0 | 0 |
| Boiler2 | 0 | 0 | 0 | 0 |
| Boiler3 | 0 | 0 | 0 | 0 |
| PP1 | 0 | 0 | 0 | 0 |
| PP2 | 1 | 0 | 0 | 0 |

Place the cursor at the PP2 coal input square and type in 1 (Any number will do, they are all relative to the other fuel input squares)

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

EnergyPLAN 12.0: exercise1.txt

Home Add-On Tools Help

Home New Import from excel Open Save Save As Settings Notes Web Run (Clipboard) Run (Screen) **Run (Print)** Run (Serial)

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

| Input | | | | | | | | | | exercise1.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 0.00 | | | | | Solar Thermal 0.00 | | | | | Industrial CHP (CSHP) 0.00 | | | | | Demand after solar and CSHP 0.00 | | | | | | | | | | | | | | | | | | | |
| Wind 2000 MW | | | | | 3.93 TWh/year | | | | | 0.00 | | | | | Grid stabilisation 0.00 | | | | | Photo Voltaic 0 MW | | | | | Wave Power 0 MW | | | | | River Hydro 0 MW | | | | | Hydro Power 0 MW | | | | | Geothermal/Nuclear 0 MW | | | | | | | | | | | | | | | | | | | |
| Heatstorage: gr.2: 0 GWh | | | | | Fixed Boiler: gr.2: 0.0 Per cent | | | | | gr.3: 0 GWh | | | | | 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: 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 | | | | |
| Fuel Price level: Basic | | | | | Capacities Storage Efficiency | | | | | MW-e GWh elec. Ther. | | | | | Hydro Pump: 0 0 0.80 | | | | | Hydro Turbine: 0 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 | | | | | Household 0.00 | | | | | Industry 0.00 | | | | | Various 0.00 | | | | | | | | | | | | | | | | | | | |

Output WARNING!!: (1) Critical Excess;

| District Heating | | | | | | | | | | Electricity | | | | | | | | | | Exchange | | | | | | | | | | | |
|--------------------------|-------|-------------|---------|---------|------------|--------|--------|-------|-----------|-----------------------|--------------|----------------|------|----------------|------------|------------|---------|---------|---------|--------------------|-------------|---------|-----------|--------------------|---------|-------|-------|------|------|------|------|
| Demand | | | | | Production | | | | | Consumption | | | | | Production | | | | | Balance | | | | | Payment | | | | | | |
| Distr. heating | Solar | Waste- CSHP | DHP | CHP | HP | ELT | Boiler | EH | MW | Balance | Elec. demand | Flex. & Transp | HP | Elec. trolyser | EH | Hydro Pump | Turbine | RES | Hydro | Geo- thermal | Waste- CSHP | CHP | PP | Stab- Load % | Imp | Exp | CEEP | EEP | Imp | Exp | |
| January | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6211 | 0 | 0 | 0 | 0 | 0 | 0 | 399 | 0 | 0 | 0 | 0 | 5813 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| February | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6213 | 0 | 0 | 0 | 0 | 0 | 0 | 610 | 0 | 0 | 0 | 0 | 5803 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| March | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6080 | 0 | 0 | 0 | 0 | 0 | 0 | 469 | 0 | 0 | 0 | 0 | 5593 | 100 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| April | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5466 | 0 | 0 | 0 | 0 | 0 | 0 | 375 | 0 | 0 | 0 | 0 | 5081 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5155 | 0 | 0 | 0 | 0 | 0 | 0 | 386 | 0 | 0 | 0 | 0 | 4769 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5081 | 0 | 0 | 0 | 0 | 0 | 0 | 394 | 0 | 0 | 0 | 0 | 4667 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4856 | 0 | 0 | 0 | 0 | 0 | 0 | 284 | 0 | 0 | 0 | 0 | 4392 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5287 | 0 | 0 | 0 | 0 | 0 | 0 | 388 | 0 | 0 | 0 | 0 | 4680 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| September | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5355 | 0 | 0 | 0 | 0 | 0 | 0 | 373 | 0 | 0 | 0 | 0 | 4682 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5816 | 0 | 0 | 0 | 0 | 0 | 0 | 662 | 0 | 0 | 0 | 0 | 4954 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5981 | 0 | 0 | 0 | 0 | 0 | 0 | 837 | 0 | 0 | 0 | 0 | 5343 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5934 | 0 | 0 | 0 | 0 | 0 | 0 | 424 | 0 | 0 | 0 | 0 | 5511 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5678 | 0 | 0 | 0 | 0 | 0 | 0 | 447 | 0 | 0 | 0 | 0 | 5131 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maximum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8730 | 0 | 0 | 0 | 0 | 0 | 0 | 2000 | 0 | 0 | 0 | 0 | 8585 | 100 | 0 | 814 | 814 | 0 | 0 | 0 | 0 |
| Minimum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TWh/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 | 3.93 | 0.00 | 0.00 | 0.00 | 0.00 | 45.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| FUEL BALANCE (TWh/year): | | | | | | | | | | CAES BioCon-Synthetic | | | | | | | | | | CO2 emission (Mt): | | | | | | | | | | | |
| DHP | CHP2 | CHP3 | Boiler2 | Boiler3 | PP | Geo/Nu | Hydro | Waste | Elec. ly. | version | Fuel | Wind | PV | Wave | Hydro | Solar | TH | Transp. | househ. | Various | Totals | Imp/Exp | Corrected | CO2 emission (Mt): | | | | | | | |
| Coal | - | - | - | - | - | 100.16 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 100.16 | 0.00 | 100.16 | 34.25 | 34.25 | | | | | |
| Oil | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| N. Gas | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| Biomass | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | 0.00 | 0.00 | 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 | - | - | - | - | - | 100.16 | - | - | - | - | - | 3.93 | - | - | - | - | - | - | - | - | - | - | 104.09 | 0.00 | 104.09 | 34.25 | 34.25 | | | | |

Read results:

Wind power production = 3.93 TWh/year.

Condensing Power production = 45.07 TWh/year.

Coal consumption = 100.16 TWh/year.

CO2 emissions = 34.25 Mt.

Step 5: Change installed wind power capacity

Repeat step 1 for 6000 MW wind power.

The results are now:

Wind power production = 11.79 TWh/year.

Excess production (export) = 0.06 TWh/year.

Condensing Power production = 37.28 TWh/year.

Coal consumption = 82.83 TWh/year.

CO2 emission = 28.33 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 “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?

How to do exercise 1.3: Use input data file from exercise 1.2.

Step 1: Define individual house heating

Choose “Heating” window and the following window will open:

The screenshot shows the EnergyPLAN 12.0 software interface. The 'Overview' pane on the left has 'Heating' selected. The main window displays the 'Individual Heating' configuration table. The 'District Heating' section is also visible at the bottom.

| TWh/year | Fuel Consumption | | Efficiency Thermal | Heat Demand | Efficiency Electric | Capacity Limit* | Estimated Electricity Production | Heat Storage* | | Solar Thermal | |
|---|------------------|--------|--------------------|-------------|---------------------|-----------------|----------------------------------|--------------------------------|--------------------------------|--------------------------------|-----------------------------------|
| | Input | Output | | | | | | Heat | Share* | Input | Output |
| Distribution: <input type="button" value="Heat"/> Hour_distr-heat.txt | | | | | | | | | | | |
| Coal boiler : | 0.01 | 0.01 | 0.8 | 0.01 | | | | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Oil boiler : | 6.72 | 6.72 | 0.85 | 5.71 | | | | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Ngas boiler : | 9.05 | 9.05 | 0.9 | 8.15 | | | | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Biomass boiler : | 7.29 | 7.29 | 0.8 | 5.83 | | | | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| H2 micro CHP : | 0.00 | 0.00 | 0.5 | 0 | 0.3 | 1 | 0.00 | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Ngas micro CHP : | 0.00 | 0.00 | 0.5 | 0 | 0.3 | 1 | 0.00 | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Biomass micro CHP : | 0.00 | 0.00 | 0.5 | 0 | 0.3 | 1 | 0.00 | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Heat Pump : | | | | 0 | 3 | 1 | 0.00 | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Electric heating : | | | | 0 | | 1 | 0.00 | <input type="text" value="0"/> | <input type="text" value="1"/> | <input type="text" value="0"/> | <input type="text" value="0.00"/> |
| Total Individual: | | 23.07 | | 19.70 | | | 0.00 | | | | 0.00 |

| District Heating: | | | | | |
|-------------------|----------------|------------|------------|--------------|---|
| Production: | Group 1: 39.18 | Group 2: 0 | Group 3: 0 | Total: 39.18 | Distribution: <input type="button" value="Change"/> Hour_distr-heat.txt |
| Network Losses: | 0.2 | 0.15 | 0.1 | | |
| Heat Demand: | 31.34 | 0.00 | 0.00 | 31.34 | |

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

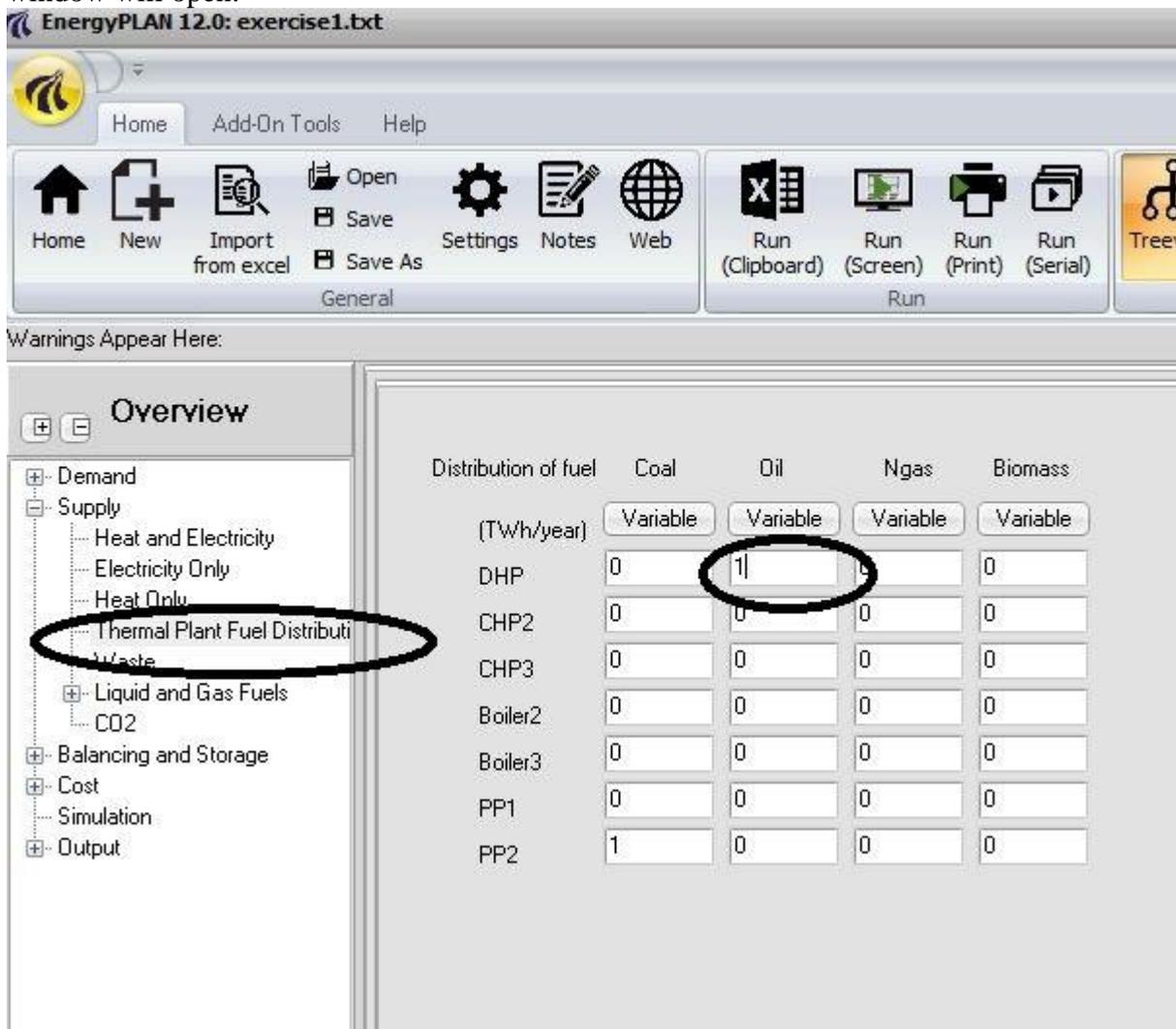
Read the answer of question 1.3.1: The annual house heat demand is 19.7 TWh.

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:



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

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”.

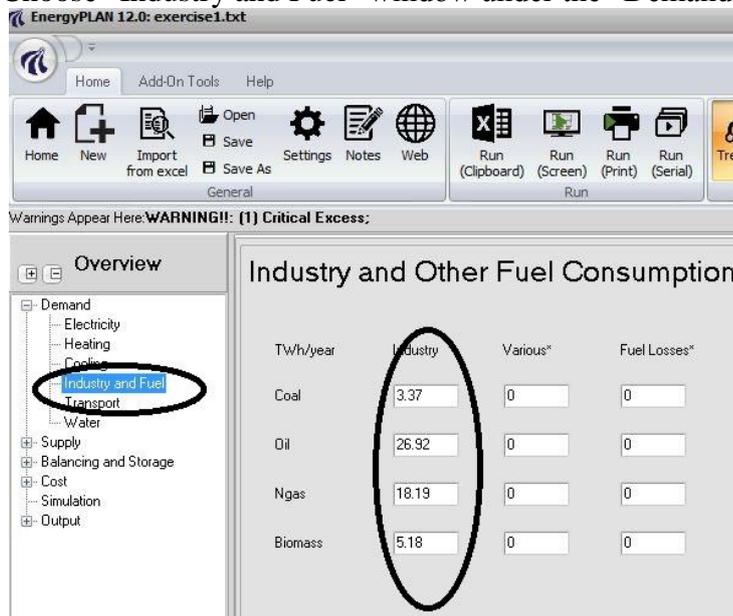
Question 1.4.1: What is the annual primary energy supply of the system? And what is the annual CO2 emission?

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 exercise 1.3.

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:



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:

Warnings Appear Here: **WARNING!!: (1) Critical Excess:**

Overview

- Demand
- Supply
- Heat and Electricity**
- Electricity Only
- Heat Only
- Thermal Plant Fuel Distributi
- Waste
- Liquid and Gas Fuels
- CO2
- Balancing and Storage
- Cost
- Simulation
- Output

| | | | | |
|--------------------|-----|-----|-----|---------|
| Thermal Capacity | 0 | 0 | | MJ/s |
| Boiler Efficiency | 0.9 | 0.9 | 0.9 | Percent |
| Fixed Boiler share | 0 | 0 | | Percent |

Combined Heat and Power (CHP)

CHP Condensing Mode Operation*

| | | | | |
|---------------------------|------|--|--|--|
| Electric Capacity (PP1) | 0 | | | |
| Electric Efficiency (PP1) | 0.45 | | | |

CHP Back Pressure Mode Operation*

| | | | | |
|---------------------|------|-----|---|---------|
| Electric Capacity | 0 | 0 | | MW-e |
| Thermal Capacity | Auto | 0 | 0 | MJ/s |
| Electric Efficiency | 0.4 | 0.4 | | Percent |
| Thermal Efficiency | 0.5 | 0.5 | | Percent |

Industrial CHP

| | | | | | |
|---------------------|------|------|------|------|----------|
| CHP Electricity | 2.41 | 0 | 0 | 2.41 | TWh/year |
| CHP Heat Produced | 1.73 | 0 | 0 | 1.73 | TWh/year |
| CHP Heat Own Use | 0 | 0 | 0 | 0.00 | TWh/year |
| CHP Heat Delivered* | 1.73 | 0.00 | 0.00 | 1.73 | TWh/year |

Distribution: const.txt

Place the cursor in the input squares of group 1 CHP Electricity and CHP Heat Production and type in 2.41 and 1.73.

The hour-distribution-file is "Hour_cshpel".

Activate the **Change 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)

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

Read the results of question 1.4.1:

Primary energy supply = 217.07 TWh/year.

CO2 emissions = 59.19 Mt.

Step 3: Change district heating and electricity production

Repeat steps 1 and 2:

EnergyPLAN 12.0: exercise1.txt

Home Add-On Tools Help

Home New Import from excel Open Save Save As Settings Notes Web Run (Clipboard) Run (Screen) Run (Print) Run (Serial) Treeview Tabs Show Hints*

Warnings Appear Here: **WARNING!!: (1) Critical Excess;**

Overview

- Demand
- Supply
 - Heat and Electricity**
 - Electricity Only
 - Heat Only
 - Thermal Plant Fuel Distributi
 - Waste
 - Liquid and Gas Fuels
 - CO2
- Balancing and Storage
- Cost
- Simulation
- Output

Thermal Capacity MJ/s

Boiler Efficiency Percent

Fixed Boiler share Percent

Combined Heat and Power (CHP)

CHP Condensing Mode Operation*

Electric Capacity (PP1)

Electric Efficiency (PP1)

CHP Back Pressure Mode Operation*

Electric Capacity MW-e

Thermal Capacity MJ/s

Electric Efficiency Percent

Thermal Efficiency Percent

Industrial CHP

| | | | | | |
|---------------------|--------------------------------|--------------------------------|--------------------------------|------|----------|
| CHP Electricity | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> | 0.00 | TWh/year |
| CHP Heat Produced | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> | 0.00 | TWh/year |
| CHP Heat Own Use | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> | 0.00 | TWh/year |
| CHP Heat Delivered* | 0.00 | 0.00 | 0.00 | 0.00 | TWh/year |

Distribution const.txt

Fuel

Solar thermal

CHP plants are m so the Max CHP:

Place the cursor in the input squares of group 1 CHP Electricity and CHP Heat Production and type in 0.

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 [exercise 1.4](#):

- 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?

How to do exercise 1.5: Use input data file from [exercise 1.4](#).

Step 1: Define fuel demand for transportation.

Choose the “Transport” window under the “Demand” tab and the following window open:

The screenshot shows the EnergyPLAN 12.0 software interface. The 'Overview' window is open, displaying a table of demand data. The 'Fossil' column has input fields for JP (Jet Fuel), Diesel, and Petrol, which are circled in red. A 'Help to design inputs' button is also circled in red. The table shows the following data:

| | TWh/year | Fossil | Biofuel | Waste* | Synthetic Fuel | Total | Distribution |
|-------------------------------|----------|--------|---------|--------|----------------|-------|--------------------------|
| JP (Jet Fuel) | 13.25 | 0 | | | 0 | 13.25 | |
| Diesel | 27.5 | 0 | 0.00 | | 0 | 27.50 | |
| Petrol | 28.45 | 0 | | | 0 | 28.45 | |
| Ngas* (Grid Gas) | 0 | | | | | 0.00 | Gas const.txt |
| LPG | 0 | | | | | 0.00 | |
| H2 (Produced by Electrolysis) | | | | | 0 | | H2 Hour_transport.txt |
| Electricity (Dump Charge) | | | | | 0 | | Dump Hour_transport.txt |
| Electricity (Smart Charge) | | | | | 0 | | Smart Hour_transport.txt |

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

Step 2: Calculate annual transportation demand in km

Activate the [Help to design inputs](#) button and the following window will open:

Warnings Appear Here:

Overview

| TWh/year | Fossil | Biofuel | Waste* | Synthetic Fuel | Total | Distribution |
|--------------------------------|--------|---------|--------|----------------|-------|--------------------------|
| JP (Jet Fuel) | 13.25 | 0 | | 0 | 13.25 | |
| Diesel | 27.5 | 0 | 0.00 | 0 | 27.50 | |
| Petrol | 28.45 | 0 | | 0 | 28.45 | |
| Ngas* (Grid Gas) | 0 | | | | 0.00 | Gas const.txt |
| LPG | 0 | | | | 0.00 | |
| H2 (Produced by Electrolysers) | | | | 0 | 0 | H2 Hour_transport.txt |
| Electricity (Dump Charge) | | | | 0 | 0 | Dump Hour_transport.txt |
| Electricity (Smart Charge) | | | | 0 | 0 | Smart Hour_transport.txt |

| | km/kWh | Billion km/year |
|--|--------|-----------------|
| | 1.5 | 41 |
| | 1.5 | 43 |
| | 1.5 | 0 |
| | 1.5 | 0 |
| | 3 | 0 |
| | 5 | 0 |
| | 5 | 0 |

84

The average efficiencies are already 1.5 km/kWh and the result of question 1.5.1 is 84 billion km/year.

Step 3: Calculate and see result in print output (or clipboard)

Activate the  button and look at the following print output:

Read the results of question 1.5.2:
 Primary energy supply = 286.27 TWh/year.
 CO2 emissions = 77.62 Mt.

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