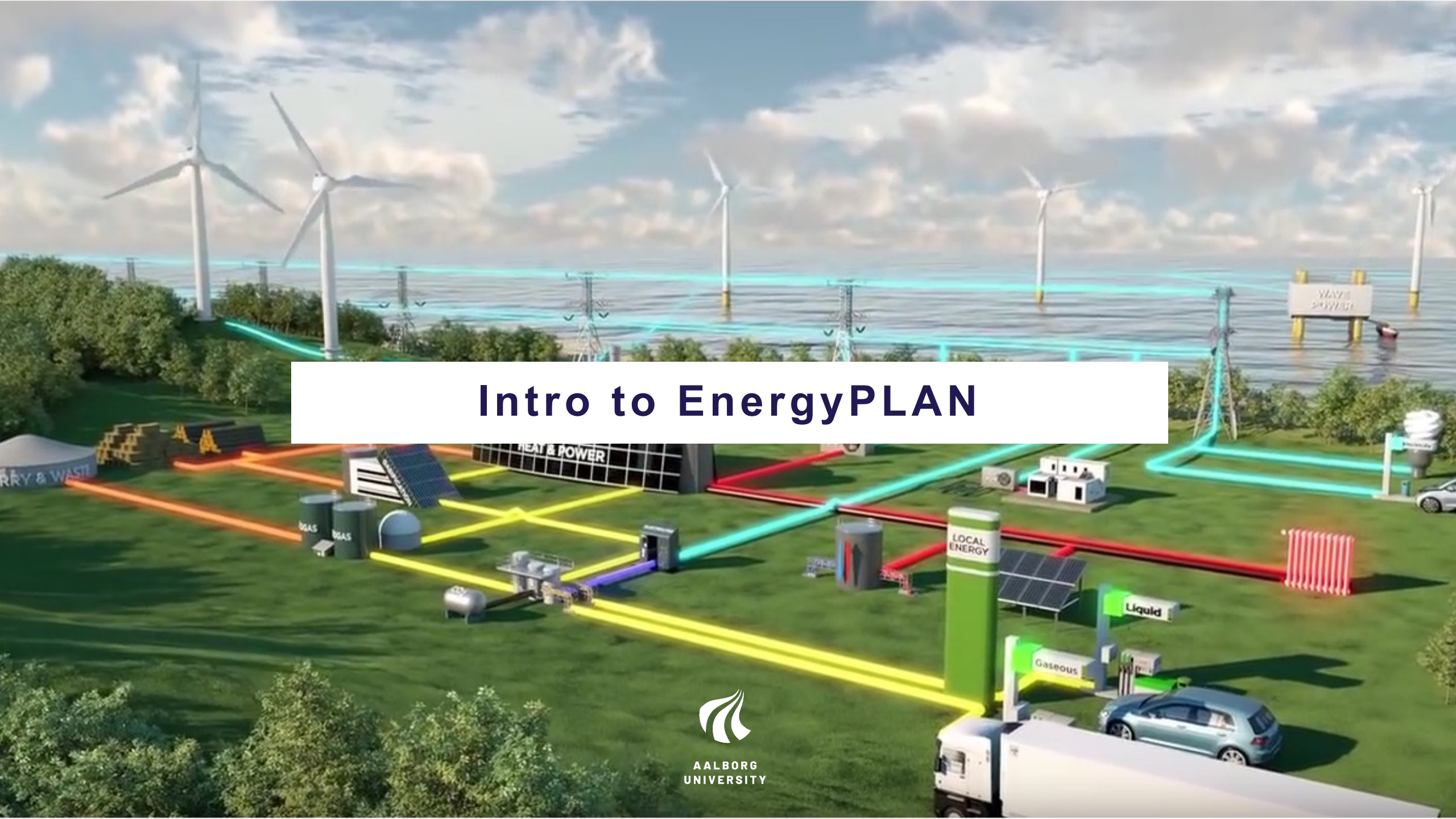
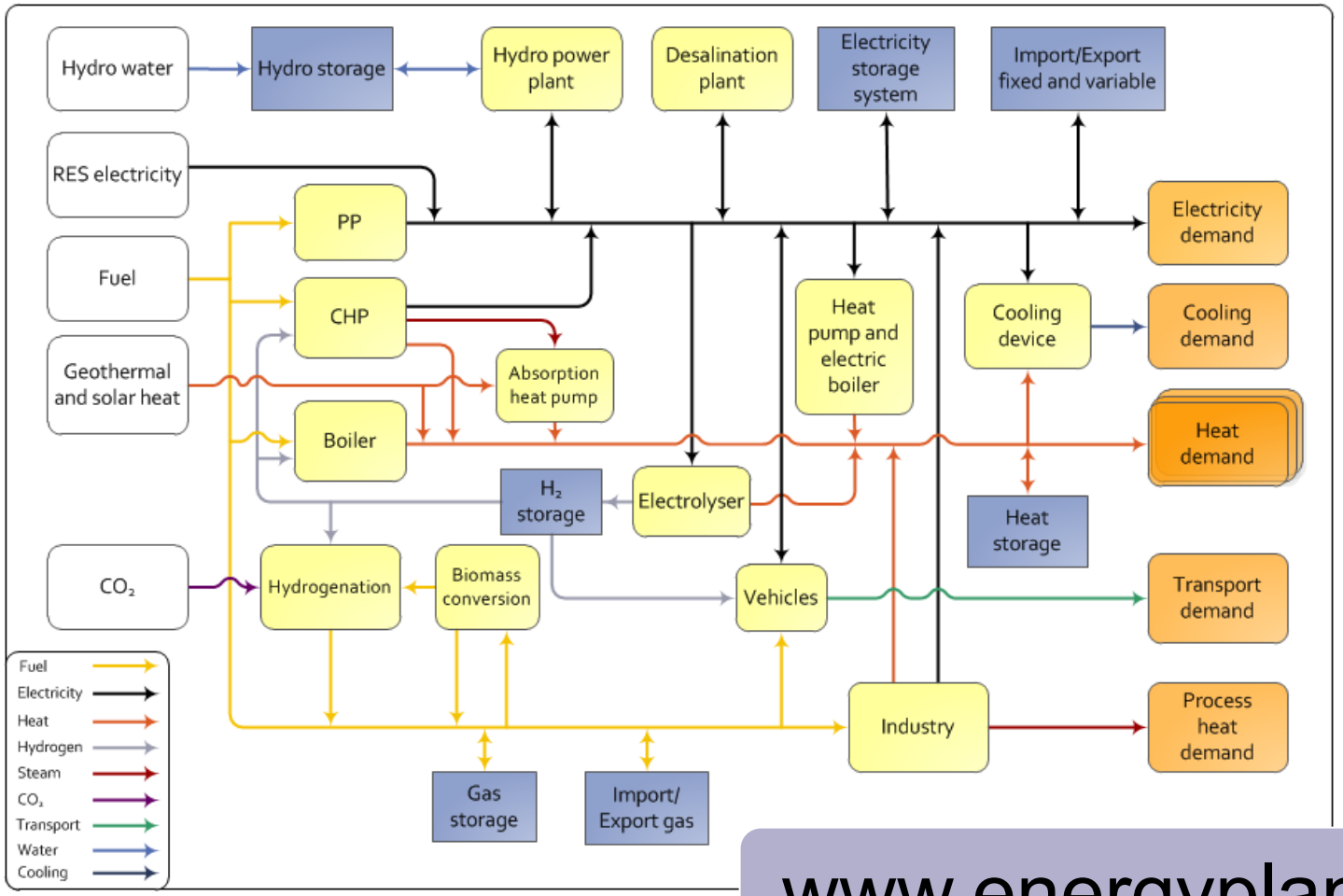


Intro to EnergyPLAN

AALBORG UNIVERSITY

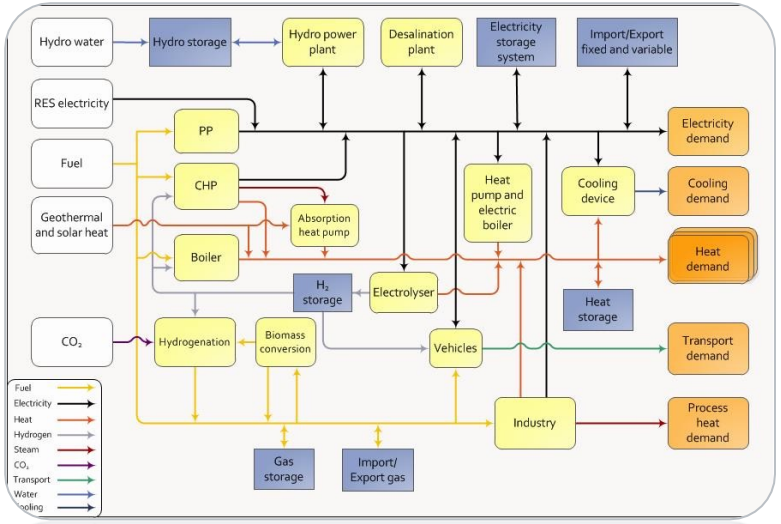
EnergyPLAN

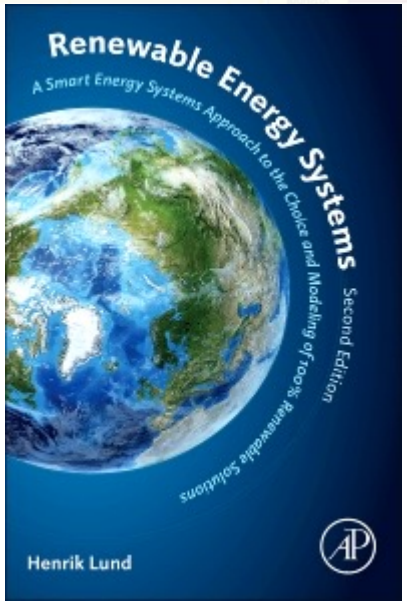


www.energyplan.eu

EnergyPLAN

- A consistent and comparative analysis of alternatives
- Able to analyse radical technological change
- Able to provide suitable information for feasibility studies and the design of public regulation measures
- Able to explore a wide range of future options (speed of calculation)





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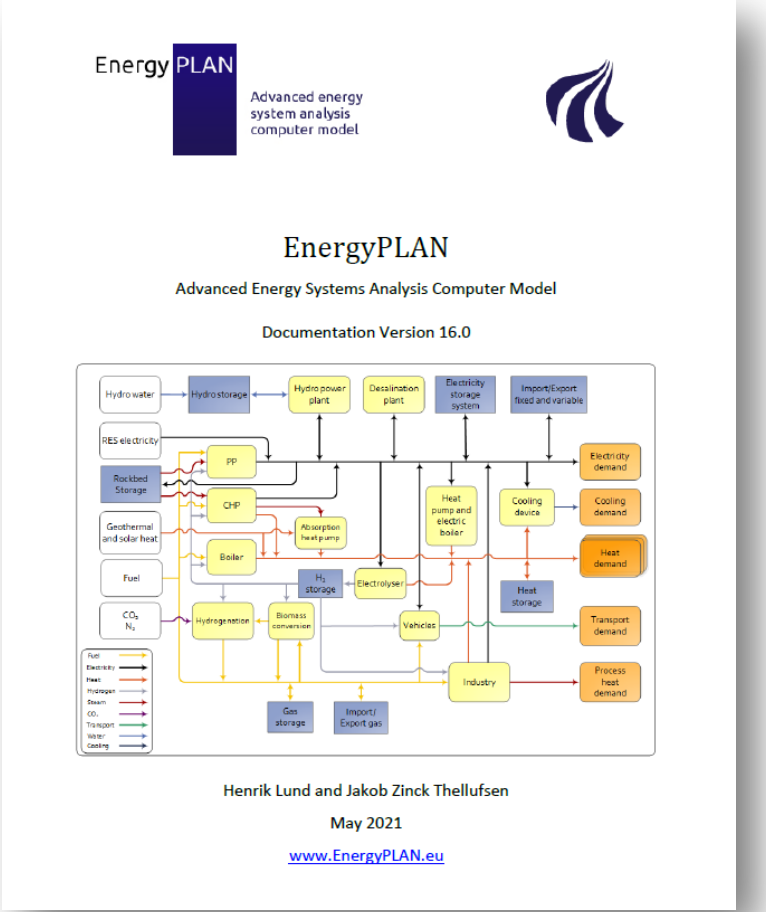
DENMARK

Why to choose EnergyPLAN

User friendly analysis of national / regional and city energy systems
Simplified modelling of energy system.

Main focus:

- Design energy systems to accommodate fluctuating renewable energy
- Renewable-energy penetration up to 100% renewable energy
- Long term projections

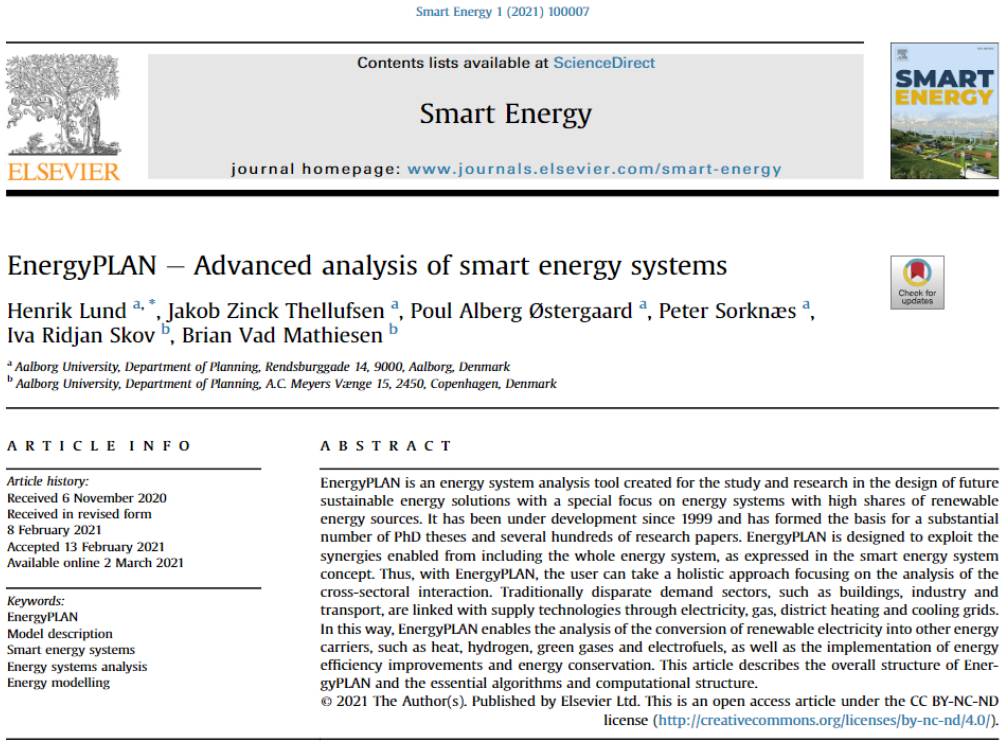


Why to choose EnergyPLAN

- >3,000 users worldwide
- Sharing the data online - http://www.energyplan.eu/useful_resources/existingmodels/
- Free-download
- You can create add-on tools

General characteristics

- Analysis of all energy sectors:
  - Electricity
  - Heating
  - Transport
  - Industry
- 1 year in our-by-hour steps
- Aggregated model
  - Does not model each plant individually, but all plants in a system
- Fast simulation - the computation of 1 year requires only a few seconds



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EnergyPLAN – Advanced analysis of smart energy systems

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ABSTRACT

EnergyPLAN is an energy system analysis tool created for the study and research in the design of future sustainable energy solutions with a special focus on energy systems with high shares of renewable energy sources. It has been under development since 1999 and has formed the basis for a substantial number of PhD theses and several hundreds of research papers. EnergyPLAN is designed to exploit the synergies enabled from including the whole energy system, as expressed in the smart energy system concept. Thus, with EnergyPLAN, the user can take a holistic approach focusing on the analysis of the cross-sectoral interaction. Traditionally disparate demand sectors, such as buildings, industry and transport, are linked with supply technologies through electricity, gas, district heating and cooling grids. In this way, EnergyPLAN enables the analysis of the conversion of renewable electricity into other energy carriers, such as heat, hydrogen, green gases and electrofuels, as well as the implementation of energy efficiency improvements and energy conservation. This article describes the overall structure of EnergyPLAN and the essential algorithms and computational structure.

Simulation versus optimization

Or operation versus investment optimisation?

- a **simulation model** can be defined as representation of a system used to predict the behaviour of the system under a given set of conditions

- while an **optimization model** is typically used synonymously with mathematical programming to refer to a mathematical formulation in which a formal algorithm is used to compute a set of decision-variable values that minimize or maximize an objective function subject to constrains.

EnergyPLAN

INPUT

Demands
Electricity
Cooling
District Heating
Individual Heating
Fuel for Industry
Fuel for Transport

RES
Wind
Solar Thermal
Photovoltaic
Geothermal
Hydro Power
Wave

Capacities & efficiencies
Power Plant
Boilers
CHP
Heat Pumps
Electric Boilers
Micro CHP

Storage
Heat Storage
Hydrogen Storage
Electricity Storage
CAES

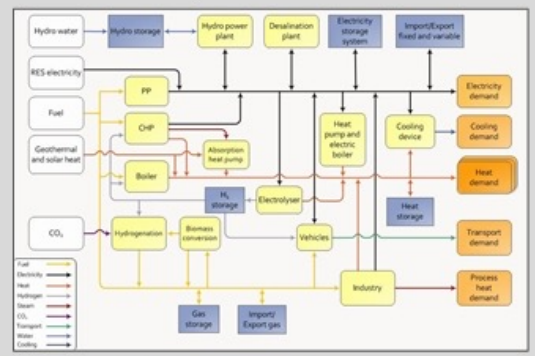
Transport
Petrol/Diesel Vehicles
Gas Vehicles
Electric Vehicles
V2G Electric Vehicles
Hydrogen Vehicles
Biofuel Vehicles

Distribution data
Electricity Demand | District Heating | Wind | Hydro | Wave | Waste
Solar thermal | Photovoltaic | Geothermal | Individual Heating
Industrial CHP | Transportation | Market Prices

Regulation
Technical Limitations
Choice of Strategy
CEEP Strategies
Transmission Cap.
External Electricity Market

Fuel Cost
Types of fuel
CO2 Emission Factor
CO2 Emission Costs
Fuel Prices

Cost
Variable Operation
Fixed Operation
Investment
Interest Rate



Either: **Technical regulation strategies**

1) Balancing heat demand
2) Balancing both heat and electricity demand
3) Balancing both heat and electricity demand (reducing CHP even when partially needed for grid stabilisation
4) Balancing heat demand using triple tariff

Or: **Electricity market strategy**

Market simulation of plant optimization based on business economic marginal production costs.

And: **Critical Excess Electricity Production**

Reducing wind
Replacing CHP with boiler or heat pump
Electric heating and/or bypass

OUTPUT

Results
(Annual, Monthly and Hourly Values)

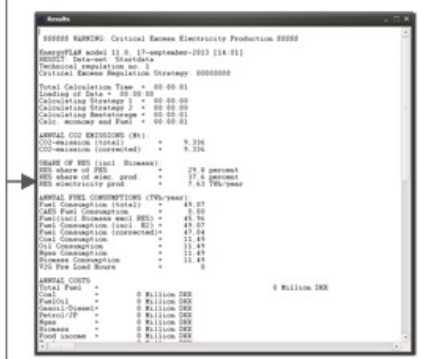
Electricity Production
Electricity Import/Export
electricity Excess Production

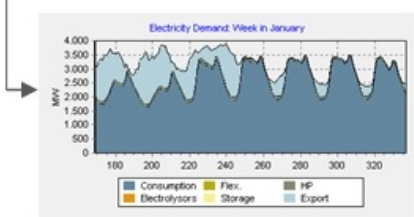
Import Expenditures
Export Revenues

Fuel Consumption

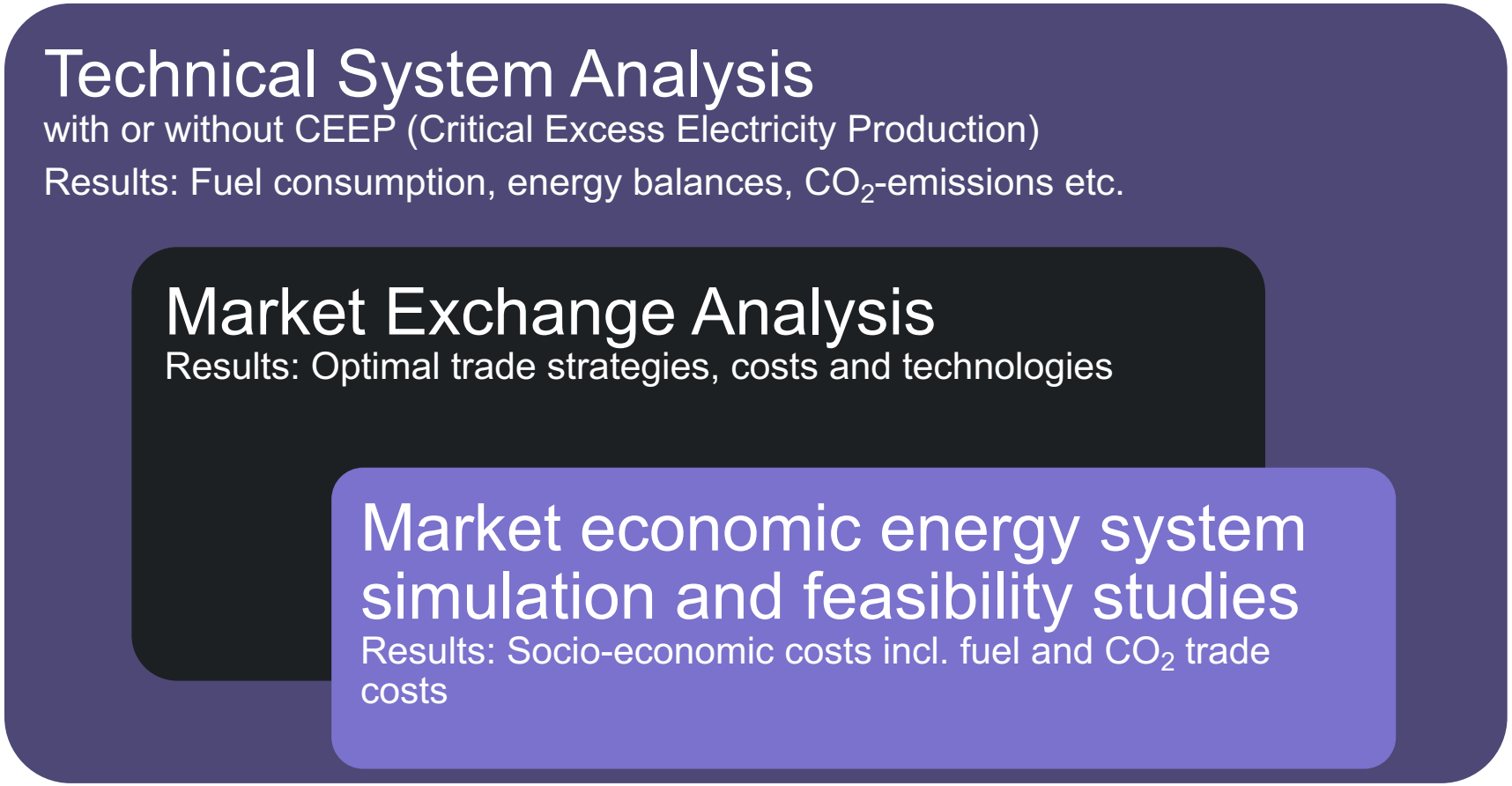
CO2 Emissions

Share of RES





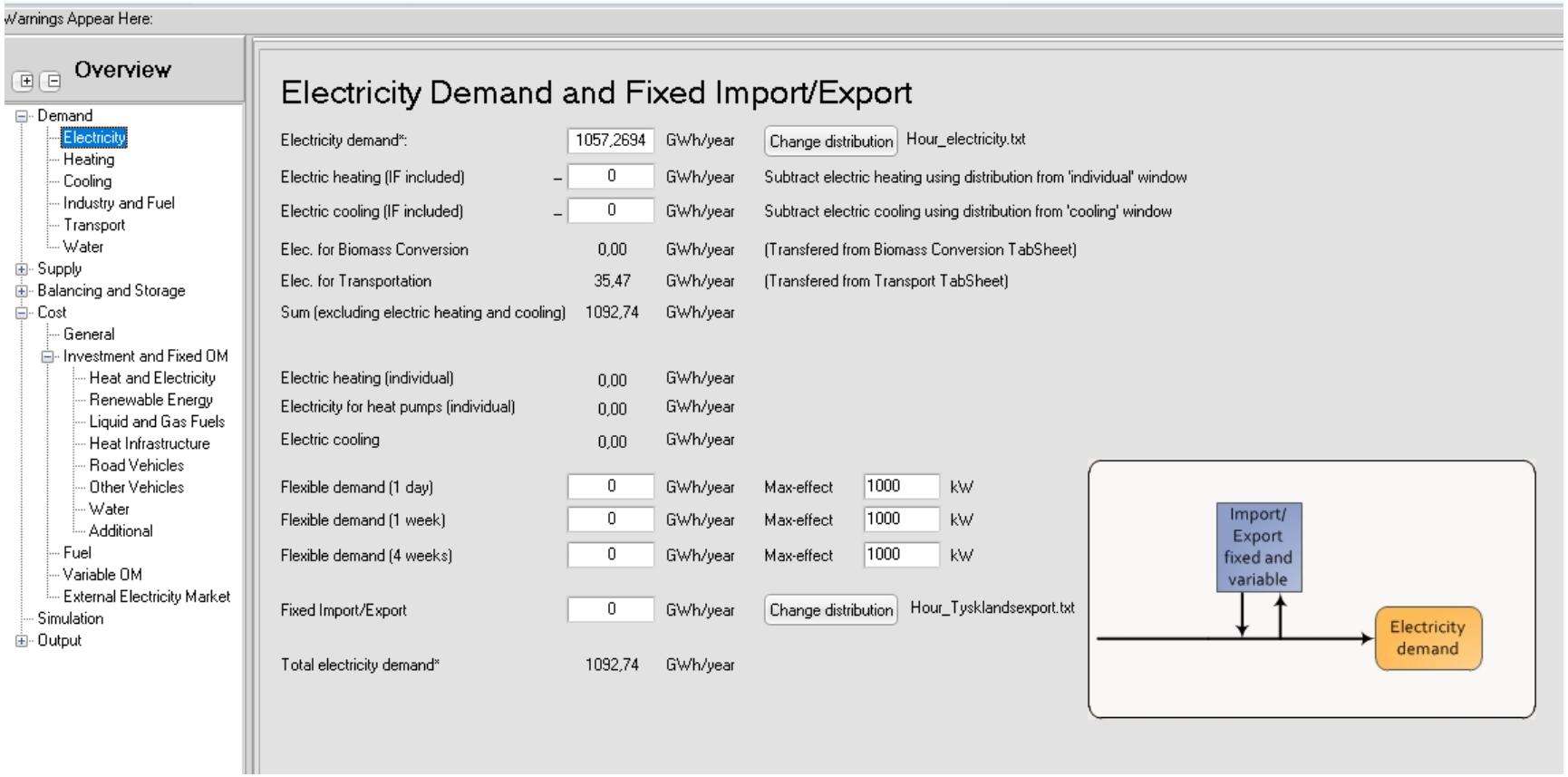
Three different types of analyses



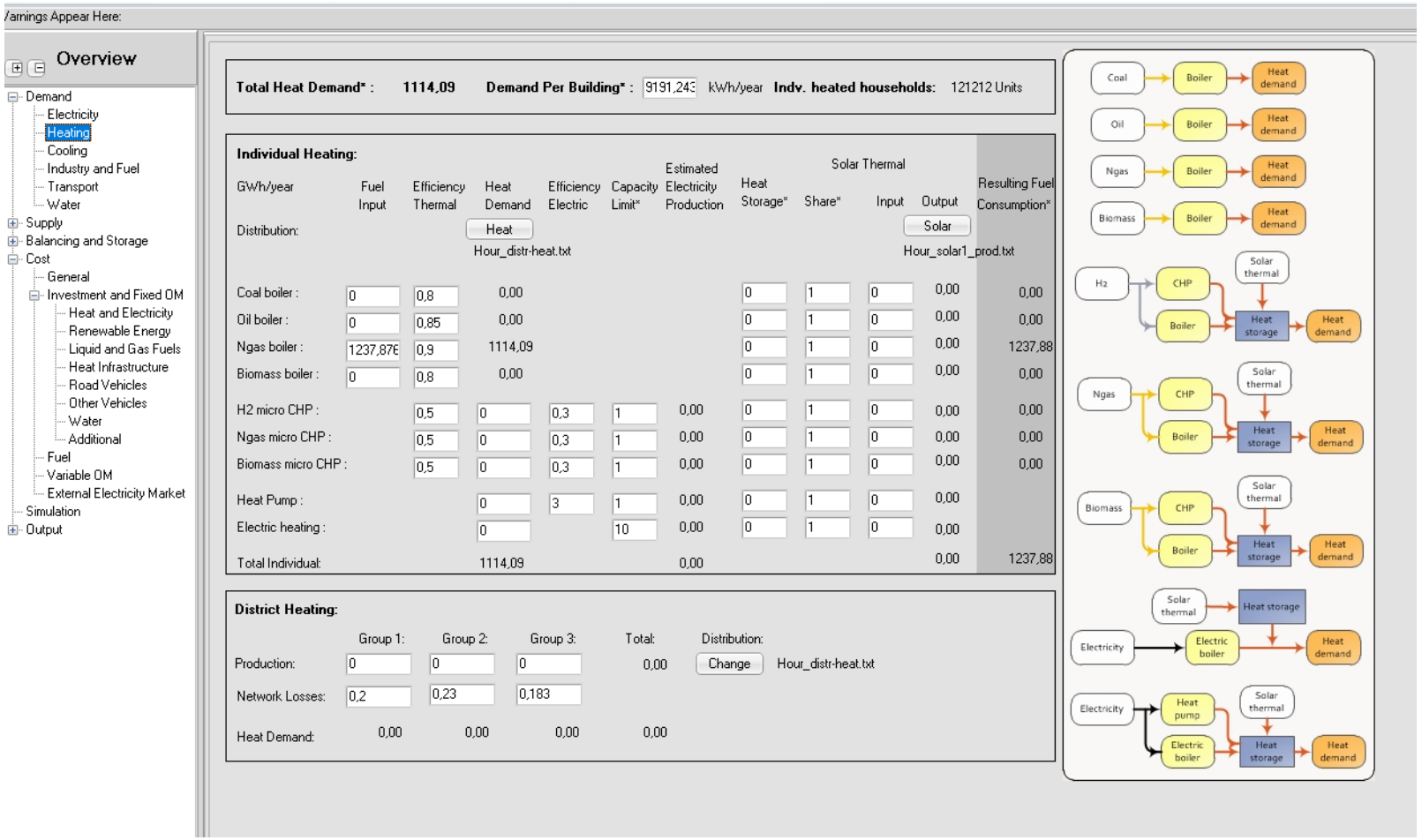
Step by step using EnergyPLAN

1. Defining energy demands (electricity, individual and district heating demands)
2. Defining energy production
3. Balancing and storage

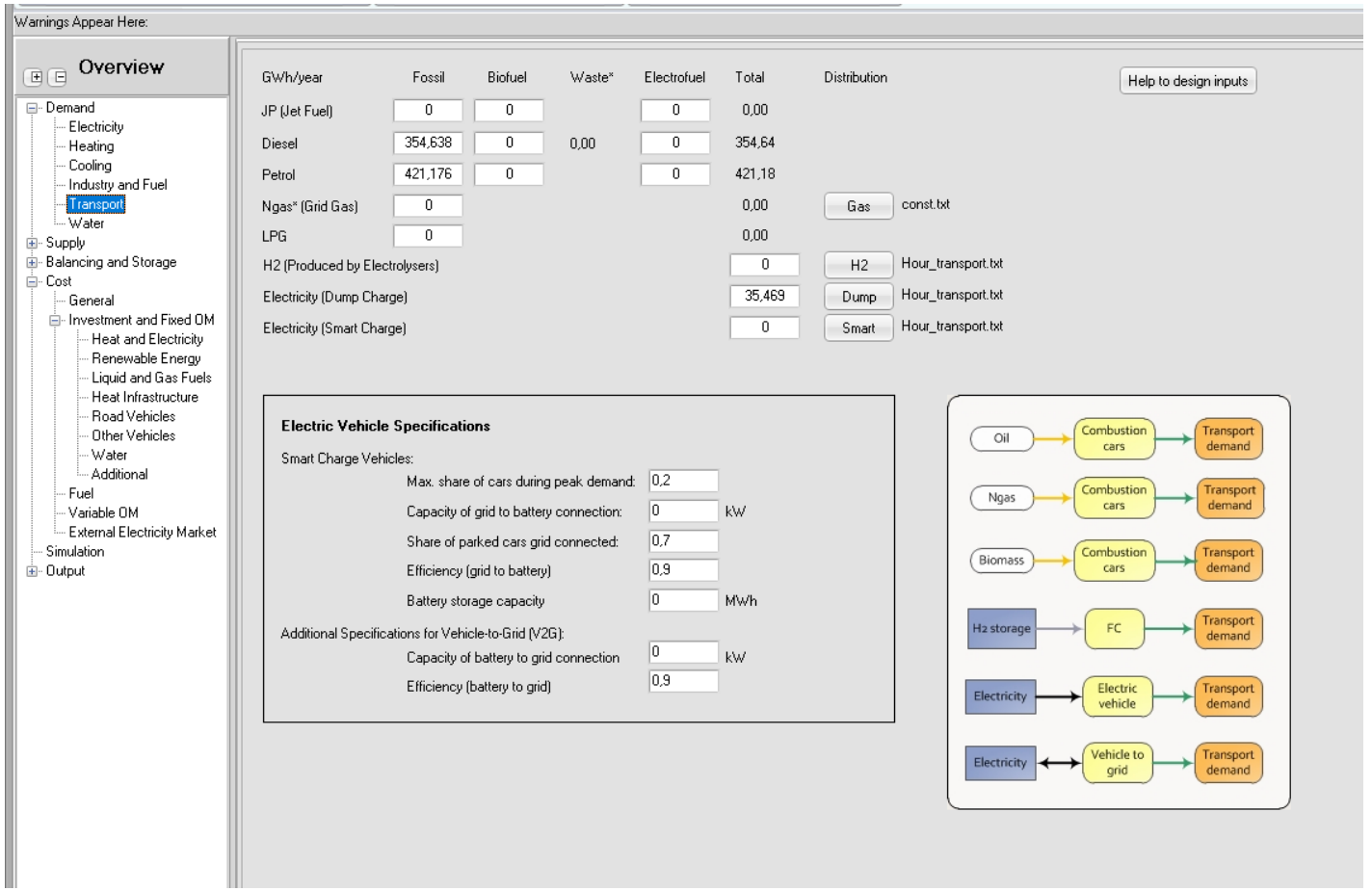
Step 1: Defining electricity demand



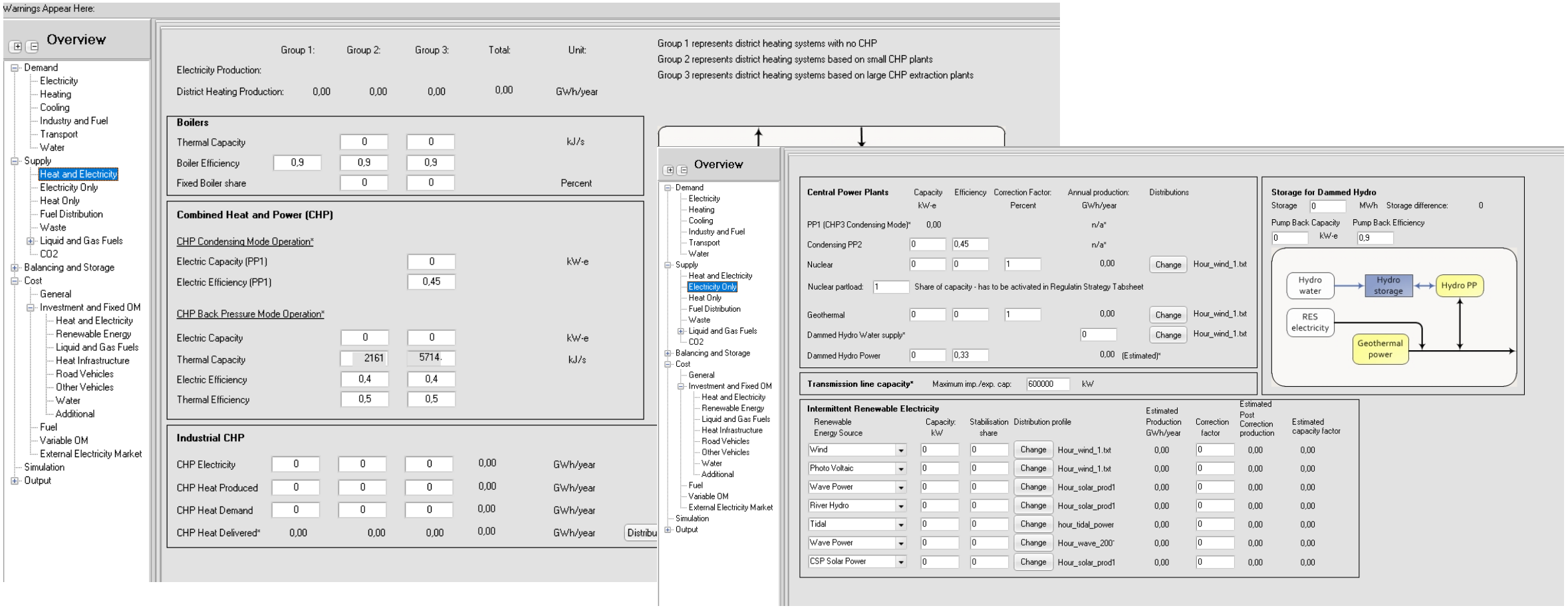
Step 1: Defining heat demands



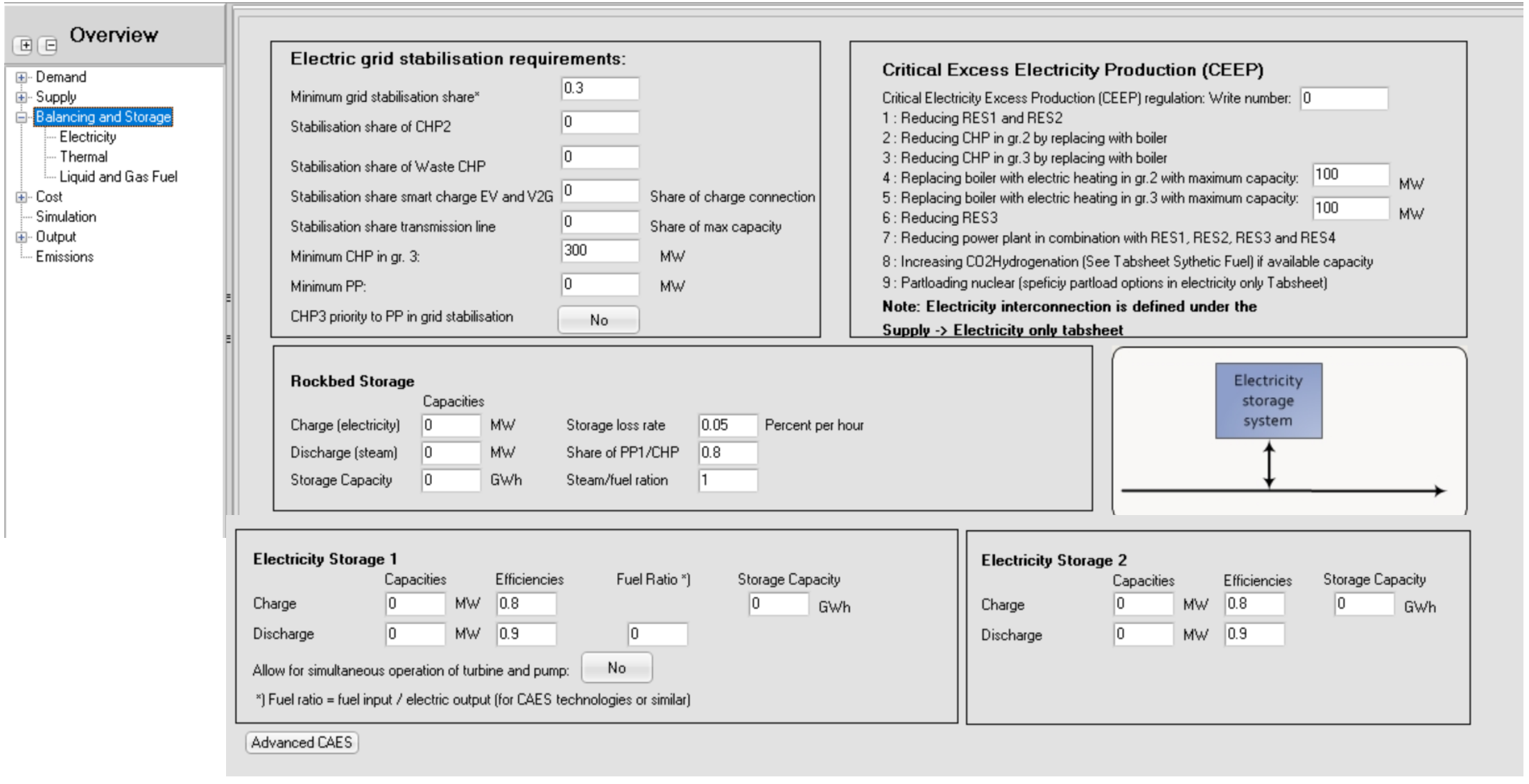
Step 1: Defining transport demands



Step 2: Defining the production



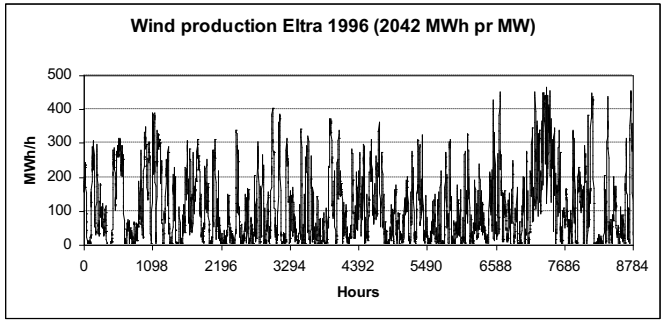
Step 3: Balancing and storage

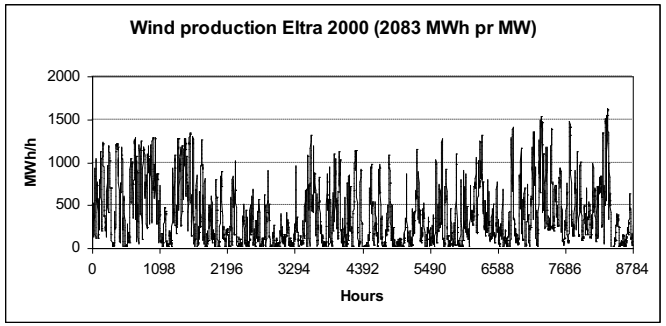


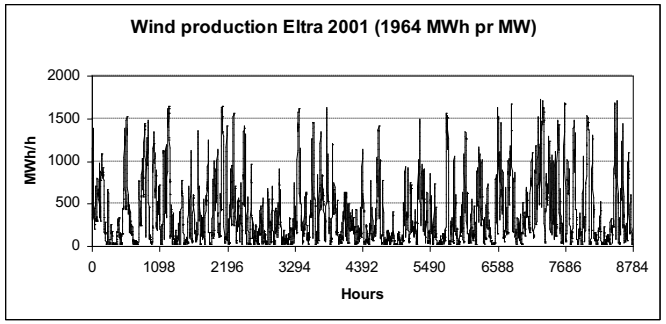
From annual values to hour by hour

- Using the annual value the hour by hour values are calculated
  - Demands

    (electricity, district heating, transport etc.)
  - RES (wind, PV etc.)
  - Fixed import/export



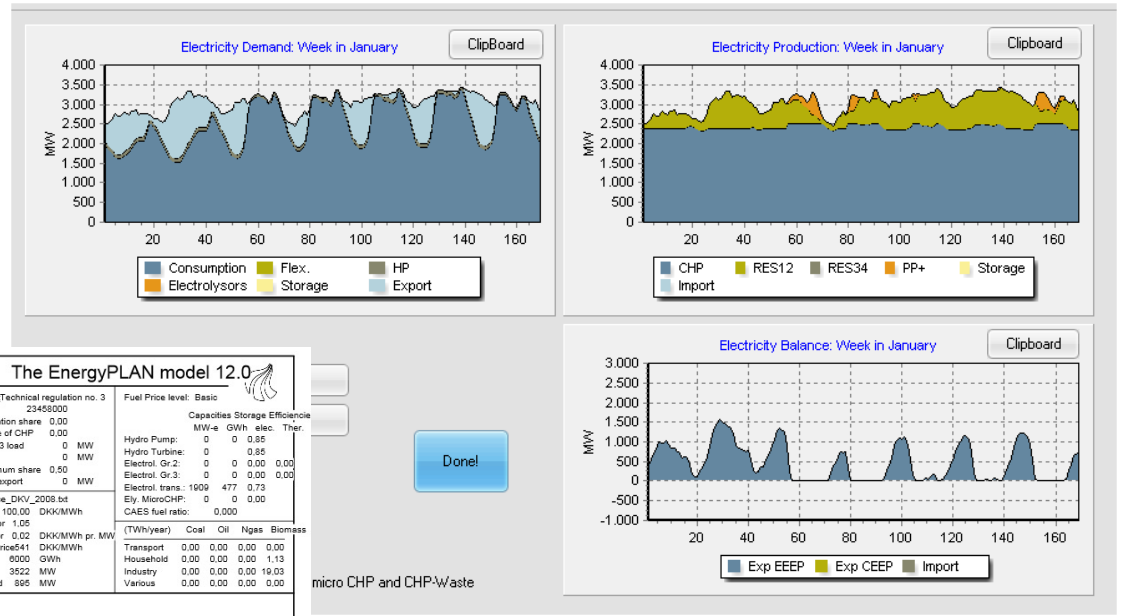




Results in seconds

Results

```
EnergyPLAN model 12.0
RESULT: Data-set:                          Startdata
Technical regulation no. 1
Critical Excess Regulation Strategy:       00000000

Total Calculation Time                     12:00:00
Loading of Data                            12:00:00
Calculating Strategy 1                     12:00:00
Calculating Strategy 2                     12:00:00
Calculating Heatstorage                    12:00:00
Calc. economy and Fuel                     12:00:00

ANNUAL CO2 EMISSIONS (Mt):
CO2-emission (total)                         9,458
CO2-emission (corrected)                     9,458

SHARE OF RES (incl. Biomass):
RES share of PES                            28,7 percent
RES share of elec. prod.                    34,6 percent
RES electricity prod.                        7,01 TWh/year

ANNUAL FUEL CONSUMPTIONS (TWh/year)    TOTAL:    HOUSEHOLDS:
Fuel Consumption (total)                   48,98
CAES Fuel Consumption                       0,00
Fuel(incl.Biomass excl.RES)                46,56
Fuel Consumption (incl. H2)                48,98
Fuel Consumption (corrected)               47,84
Coal Consumption                           11,64        0,00
Oil Consumption                            11,64        0,00
Ngas Consumption                           11,64        0,00
Biomass Consumption                        11,64        0,00
Nuclear Fuel Consumption                    0,00
Waste Input                                 0,00
V2G Pre Load Hours                          0,00

ANNUAL COSTS (M DKK)                   TOTAL:    VARIABLE: BF
Fuel ex. Ngas exchange                                    0
Coal
FuelOil
Gasoil/Diesel
Petrol/JP
Gas handling
Biomass
Food income
Waste

Ngas Exchange costs                                       0

Marginal operation costs                                  0

Electricity exchange                                    -93
Import
Export
Bottleneck
Fixed imp/exp

CO2 emission costs                                        0

Variable costs                                 -93

Fixed operation costs                            0

Annual Investment costs                          0

TOTAL ANNUAL COSTS                             -93
```



Input New CEESA.txt — The EnergyPLAN model 12.0

Output WARNING!!: (1) Critical Excess;

	District Heating Demand: Distr. heating MW	District Heating Production: Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Electricity Consumption: Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Electricity Production: Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP MW	Balance: Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Exchange: Payment Imp Million DKK	Payment Exp Million DKK
January	6657	190	1307	446	1331	2693	0	620	73	-2	2787	1398	1042	3366	73	0	0	5913	0	0	200	2339	385	100	0	15	15	0	0	4
February	6790	401	1307	391	873	2858	0	783	175	4	2759	1399	1079	4407	175	0	0	8144	0	0	200	1537	207	100	0	96	96	0	0	25
March	5921	454	1307	308	989	2460	0	311	80	11	2661	1422	944	4180	80	0	0	7311	0	0	200	1744	216	100	0	148	148	0	0	29
April	4928	692	1307	170	841	1854	0	74	24	-34	2361	1382	699	4164	24	0	0	6858	0	0	200	1490	223	100	0	142	142	0	0	34
May	4066	758	1306	63	717	1189	0	3	2	28	2307	1394	459	4435	2	0	0	7331	0	0	200	1274	192	100	0	400	400	0	0	96
June	2347	624	1270	17	241	237	0	0	1	-43	2246	1408	109	4115	1	0	0	7451	0	0	204	406	121	100	0	303	303	0	0	77
July	2347	685	1284	17	270	144	0	0	1	-33	2060	1411	70	2938	1	0	0	5751	0	0	205	462	381	100	0	321	321	0	0	63
August	2347	644	1266	17	249	205	0	0	0	-35	2349	1389	96	3247	0	0	0	6280	0	0	205	425	410	100	0	237	237	0	0	74
September	3109	581	1300	23	586	629	0	1	1	-13	2407	1412	256	3732	1	0	0	6417	0	0	201	1028	316	100	0	152	152	0	0	61
October	4179	398	1307	150	500	1780	0	11	19	14	2492	1408	659	5068	19	0	0	8798	0	0	200	875	154	100	0	381	381	0	0	114
November	5196	216	1307	325	751	2335	0	156	105	1	2682	1400	881	4638	105	0	0	8183	0	0	200	1323	148	100	0	141	141	0	0	39
December	6024	128	1307	416	1398	2284	0	407	74	10	2683	1378	905	3749	74	0	0	5917	0	0	200	2458	361	100	0	54	54	0	0	12
Average	4487	481	1296	195	729	1552	0	196	46	-8	2482	1400	599	3999	46	0	0	7021	0	0	202	1281	260	100	0	200	200	0	Average price	
Maximum	10955	3841	1307	836	2532	3150	0	3720	600	1614	3754	6922	1184	7658	600	0	0	18481	0	0	228	4445	3285	100	0	6427	6427	0	(DKK/MWh)	
Minimum	2170	0	1056	16	0	21	0	0	0	-2307	1312	-246	6	0	0	0	0	31	0	0	200	0	0	100	0	0	0	0	558	369
TWh/year	39,41	4,22	11,38	1,71	6,41	13,63	0,00	1,72	0,40	-0,07	21,80	12,30	5,26	35,13	0,40	0,00	0,00	61,67	0,00	0,00	1,77	11,25	2,29	0,00	1,76	1,76	0,00	0	647

FUEL BALANCE (TWh/year):	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	PV	Wave	Solar.Th	Transp.	household	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (Mt): Total	Netto
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
N.Gas	-	8,43	10,60	-	-	3,81	-	-	-	-	-22,85	-0,02	-	-	-	-	-	-	-	-	-0,03	-2,93	-2,96	-0,01	-0,61
Biomass	1,81	-	-	0,77	1,05	-	-	-	4,16	-	36,87	-	-	-	-	-	-	-	0,92	19,11	66,68	0,00	66,68	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	3,45	-	-	-	12,63	41,75	6,46	0,79	6,39	-	-	-	71,51	0,00	71,51	0,00	0,00
H2 etc.	-	0,00	0,00	0,00	0,00	0,00	-	-	-	-24,78	-10,86	35,63	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-32,15	-	-	-	-	-	32,15	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	1,81	8,43	10,60	0,77	1,05	3,81	-	-	7,61	-24,78	5,17	3,45	12,63	41,75	6,46	0,79	6,39	32,15	0,92	19,11	138,16	-2,93	135,23	-0,01	-0,61

19-juni-2015 [14:54]