Danish Vision for Sustainable Energy: 100% Renewable Energy in 2030

INFORSE-Europe, OVE and SEK[1], September 21, 2009

This paper describes a Danish Sustainable Energy Vision that includes a transition of the energy supply and demand with phase-out of fossil energy over a 20-year period, and with no nuclear power

Strong Energy Efficiency

In line with INFORSE's[2] global vision for sustainable energy, the Danish Vision is based on substantial increase of energy efficiency, leading to 40-64% increase of energy efficiency until 2030 for different sectors. Most energy consuming equipments will be changed one or more times until 2030 2050, and if new generations of equipment are made with optimal energy performance, and markets are made to promote the most efficient technology, it will not be a problem to reach up to 50% efficiency increase in two decades or more. The energy efficiency increase will not stop in 2030, the potential is still larger, - in the order of 4 times compared with current technology. To realise the energy efficiency is proposed a number of measures for the different sectors:

- for appliances and other energy using products for homes and offices is proposed an ambitious Ecodesign policy (EU-wide policy with regulation of energy efficiency with implementation of the EU Ecodesign Directive), taxes on energy using products according to their energy use, and campaign on energy conservation. Together this should reduce specific power consumption (increase energy efficiency) with 43%, and reduce growth in energy using products (in size and numbers) to about 1%/year

- for industry is proposed action plans for each industry or industrial sector on how to phase out fossil fuel use in 20 years. This shall be combined with taxes and return of revenues from the taxes and from sale of emission allowances to energy efficiency investments in the companies. Thus should reduce specific power consumption with 43% and specific fuel & heat consumption with 50%

- for buildings and transport are proposed special initiatives as explained below.

The success of the energy efficiency will require concerted actions from stakeholders involved, but if it is done on national scale with EU-scale regulation on energy using products, the market is large for each new generation of efficient equipment, and the costs therefore low. The extra equipment costs will be off-set by energy savings.

The Challenge of Reducing Heat Consumption

For buildings the situation is different from equipment because buildings often have lifetimes of 100 years or more. Most of the houses to be heated in 2050 are probably already built. A key measure is a proposed a subsidy scheme paying 20% of investments in energy renovation measures with 20%. The scheme should be financed 50% from a levy on heat, oil and gas use of 0.02 DKK/kWh (0.3 €-cent/kWh) and 50% by the state budget.

Efficient Transport

For road transport is assumed that the conversion-efficiency from fuel to transport-work is increased 2.8 times for personal cars and 2.1 times for lories (from current 15- 20% in combustion engine systems to 30-50% in fuel cell systems with break-energy recovery and 70-80% in direct electrically driven vehicles with batteries) This increase is expected to

[1] International Network for Sustainable Energy - Europe, see www.inforse.org/europe, Danish Organisation for Sustainable Energy (OVE), see www.ove.org, and Cooperating Energy & Environment associations (SEK), see www.sek.dk

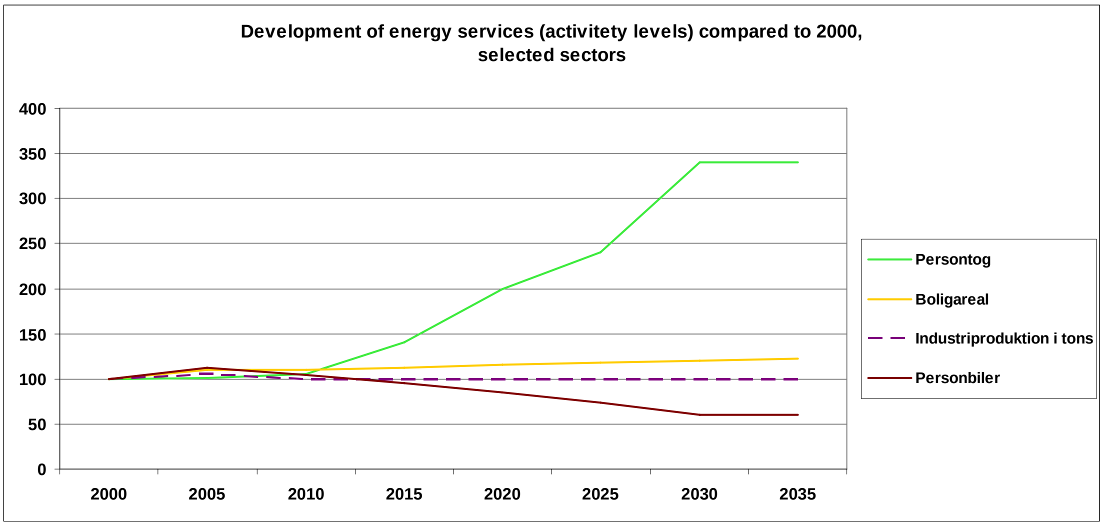
2 International Network for Sustainable Energy, see www.inforse.org

happen until 2030. For railway is expected a 40% reduction on specific energy use for passenger trains and 20% for freight trains.

Growth Factors

The growth of energy services, i.e. heated floor space, transported goods and people, energy consuming production, is expected to be low Assumed growth in activities for Denmark:

- Floor space, households: 10% in total 2000 – 2010 following current trends then increasing to 0.4%/year until 2015, 0.8%/year 2015-2020 and then below 0.4%/year until 2030 In this way the living space in 2030 will be 24% larger than in 2000
- Floor space service sectors: same development as in households
- Electric appliances in households and service: same development as for heated floor space. This shall be realised with campaigns and taxes to address consumption, not only energy efficiency.
- Industry: 6% increase in energy services (production volume) for electricity demand and 1% decrease in energy services for heat & fuels in the period 2000 – 2010 following current trends, then stable on the new higher level. Increase in electricity service demand of 24% 2000 – 2030
- Personal transport: the vision includes a 10% reduction and a modal shift so 1/3 of car use is shifted to public transport until 2030. This will lead to 40% reduction of car use and a 3.4 times increase in passenger train use.
- Freight transport: the vision includes a 25% decrease in road transport to phase out low value transport, for instance basic food and heavy materials that can be obtained from closer sources. It also includes a modal shift so road freight is decreased 37% and rail freight is increased 5.6 times



Graph: Development of selected activities 2000 - 2050 for Denmark. From top: passenger trains, area of dwellings, industrial production (heat & fuels demanding), personal cars

Renewable Energy

As a fraction of primary energy, renewable energy use is expected to reach 34% in 2020 and 95% in 2030 (where the only other energy source will be waste incineration). For electricity the renewable share is higher than the renewable share of primary energy, it is expected to reach 66% already in 2020.

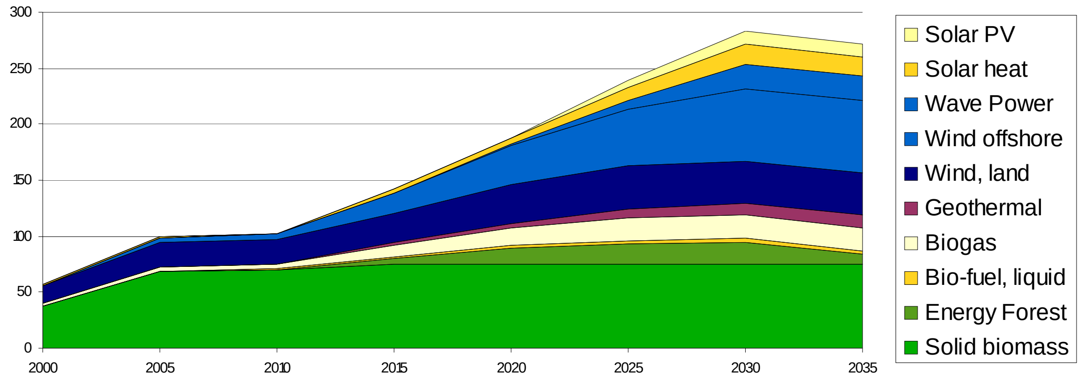
The most important developments are:

- more windpower, where is proposed an increase from 3200 MW to 10,000 MW, half of which off-shore

- increased biomass use including use of 150,000 ha of agricultural lands for energy plantations such as villow with an annual yield of 11 tons of dry matter/ha, biogas and straw use. A total of 120 PJ is expected to be used in 2030, all from Danish sources, while today about 15% of the biomass used for energy in Denmark is imported.

Also increased use of solar heating, solar PV, low temperature geothermal for district heating and wave energy is included in the vision. Large increases are proposed already until 2020, except for solar PV and Wave energy, where technologies are still costly and most developments are expected 2020-2030.

Renewable Energy Supply (PJ)



Graph: Increase of Renewable energy use following the vision

Energy Conversion, Hydrogen& Heat Pumps

The energy conversion system will also have to be changed, and made much more flexible to manage the large use of intermittent windpower, solar PV and wave power. The electric grid as well as district heating will increase in importance, because electricity will also be used for transport, directly or via conversion to hydrogen and for heating via heat pumps. The increased flexibility will be achieved with flexible electricity demand: heat pumps, electrolysers for hydrogen, smart charge of electric vehicles, and conversion of 10% of ordinary electricity use to become flexible in time. The heat pumps will supply most of the heat for the district heating and to make that flexible there should be heat storages equal to 2.2 days of average load (up from 8 hours average load today). Also hydrogen storage add to the flexibility.

Gas networks are expected to have decreasing importance; but will play a role to distribute biogas to peak load power plants that will run on biogas to become more flexible.

Waste, Nuclear and Fossil Energy

Fossil fuels will be phased out with the vision, starting with oil use for heating, to be phased

out until 2018 and coal use in power plants in 2020 (coal provide 50% of the power plant fuel today). Natural gas use will be reduced for households and industry, while for the power sector it will increase, so overall gas use will slowly decrease until 2020 and then be phased out. About 15% of the natural gas use will be replaced by biogas.
In the road transport oil shall be replaced by electricity in electric cars, and by hydrogen, mostly used in hydrogen-electric hybrid vehicles. Trains shall be electrified

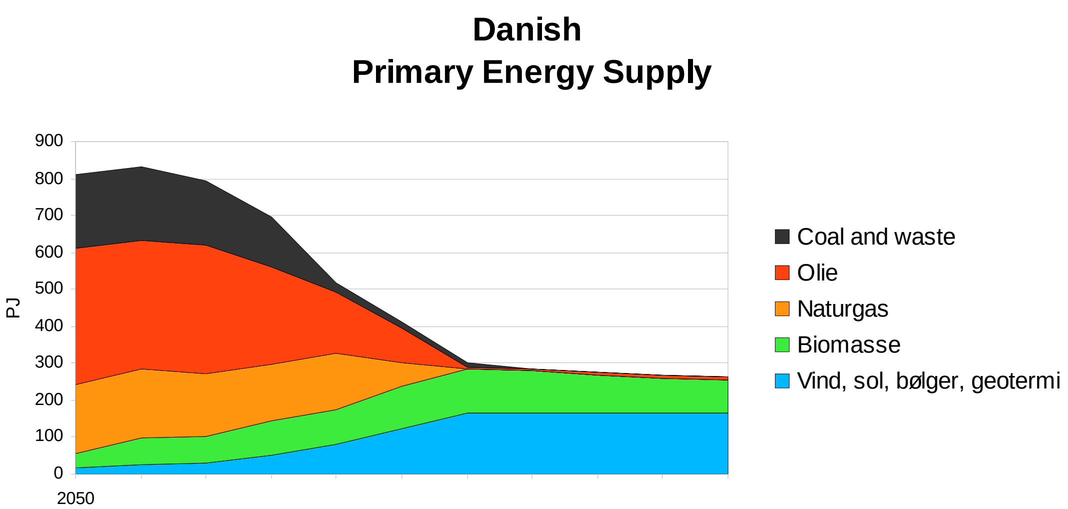
Waste provides 10% (32 PJ) of the fuel for Danish power and CHP plants today; but this shall be reduced by 50% by increased recycling and re-use.

There is no nuclear energy in Denmark, and there is no need for it in this vision, or in other plans for Danish energy supply. Beside the problems of nuclear power, it cannot be combined with renewable in a meaningful way within the framework of the energy vision presented here, because all thermal power plants must be very flexible.

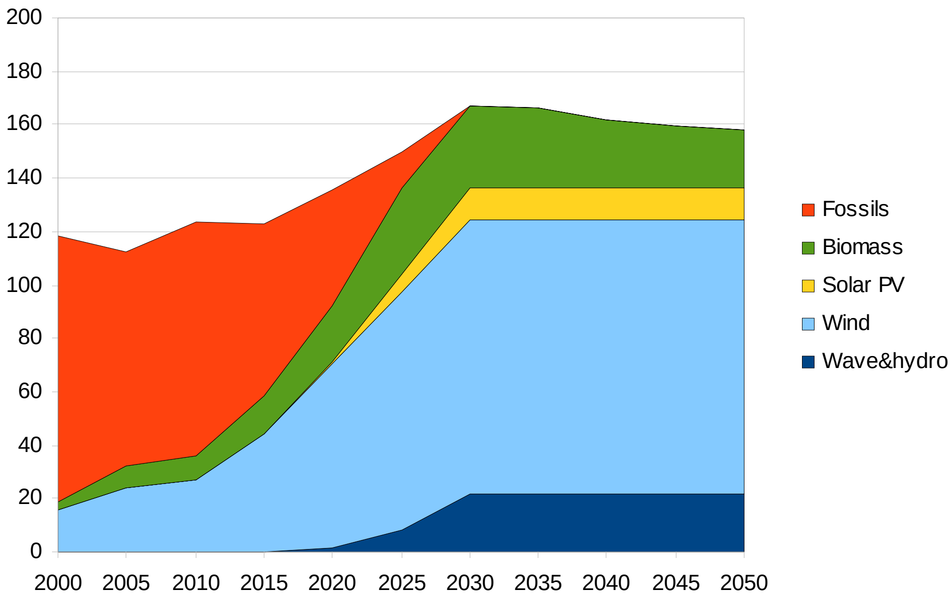
Energy Trade

Energy trade is expected to be much less than today, only a moderate electricity exchange is expected. Electricity exchange with little net import or export is likely to continue, to exchange elelctricity from renewable sources such as hydropower (currently imported from Norway on seasonal basis) and wind power.

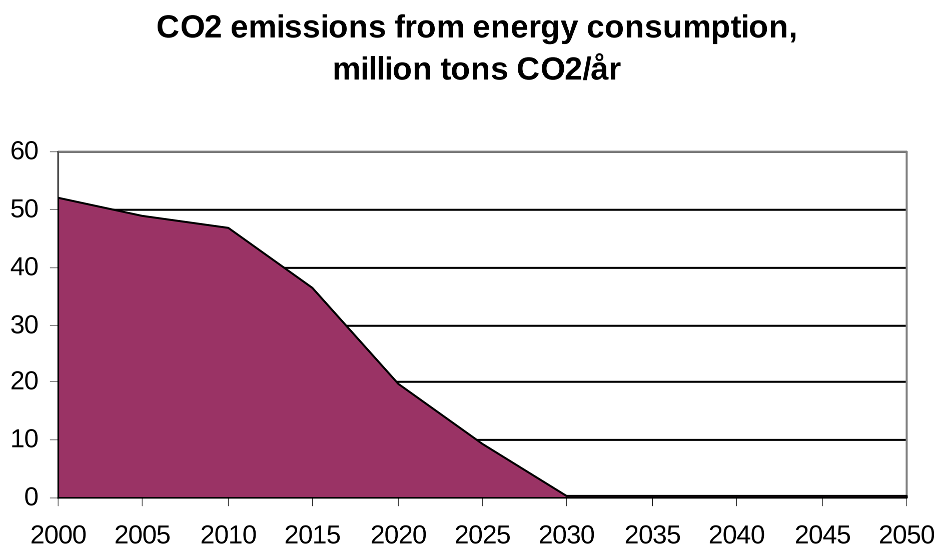
Overall Results



Graph: Change of Energy Supply, following Vision2050



Graph: Development of electricity production and sources, following Vision2050



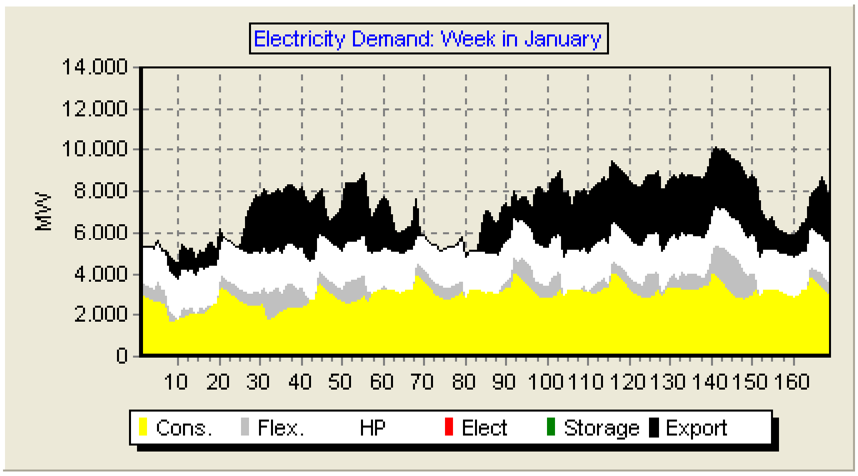
Graph: Phase out of CO_2 emissions

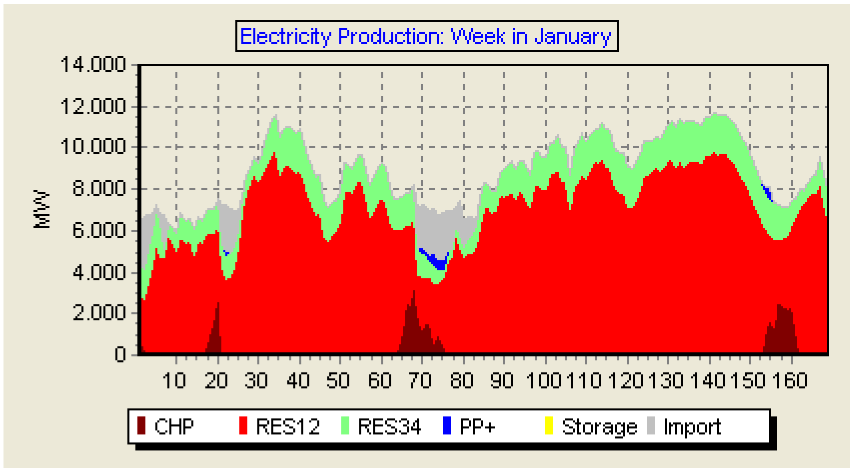
Balance in the Energy System

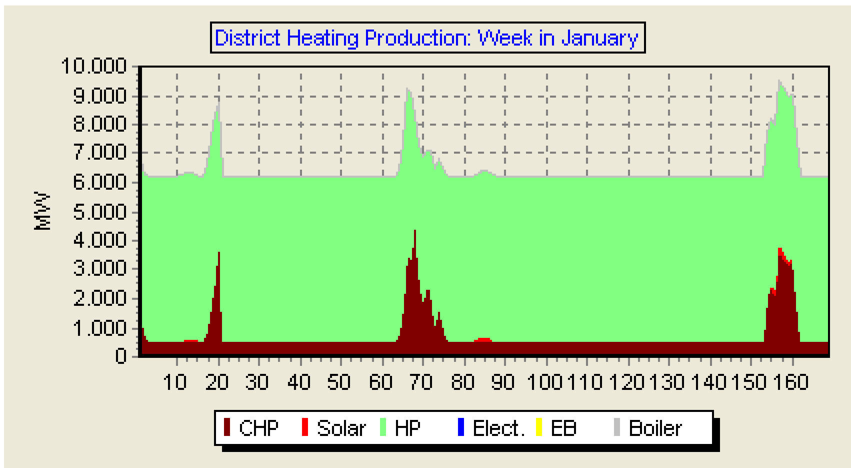
An evaluation of the hourly variation of electricity and heat loads and the windpower production was made on the EnergyPlan3 model for the year 2030, with input data for the vision's energy balance for 2020 and with variations from typical Danish conditions. The results were that there would be no critical electricity excess or lack of electricity in any hours, but electricity export in some periods with high windpower and export in other periods. The model was set to optain balance of the electricity exchange as annual average. If the

3 EnergyPlan model version 7.82,by prof. Henrik Lund and others, Aalborg University, Denmark, used with data from the vision for Denmark fo the year 2030

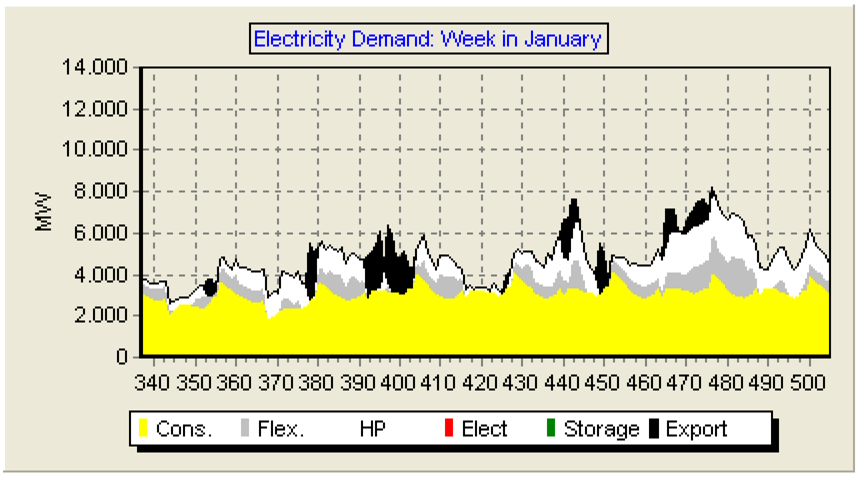
export is not possible windpower or CHP production could be reduced in these hours, in total about 1% of the windpower is curtailed because of this.

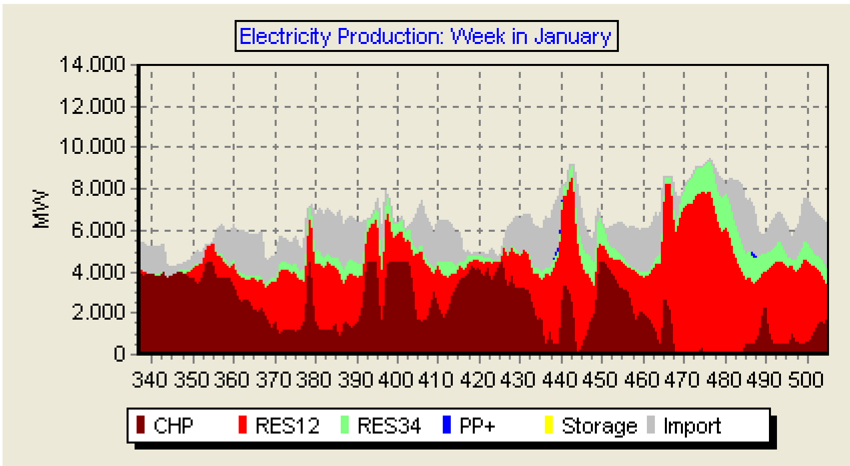


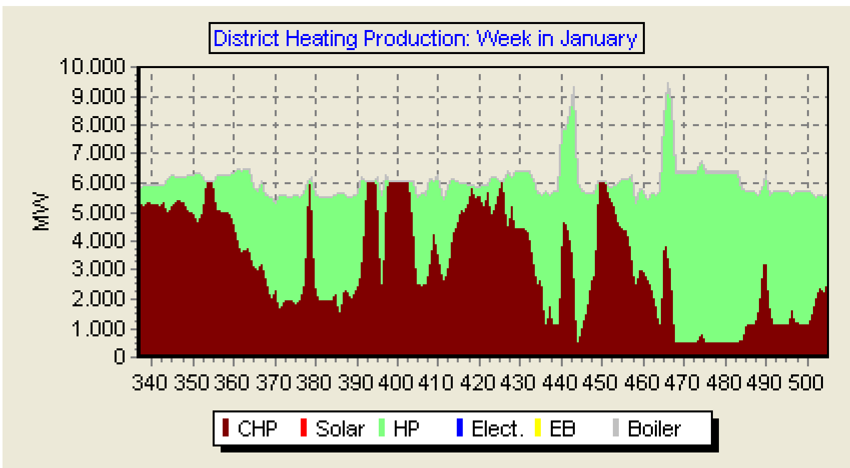




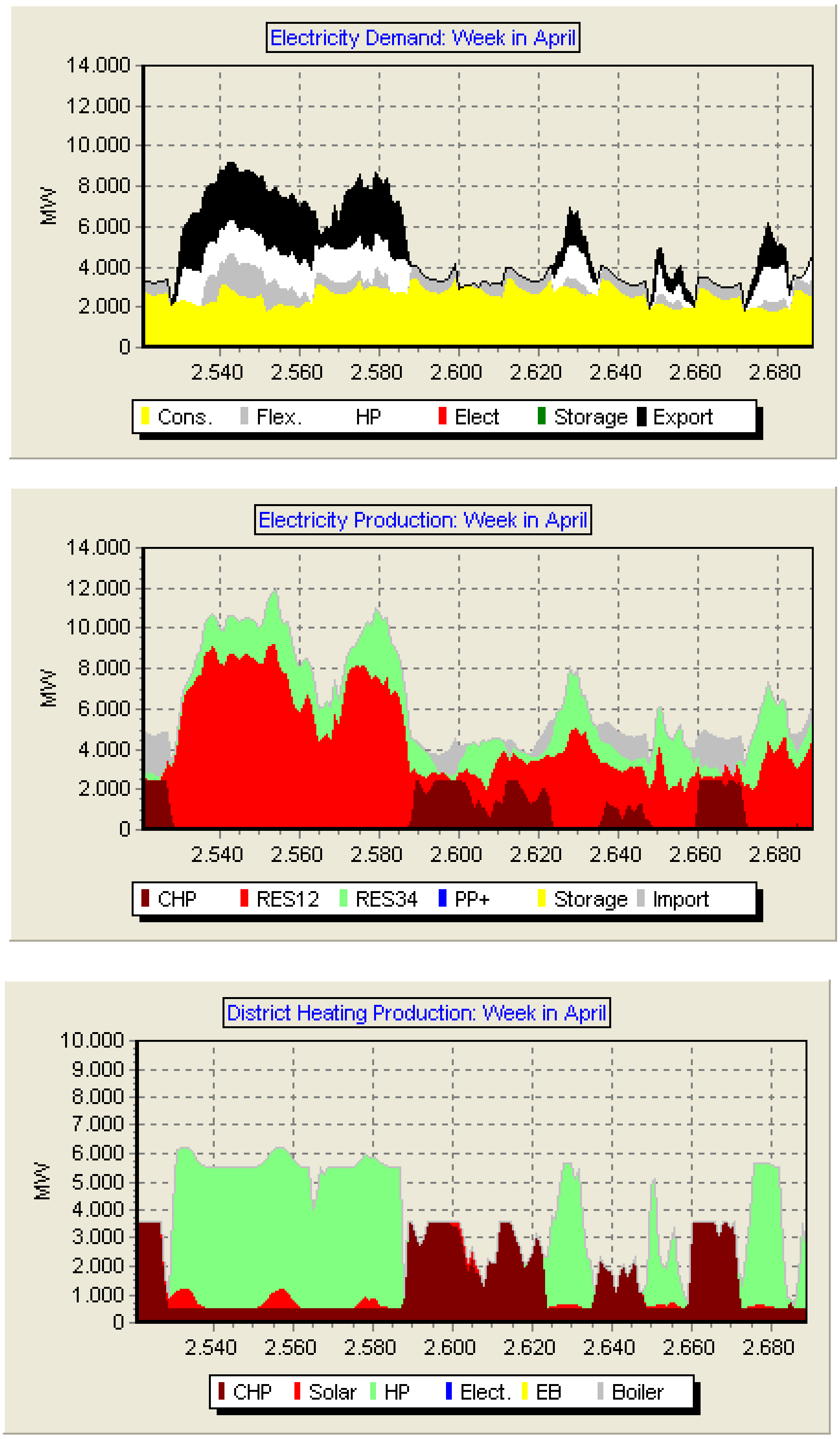
Graphs: Detailed output from the EnergyPlan model for winter weak with considerable windpower production
(RES12 is windpower, RES34 is wave and solar power, PP+ is power plants without heat production, CHP is combined heat and power production HP is heat pump)



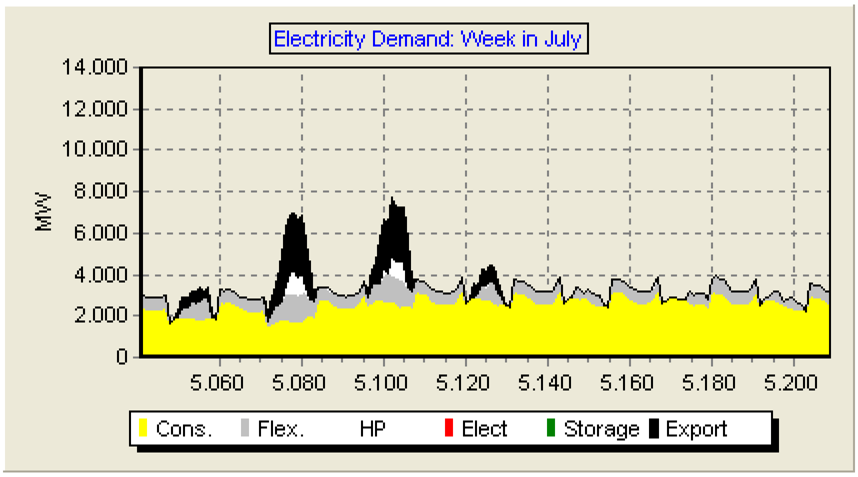


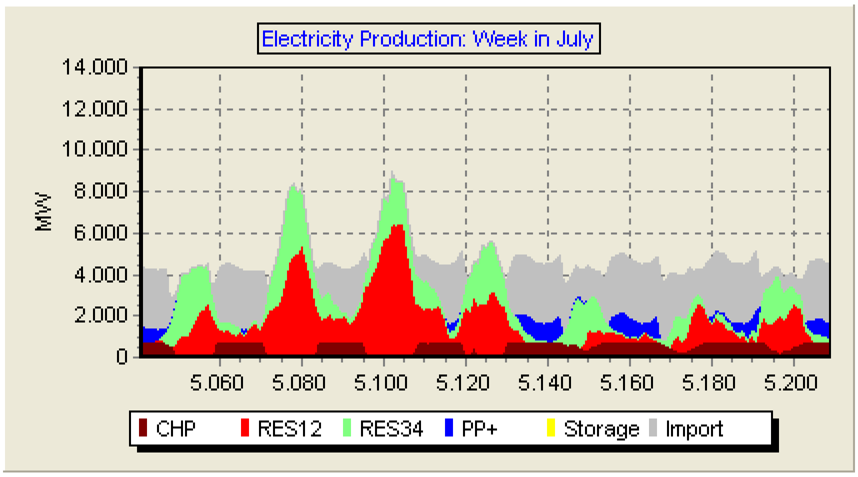


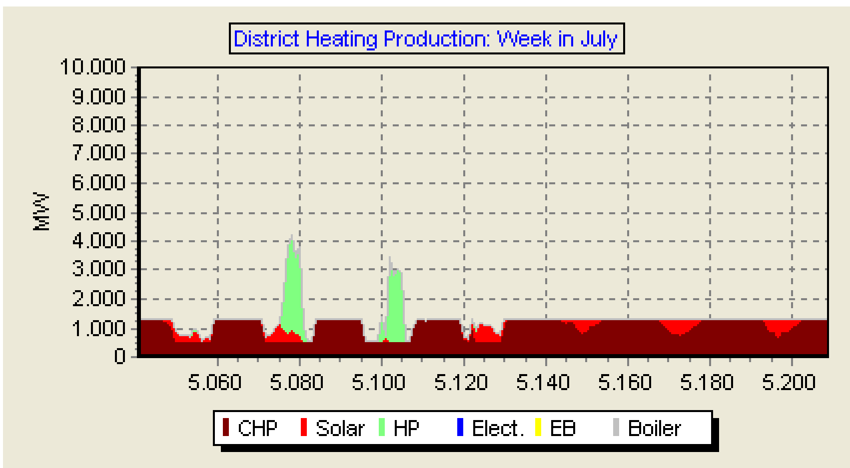
Graphs: Detailed output from the EnergyPlan model for winter weak with weaker windpower production



Graphs: Detailed output from the EnergyPlan model for weak in April

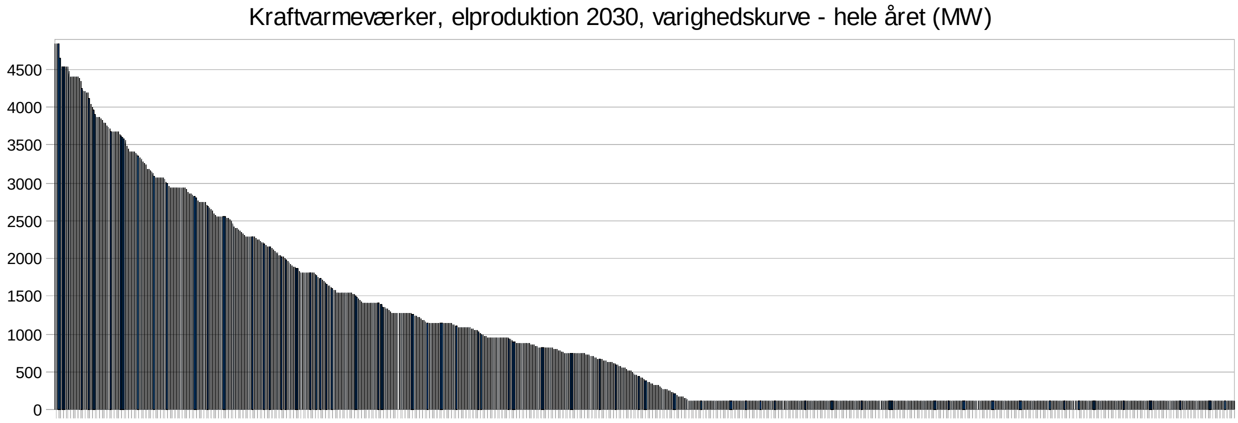






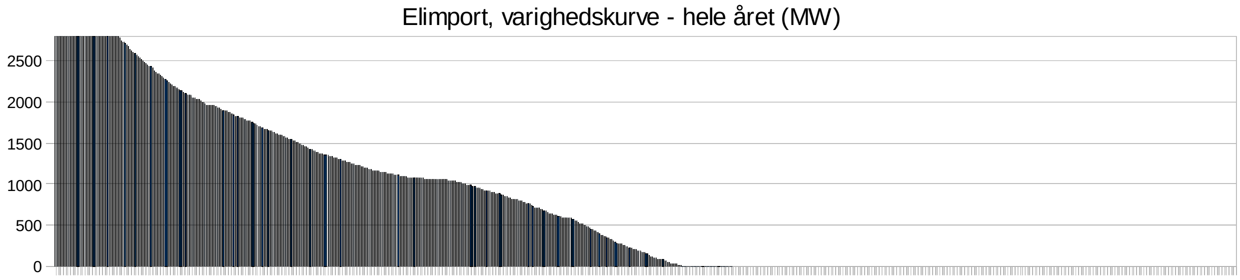
Graphs: Detailed output from the EnergyPlan model for weak in Julyl

Variation Curves
Another way of illustrating the results from the modelling of hoursly variations is with curves summarising the loads from the highest to the lowest. Variations in production from wind, sun and waves are externally given as is the demands for power and heat. Therefore the interesting variations are production on power and CHP plants, heat pump use and import/export of power.

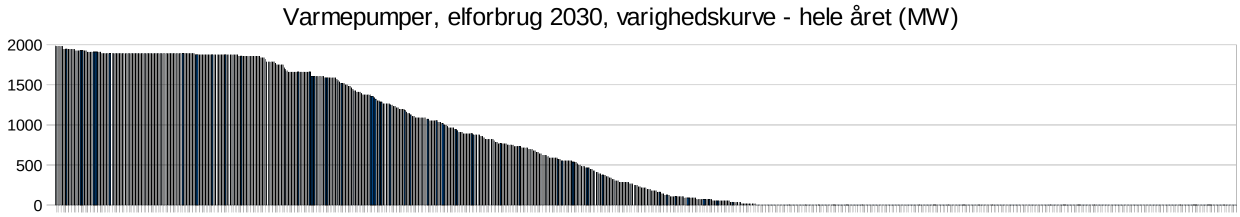


Graph: CHP Plants including waste incineration plants that are "must run"

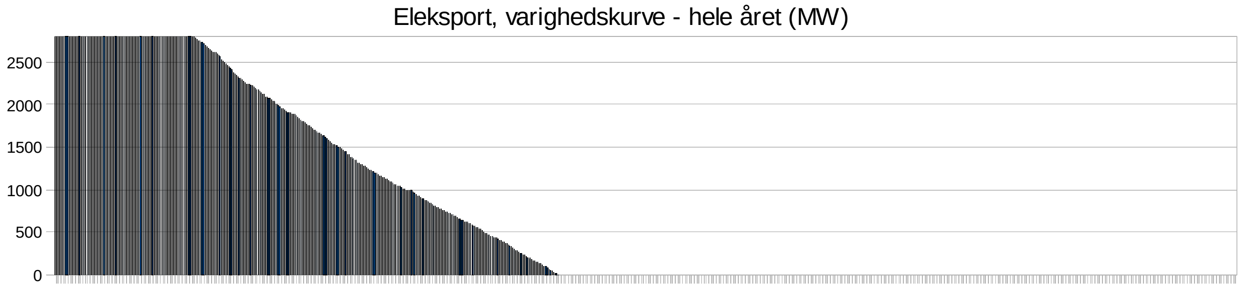
Graph: electricy only plants



Graph: electricity import



Graph: electricity use of heat pumps for district heating



Graph: electricity export

Sources and funding

The assumptions used in the vision are described in more details in documentation (in Danish) on the website www.ove.org.

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