Evolution of the Danish Energy system
+
Introduction to energy systems analyses

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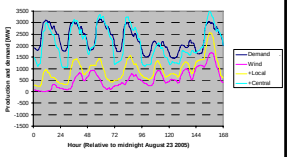
www.energyplanning.aau.dk + www.planogmiljo.aau.dk

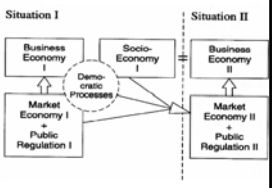
Programme of lecture

- Who are we?
- Plan og Miljø
- Danish energy planning (motives, approach, plans and results)
- The Danish energy system
- Integration of renewable energy into the energy system
- The EnergyPLAN model - example of analysis
- Using the EnergyPLAN model
- After the lecture – exercises with the model

Research area

- Inter-disciplinary work on energy planning
- Technical energy systems analyses and GIS analyses of energy systems
- Business-economic and socio-economic analyses of energy systems
- Institutional analyses
- Primary focus is on the production of energy



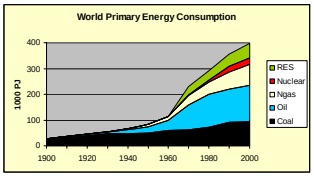


Plan & Miljø

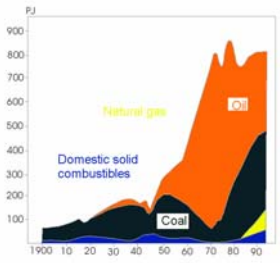
(Planning and Environment – Aménagement et Environnement)

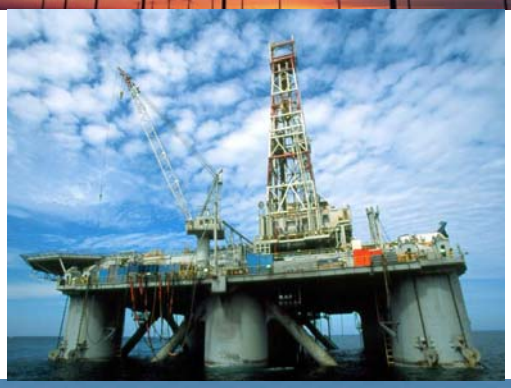
- Five year programme in engineering
- Focus on energy planning, the environment and urban planning
- Candidates with a technological, institutional and economic understanding of the energy/environmental and urban systems
- Three masters' level programmes (two last years) taught in English

World primary energy consumption



Evolution of the Danish energy demand





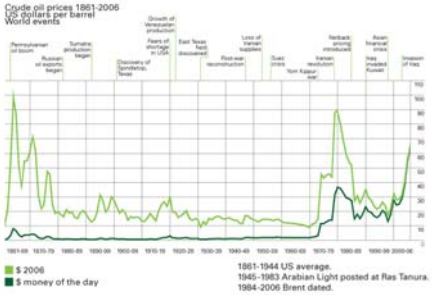
Source: BP

The happy 1960s

- large increases in the economies
- energy was considered as an important precondition for the increases of the economy
- almost 100% of the energy consumption was based on oil

The oil crises of the 1970s

Evolution of oil prices



Source: BP

After the oil crises

- Self sufficiency
- energy conservation
- increase of the energy efficiency

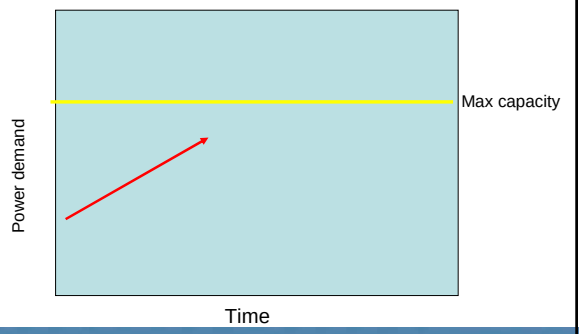
New initiatives

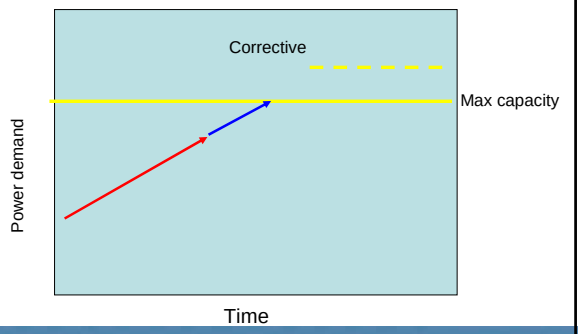
- Production of natural gas from the North Sea
- A natural gas grid was established
- Heat and electricity planning was carried out for the whole country
- Energy saving programmes
- Renewable energy was introduced

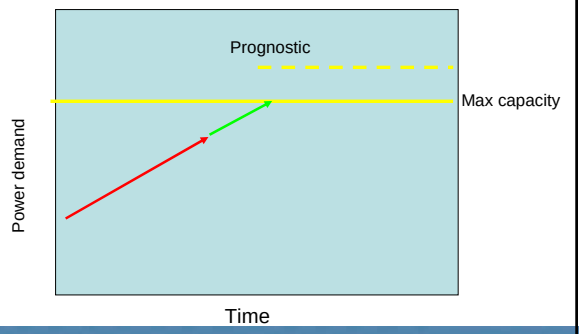
General planning strategies

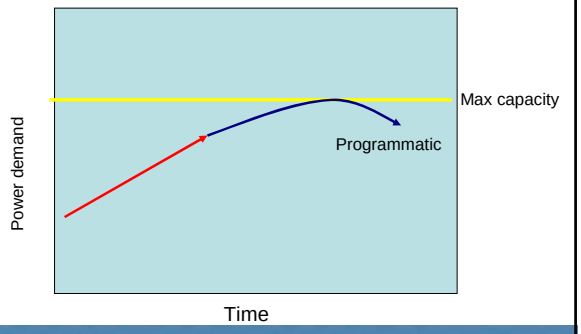
(Theodor Geiger, 1948)

- corrective,
- prognostic and
- programmatic planning





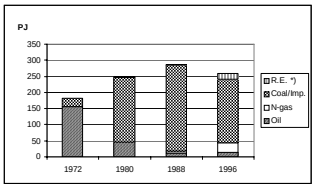




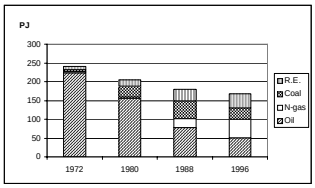
Danish Energy plans

Title	Fuel	RES	Planning approach	Focus
Danish energy policy 1976	Nuclear	No	One alternative Prognostisc	Security of supply
Energy plan 81 (1981)	Coal	A little	More alternatives Prognostic	Societal costs
Energy 2000 (1990)	Natural gas	Some	Programmatic	Environmental compliance
Energy 2000 – the follow-up (1993)	Natural gas	Some	Ditto; IRP	Ditto
Energy 21 (1996)	Natural gas	More	Ditto	Environmental compliance; re-regulation
Energy strategy 2025 (2005)	Natural gas	Maybe	Market improvement	Cost effectiveness

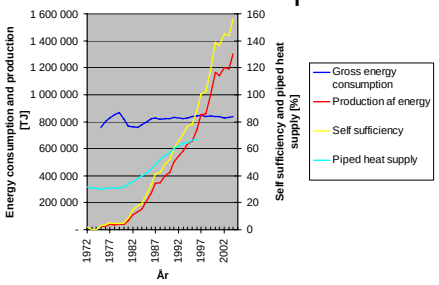
Fuels for electricity production in the transition period



Fuel for house heating in the transition period

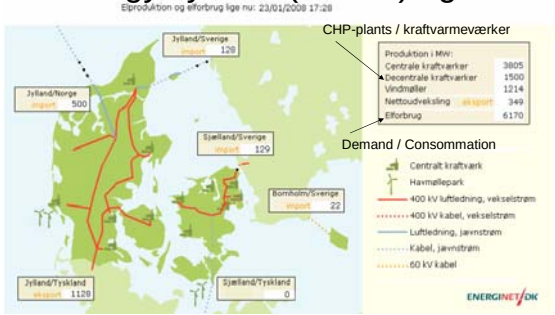


Evolution of various indicators in the transition period

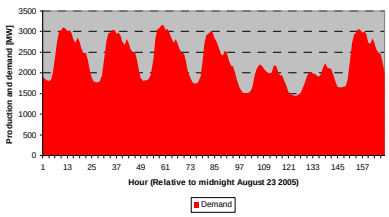


Typical Danish plants

The energy system (almost) right now



Load-curve building in complex energy systems – a summer week



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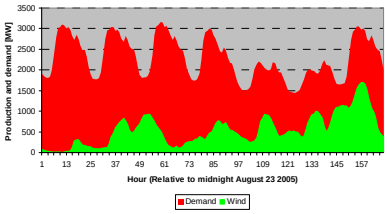
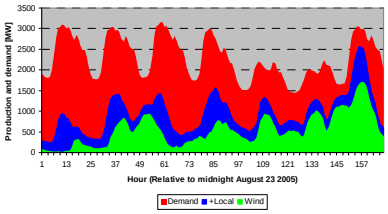


Load-curve building in complex energy systems – a summer week



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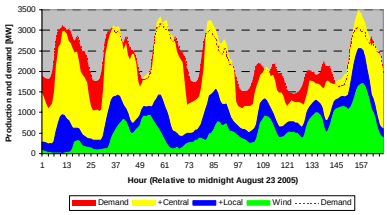
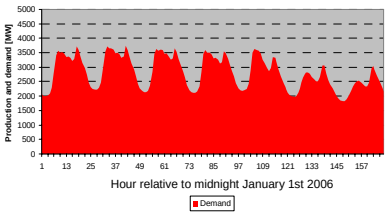
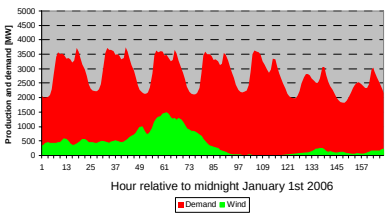


Load-curve building in complex energy systems – a winter week



Load-curve building in complex energy systems – a winter week



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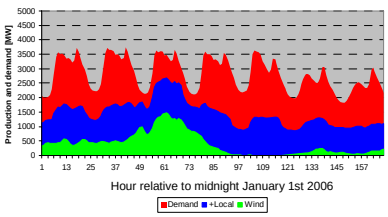
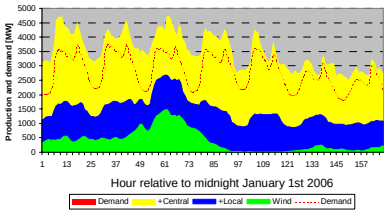
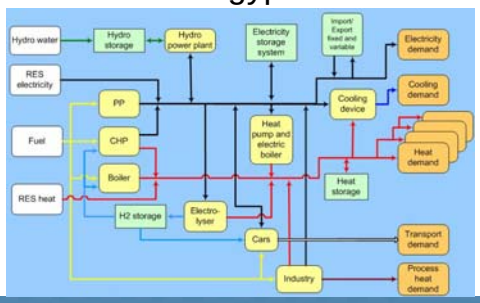


Load-curve building in complex energy systems – a winter week



Energy system description in Energyplan



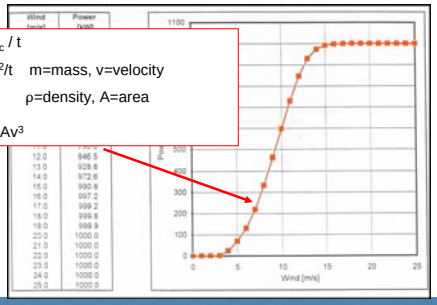
Wind power

P = $E_{Cinetic}$ / t

= ½mv²/t m=mass, v=velocity

m/t = ρAv ρ=density, A=area

=> P = ½ρAv³

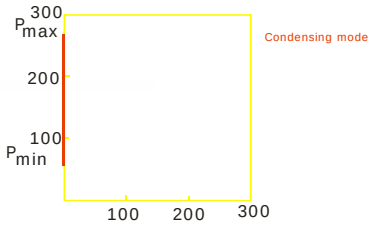


CHP plants

Electricidad / Electricity [MW]

Carnot

$$\eta = \left(\frac{T_{high} - T_{low}}{T_{high}} \right)$$



Calor / Heat [MJ/s]

CHP plants

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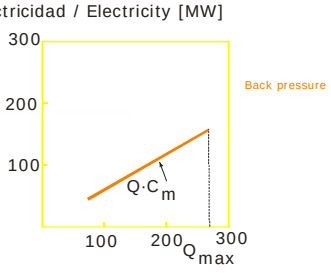

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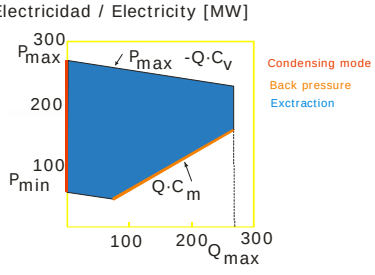

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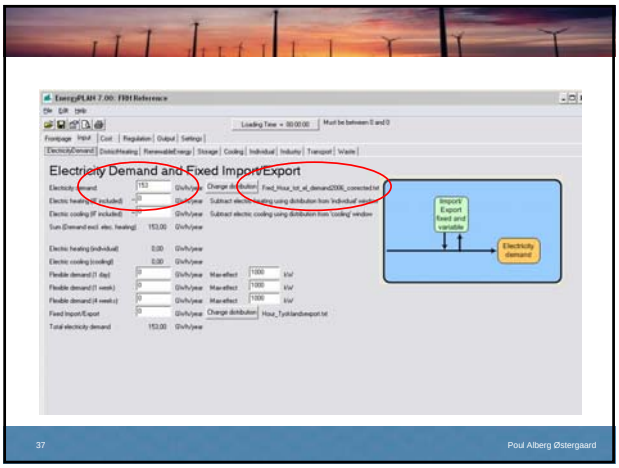

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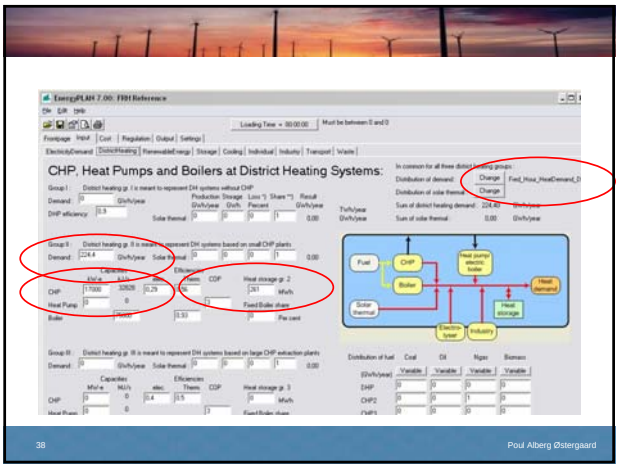

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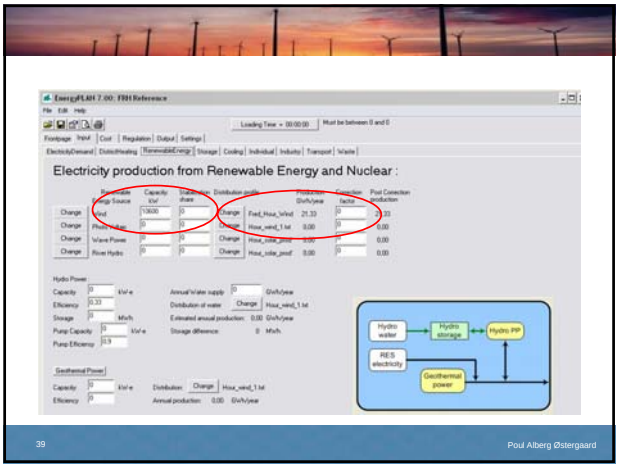

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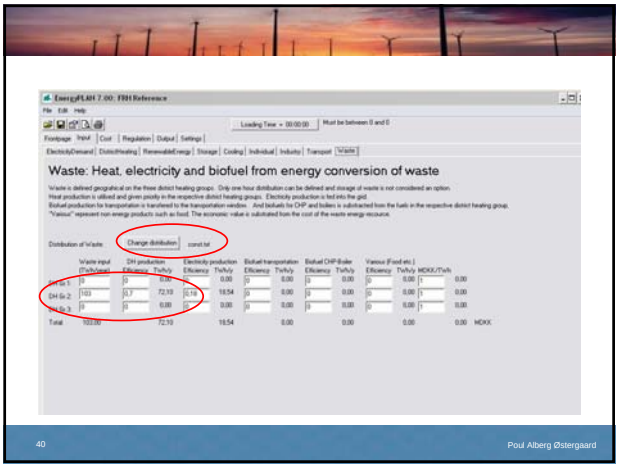

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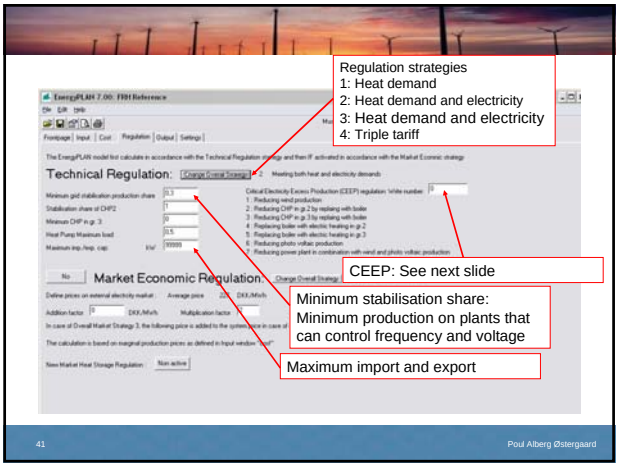

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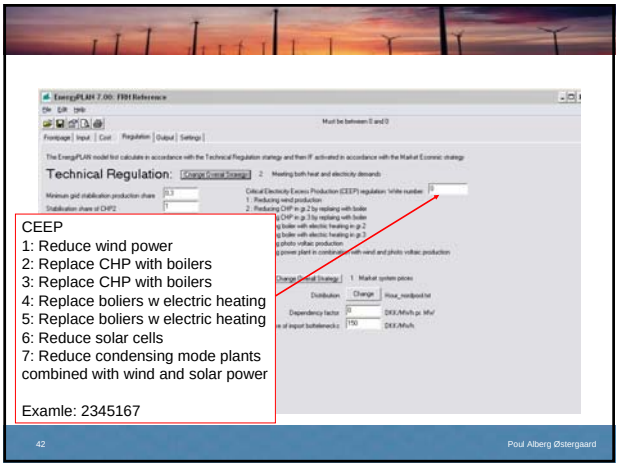

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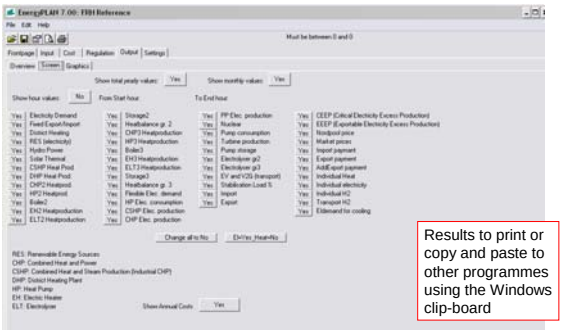
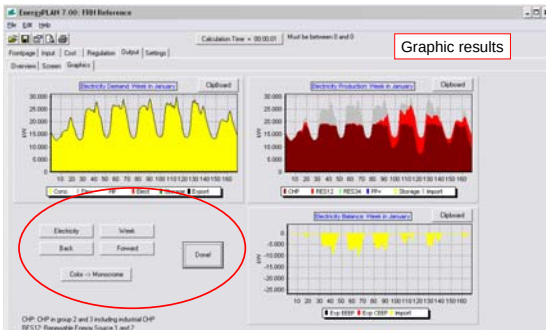


Results to print or copy and paste to other programmes using the Windows clip-board



Graphic results

Example of analysis

Large-scale integration of off-shore wind power in the Danish electricity system

Demand and thermal power plant capacity

Consumption [TWh]	Generating capacity [MW]	
24.87 Electricity 20.00 District heat	2750 Unlimited	CHP (plants producing both heat and electricity) Central plants in condensing mode (plants producing only electricity)

Modelled wind capacities

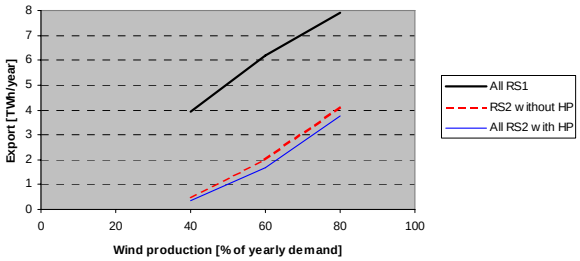
		40%	60%	80%
Inland	MW	2500	2500	2500
Off-shore	MW	920	2100	3277
Production	TWh	9.9	14.9	19.9

Regulation strategies

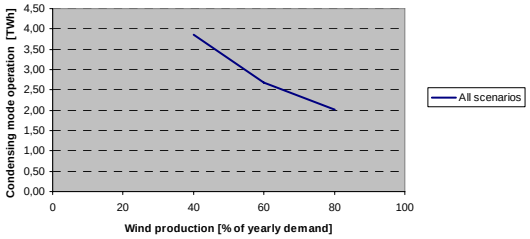
Regulation Strategy 1 (RS1) Meeting heat demand	Regulation Strategy 2 (RS2) Meeting both heat and electricity demands
Heat generated according to the following prioritised list 1 Solar Thermal 2 Industrial CHP 3 District heating CHP 4 Heat pumps 5 Boilers at CHP plants	Generally as Regulation Strategy 1. Heat pumps employed to decrease surplus electricity generation. Non-used capacity at CHP plants together with the use of heat storages employed to decrease electricity generation in condensing mode.

In addition; excess is removed with a) export b) heat pumps c) electric heating d) turbine control

Yearly electricity export



Annual electricity generation in condensing mode



Getting your hands on the EnergyPLAN model

Download the EnergyPLAN model from the EnergyPLAN website (www.energyplan.aau.dk) and un-zip the file to an appropriate location on your computer. Included in the model library is a reference model of Frederikshavn (the file called \data\FRH Reference.txt)

Notice that there is lots of extra material at the above mentioned website including manual and tutorials.