THE ROLE OF ALTERNATIVE ENERGY PLANNING AND MODELLING IN SUSTAINABLE ENERGY TRANSITION

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THE CASE OF DENMARK

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Agenda

- Short introduction to the results of Danish energy planning
- The role of energy planning in the transition including the interaction between academia, interest organisation and official planning
- The role of energy system simulation and analysis

- (If time permits – Two cases of policies to assist the establishment of wind power and CHP)

SHORT INTRODUCTION TO THE RESULTS OF DANISH ENERGY PLANNING

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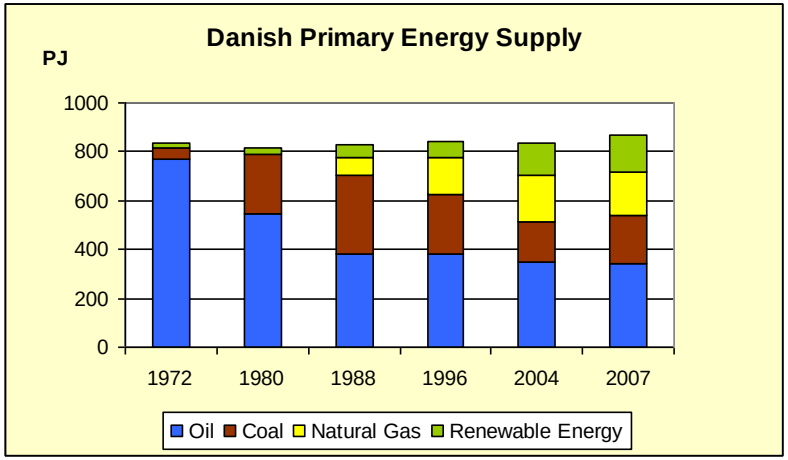
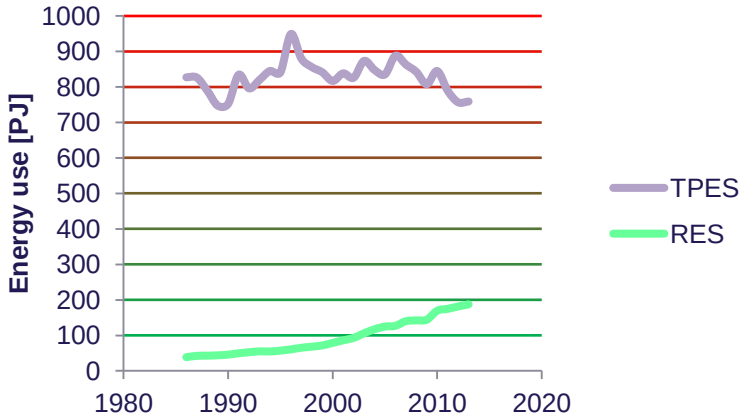
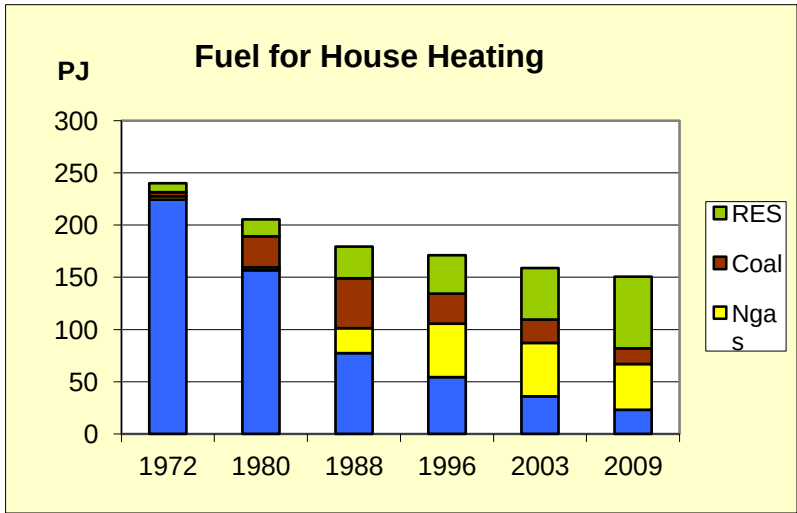
Danish energy system at a glance

- Stable primary energy supply over 40 years
- ~50% of electricity from cogeneration of heat and power
- >55% District Heating
- ~40% wind power
- High share of the world's offshore wind power







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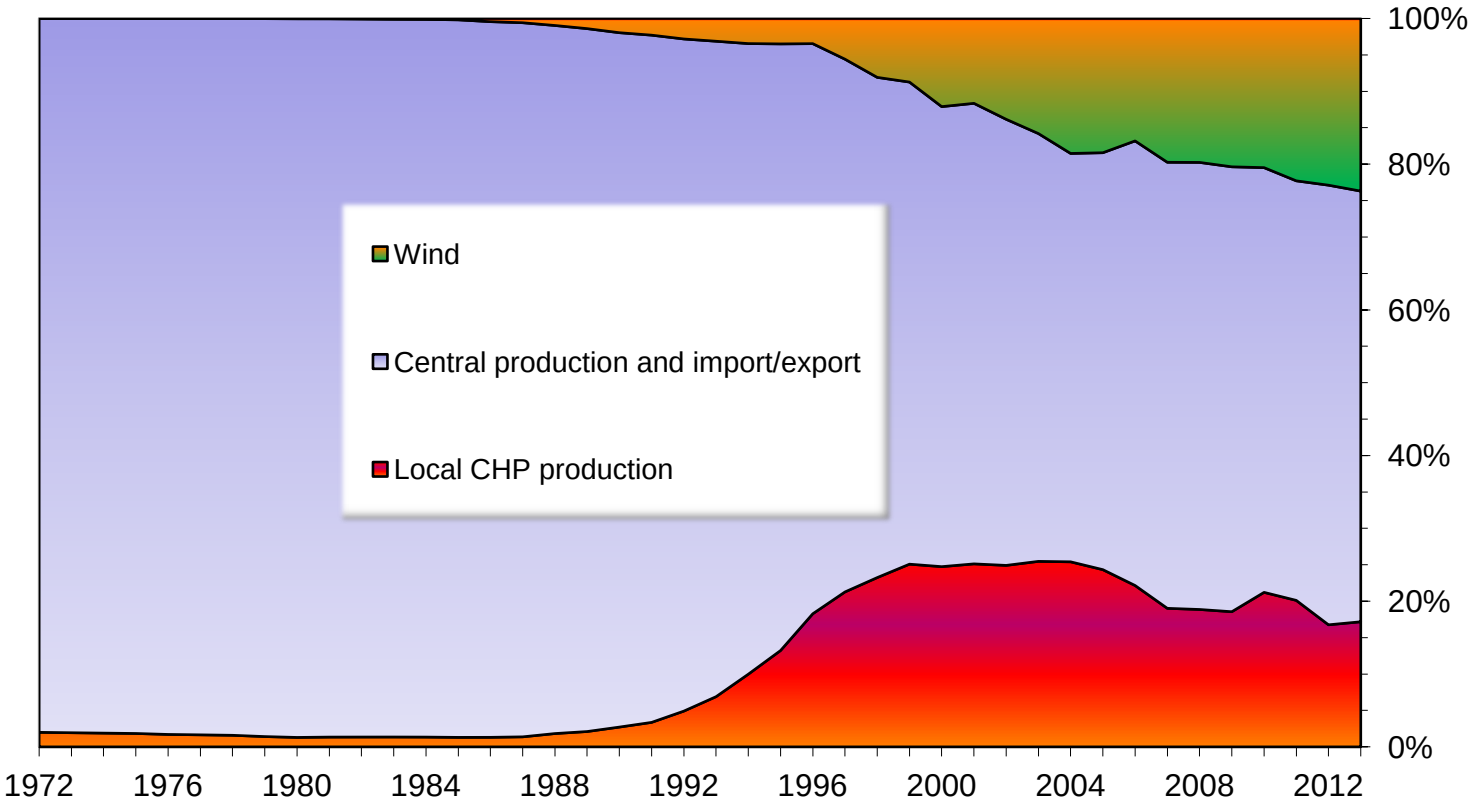
Danish electricity supply – wind and CHP



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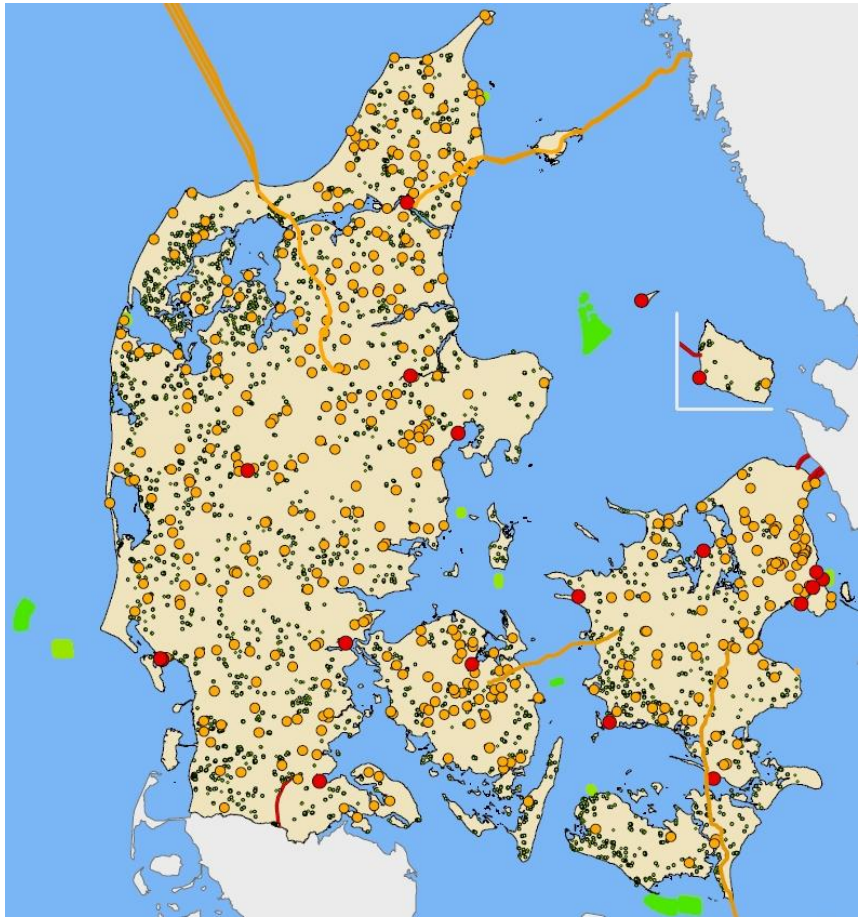
From a central to a distributed energy system



2013

Centralt kraftvarmeværk	Central CHP
Decentralt kraftvarmeværk	Local CHP
Vindmølle	Wind
Havvindmølle	Off-shore wind
Udlandsforbindelse (vekselstrøm)	AC Interconnection
Udlandsforbindelse (jævnstrøm)	DC interconnection

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Maps: Danish Energy Agency

THE ROLE OF ENERGY PLANNING IN THE TRANSITION INCLUDING THE INTERACTION BETWEEN ACADEMIA, INTEREST ORGANISATION AND OFFICIAL PLANNING

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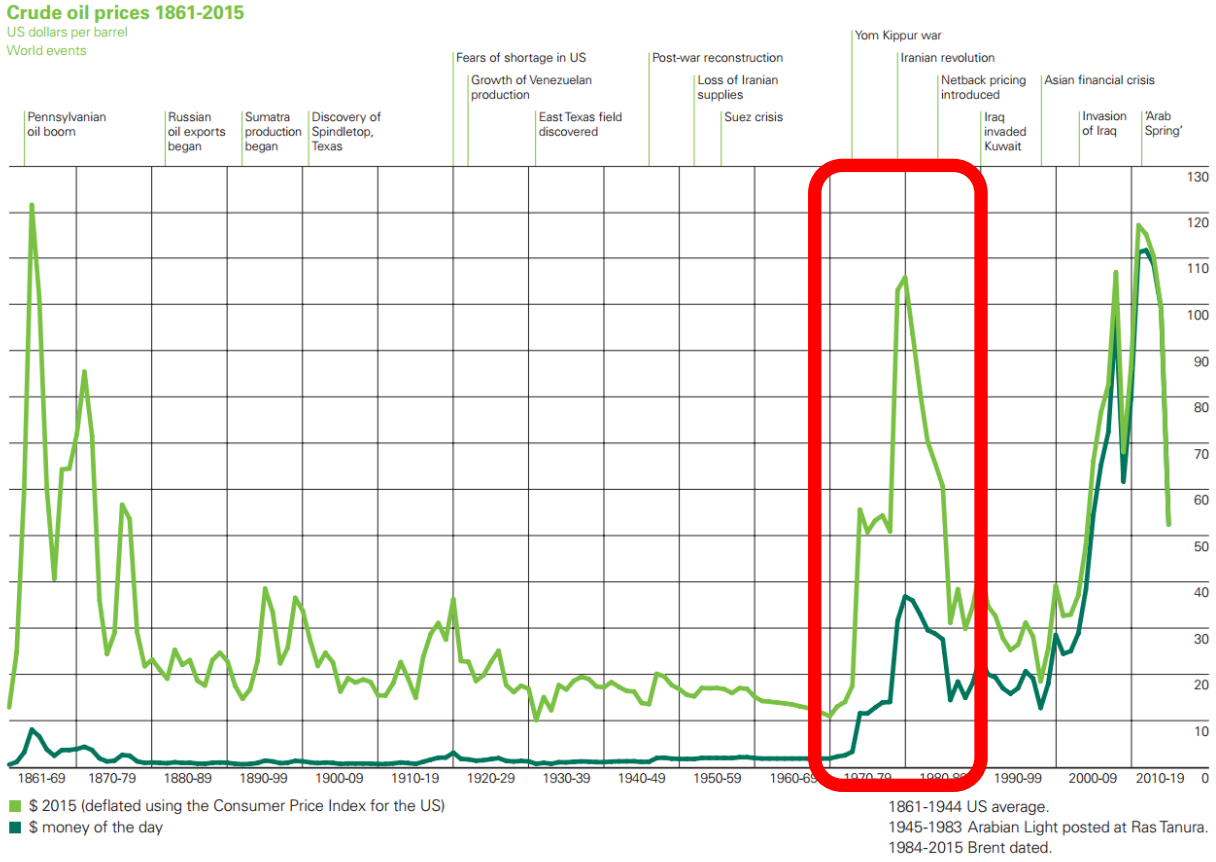
The role of energy planning in the transition

- Energy planning and energy system modelling was not a topic prior to the 1970s – however that situation changed abruptly



Danish Energy plans

Name	Fuel	RE target	Approach	Focus
Danish Energy policy 1976	Nuclear	None	One alternative Pro-gnostic	Security of supply
Energy plan 81	Coal	Marginal	More alternatives Prognostic	Socio-economic costs
Energy 2000	NG	Some	Programmatic	Environment
Energy 2000 – follow up	NG	Some	ditto; IRP	Ditto
Energy 21 (1996)	NG	More	ditto + market	Environment Re-regulation
Energy strategy 2025 (2005)	-	None	Market based	“Liberalisation” and market opening
A visionary Danish Energy policy 2025 (2007)	RE	30% & 100%	Market based	Unreliable suppliers Climate change
Energy strategy 2050 (2011)	RE	100%	Market based	Unreliable suppliers Climate change

Alternative energy plans

Name	Focus	Result
Draft to an alternative energy plan 76	Alternatives to nuclear	Appricitation of a multi-fuel strategy
Alternative energy plan 83	Technical alternatives	Away from growth philosophy
Energy action plan 90	Public regulation	Action plan approach
MOSAIK + Local energy markets (2005)	Technical options for full-scale integration of RE	Realisation of the possibility of substantial RE integration
IDA / CEESA / Local energy plans (>2005)	100% RE systems	(Municipal involvement)

Choice awareness and radical technological change

Choice awareness theory [Lund]

- Choices in democratic decision-making
- True choices and false choices
- Hobson's choice

Radical technological change

- "Technology" embraces technique, knowledge, organisation, products – and profit [Müller, Remmen and Christensen – later expanded by Hvelplund]
- Changes in technology can be measures in terms of how many constituents that are changed. More than one is denoted "radical technological change" [Hvelplund]

Choice awareness theory and technological change theory calls for energy systems scenario-making combined with analyses of the components of "technology" to be changed

THE ROLE OF ENERGY SYSTEM SIMULATION AND ANALYSIS

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Three phases of introducing Renewable Energy

1. ***Introduction phase***

   Small marginal shares of RES leading to high fuel savings (pr. Unit) by replacing marginal units.

2. ***Large-scale integration phase***

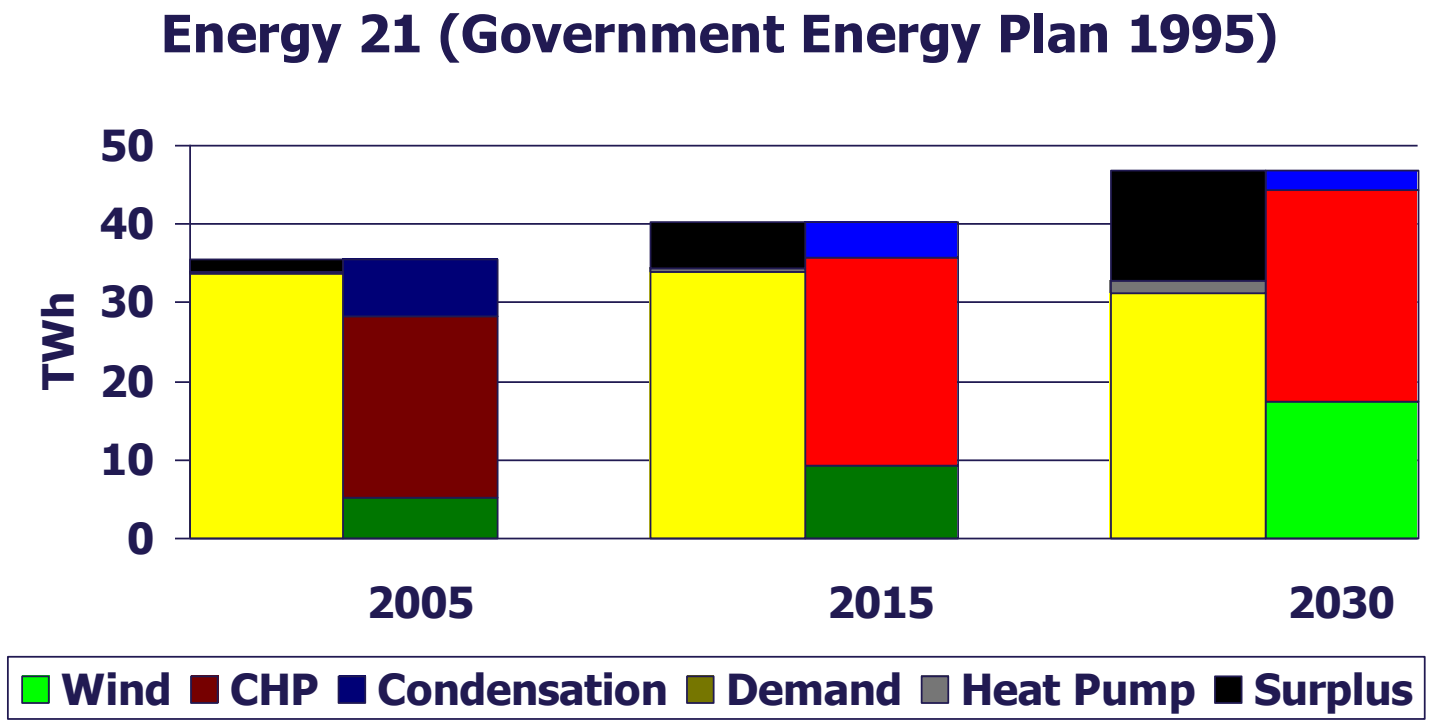
   Fuel savings vary during the season and from one hour to another due to varying system impacts

3. ***The 100% renewable energy phase***

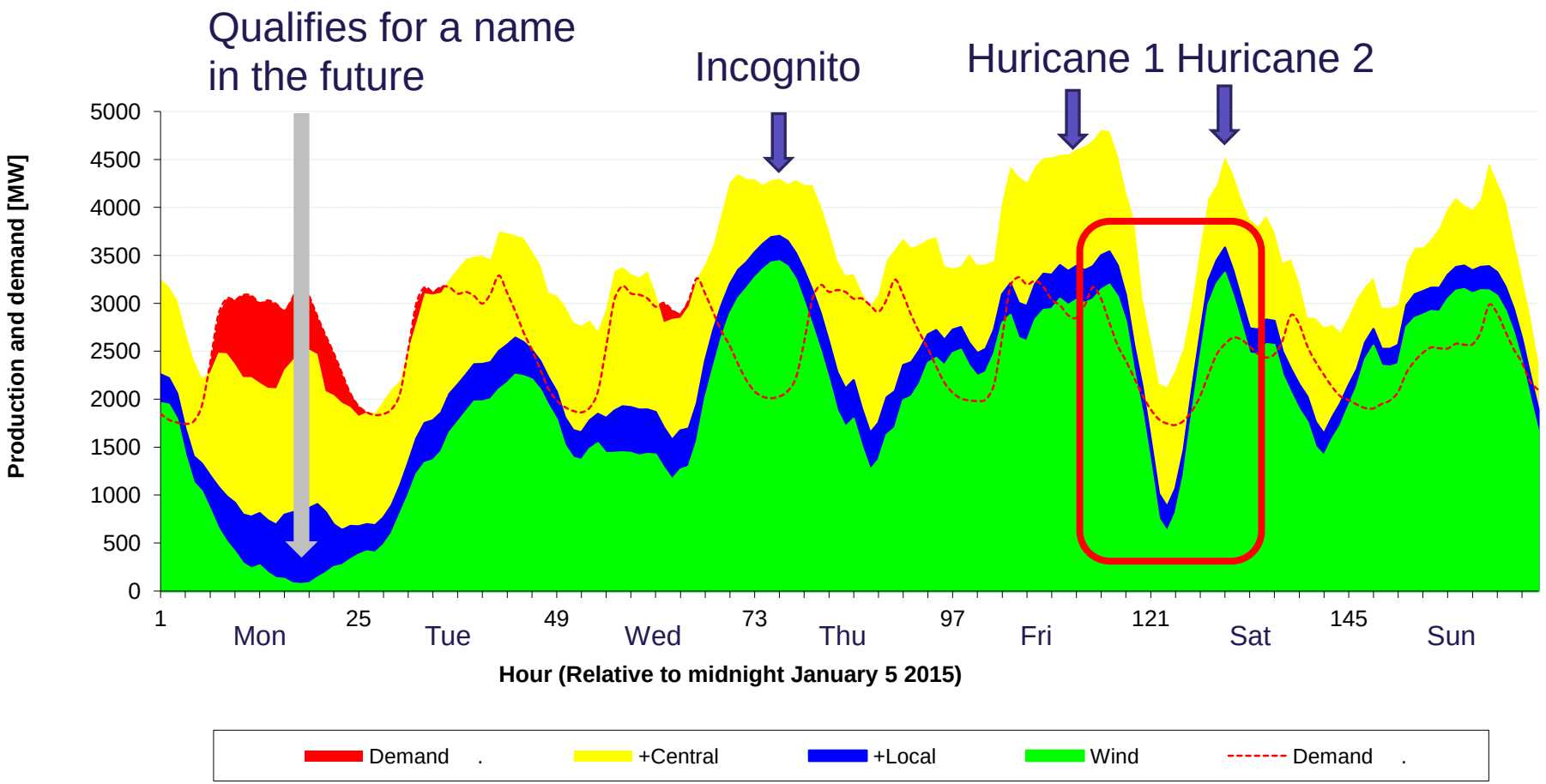
   Focus on different renewable energy sources and their ability to be integrated with savings, efficiencies and energy demands.

In general – increasing complexity and integration

Reference excess production



A week in Western Denmark in 2015



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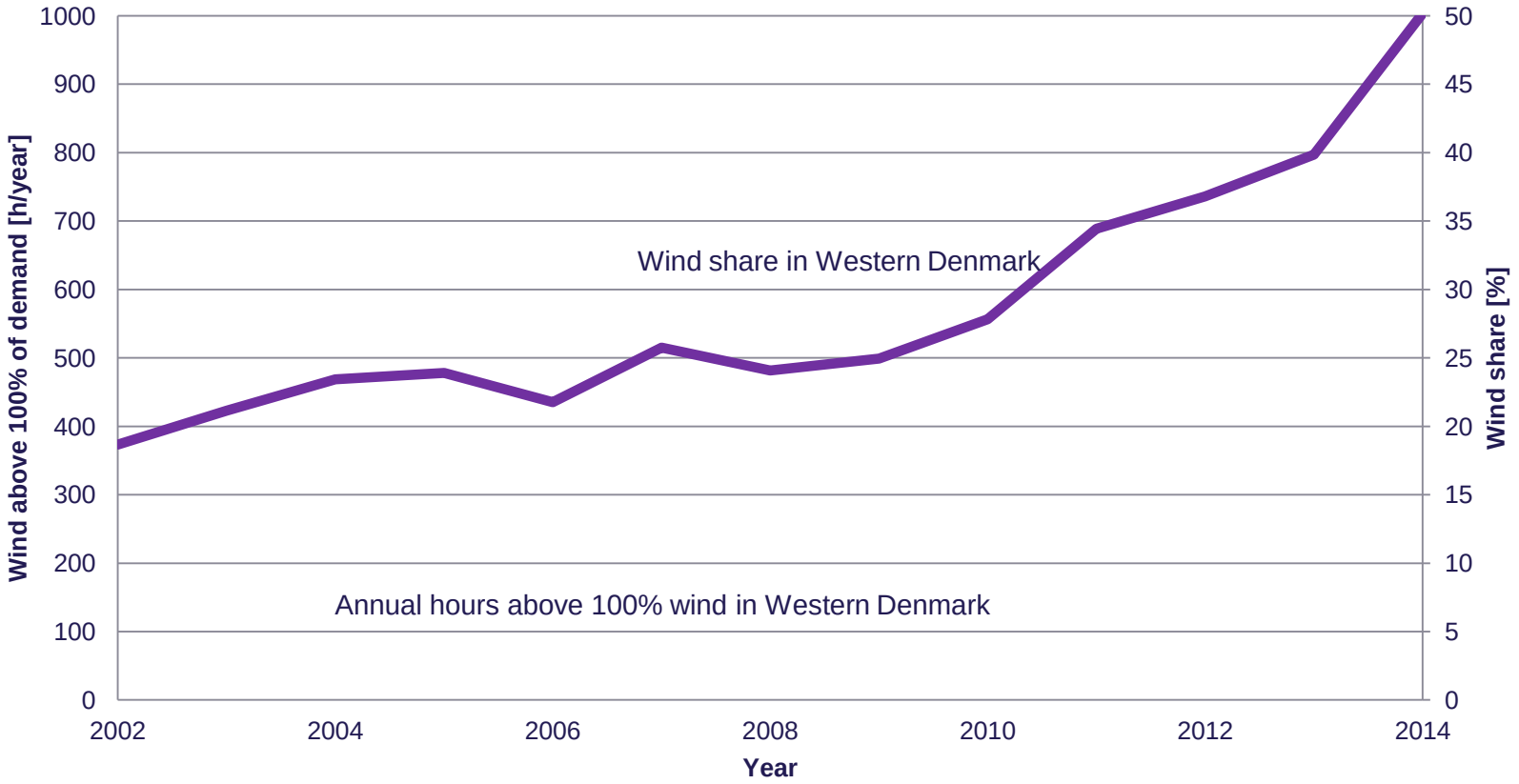
The issue of excess power generation



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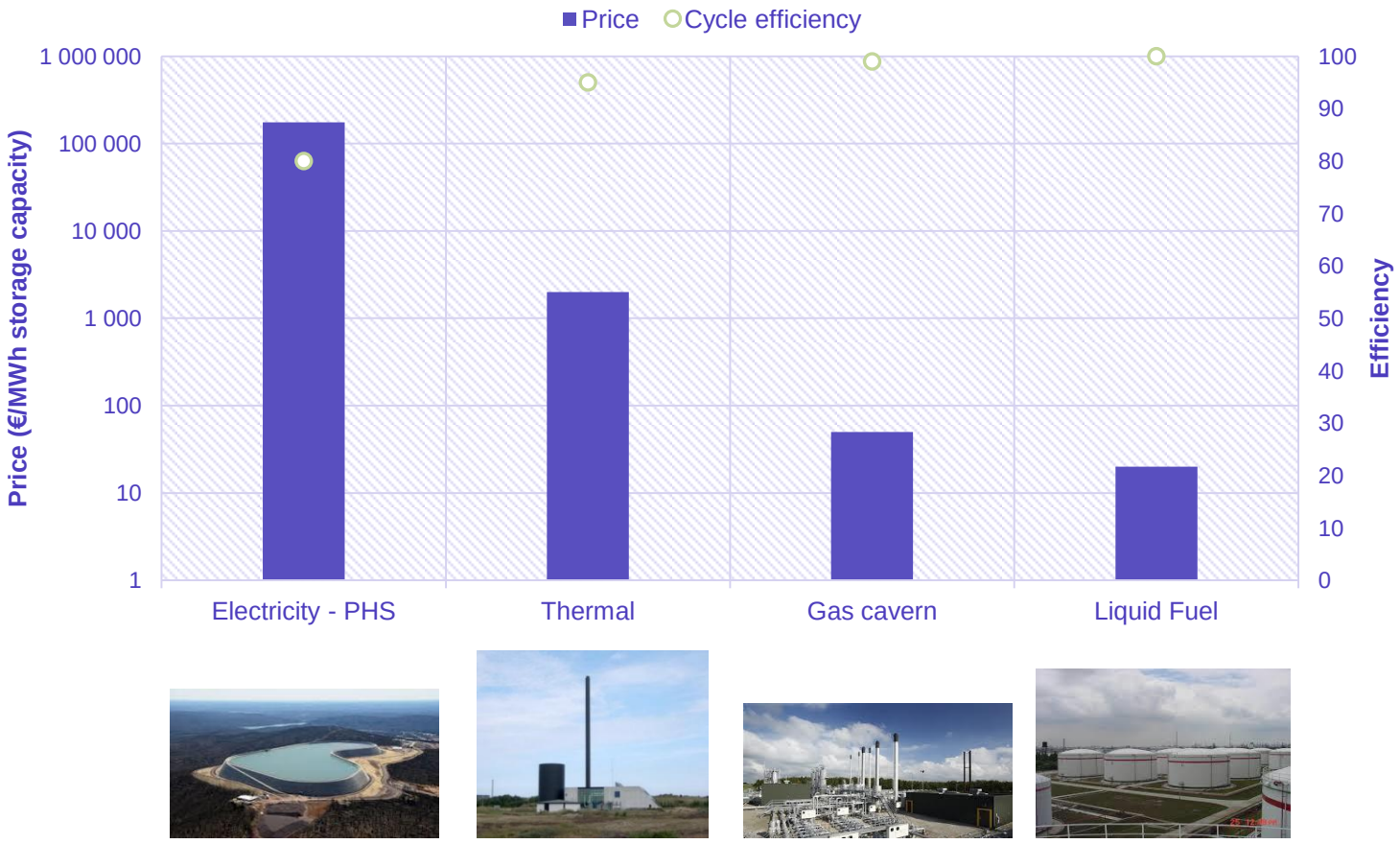
Large-scale RE integration requires sector integration



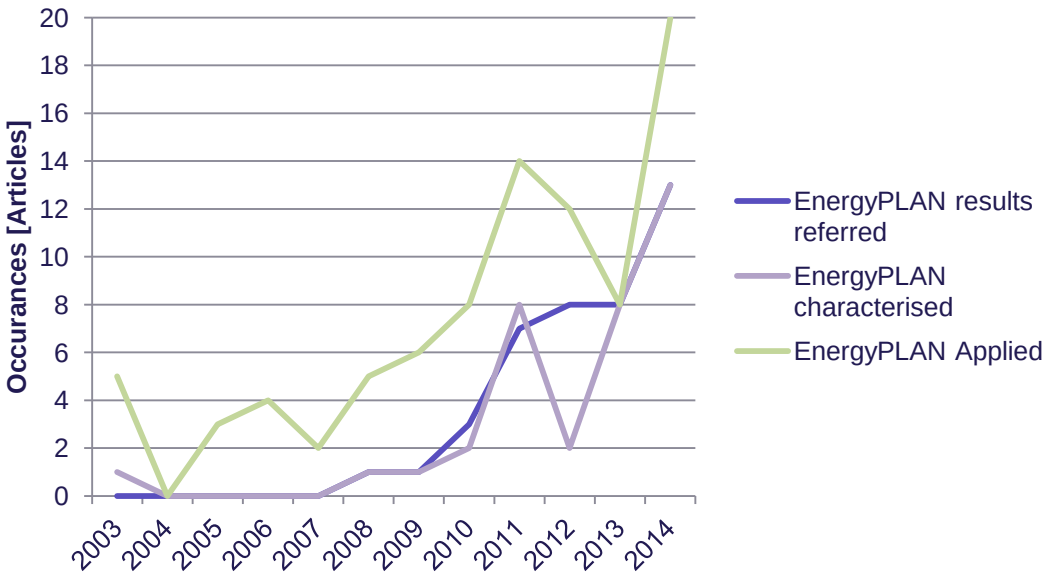
Source: dx.doi.org/10.5278/ijsepm.2016.11.2

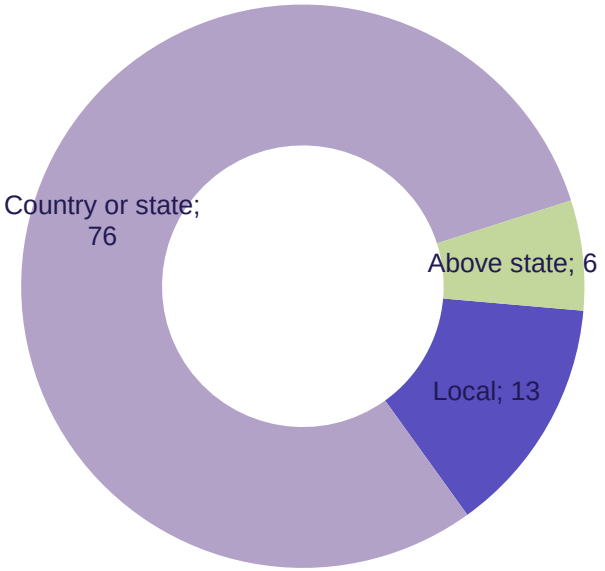
The role of energy system simulation and analysis

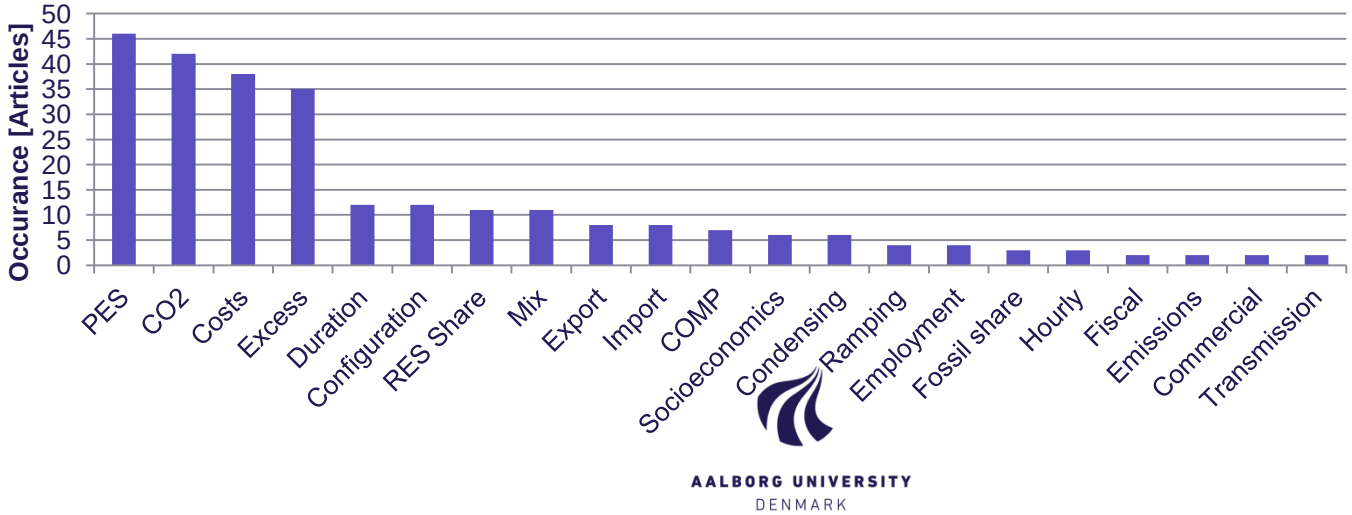
- The higher the complexity, the higher the demands for simulation and analysis
- The integration of high shares of renewable requires integration across electricity, heating, cooling, transportation and industry
- Different tools to assist in this process – however they vary in scope, temporal resolution, methodology and more

- One model that has been applied in a number of projects is the EnergyPLAN model, which has been influential on the development of the EU policy on district heating and cooling through a series of Heat Roadmap Europe projects

Application of EnergyPLAN in the academic literature







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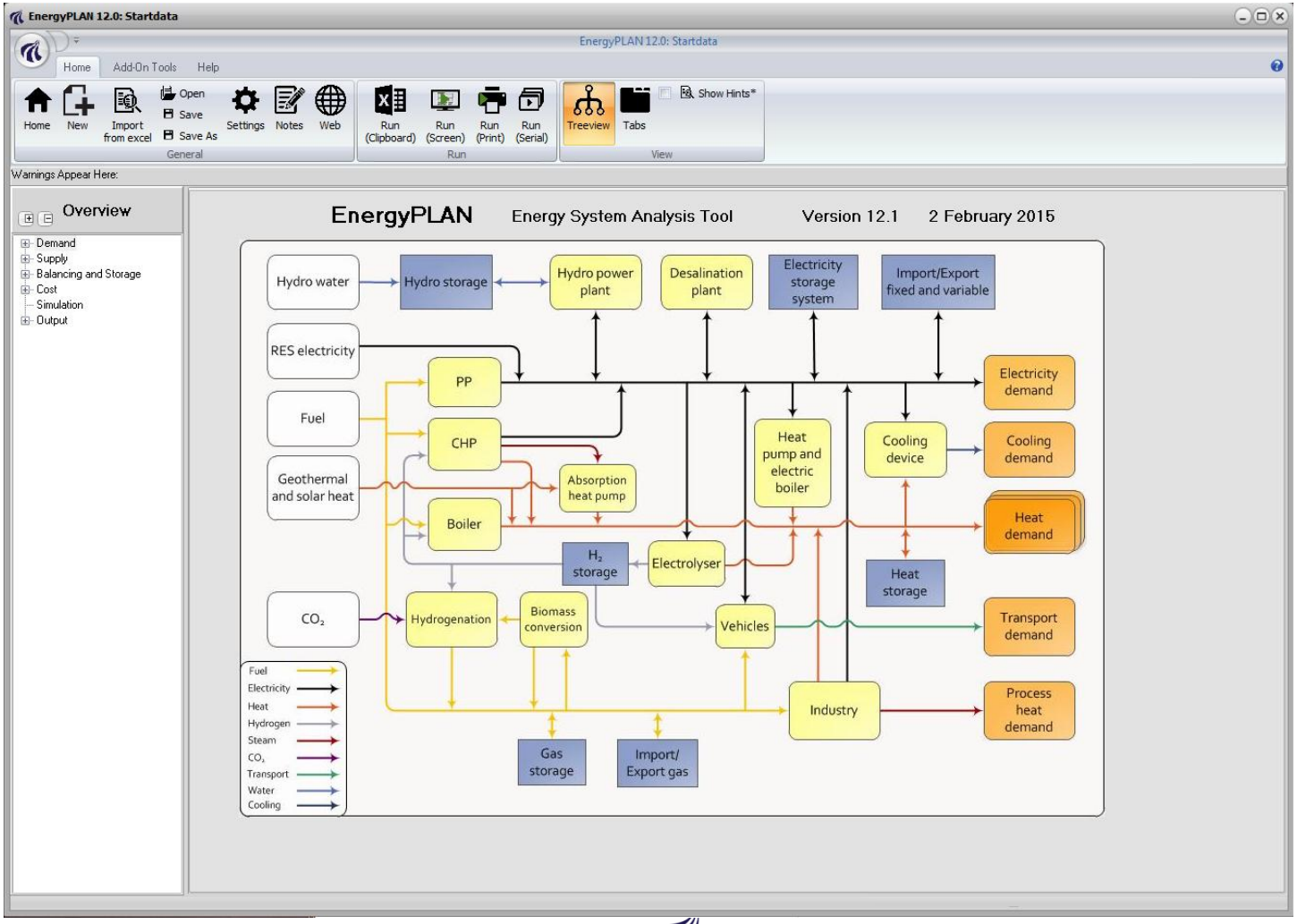
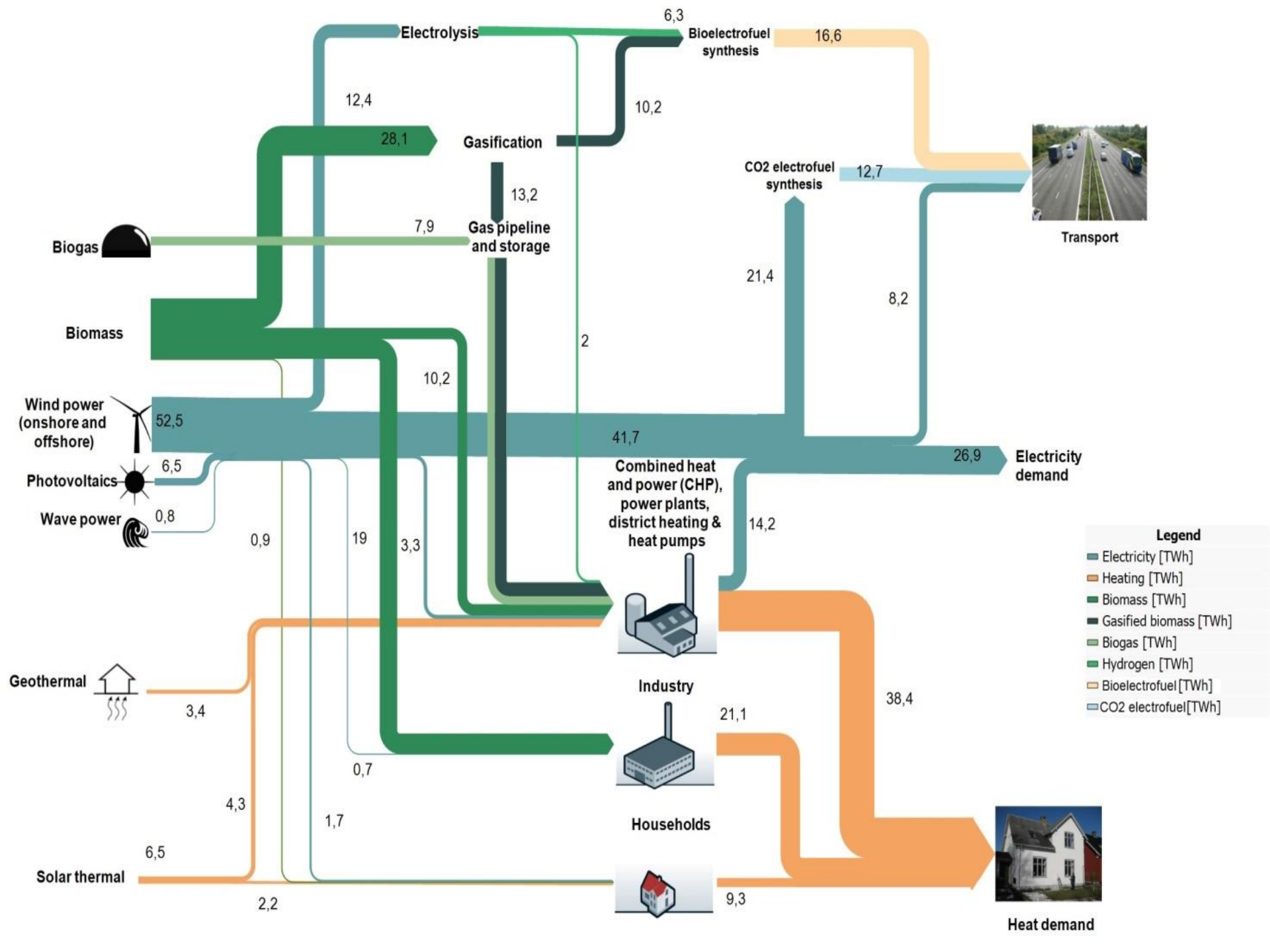
Main characteristics of the EnergyPLAN model

- Holistic
  - encompassing all sectors
  - focus on sectors and technologies with connections
- Aggregated
  - All technologies are typically represented by one unit
  - All technologies of a given kind thus share key-parameters such as efficiency
- Hourly on a yearly basis (leap year)
- Technical or economic optimisation
- Analytically programmed
  - Endogenous priorities and analytical procedures to optimise operation
- Fast
  - Computation time measured in seconds
  - Fast interaction with the user

Evolution of EnergyPLAN - Present version (12)




Electrolysis
6,3
Bioelectrofuel synthesis
16,6
12,4
10,2
28,1
Gasification
CO2 electrofuel synthesis
12,7
13,2
Biogas
7,9
Gas pipeline and storage
Transport
21,4
8,2
Biomass
2
10,2
Wind power (onshore and offshore)
52,5
41,7
26,9
Electricity demand
Photovoltaics
6,5
Combined heat and power (CHP), power plants, district heating & heat pumps
Wave power
0,8
14,2
0,9
19
3,3
Legend
Electricity [TWh]
Heating [TWh]
Biomass [TWh]
Gasified biomass [TWh]
Biogas [TWh]
Hydrogen [TWh]
Bioelectrofuel [TWh]
CO2 electrofuel [TWh]
Geothermal
3,4
Industry
21,1
38,4
0,7
4,3
1,7
Households
6,5
Solar thermal
2,2
9,3
Heat demand

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TWO CASES OF POLICIES TO ASSIST THE ESTABLISHMENT OF WIND POWER AND CHP

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Case: Wind power in Denmark

Initial conditions

- 30% investment subsidy
- Utility obligation to buy wind power at a price equal to 85% of a 20000 kWh/year consumer
- A right to produce up to 7000 kWh wind power without income tax payment
- Establishment of a public wind power research centre at Risø
- Surplus capacity in the industry looking for new areas
- A motivated population
- Wind power co-operatives

Case: CHP in Denmark

- Low interest loans were made available in the mid-eighties
- The establishment of a consumer-owned CHP DH co-operative was consistent with Danish traditions
- In 1988 a specific and publicly open set of rules for the pricing of natural gas for CHP was set up
- In 1989 a law was introduced obliging the municipalities to guarantee the loans
- At the end of 1988 standard payment rules based on the **long term** marginal costs were introduced
- In 1991 a standard set of rules concerning costs associated with grid expansion was agreed upon
- In addition to the above mentioned prices came a 0.1 DKR/kWh "CO_2-10 øre" introduced in 1993 (=4 Florint)

Case: CHP in Denmark

In Sønderholm, there was an active five-person ginger group that

- was willing and able to analyse technical alternatives, negotiated with electricity companies and arrange public meetings. They secured the support of 84 of the houses
- It was possible to work out a solution where the consumers were to raise less funds than if they did not join the co-operative. They only had to pay 100 DKK to become members

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