Modelling tools for energy planning and energy system integration

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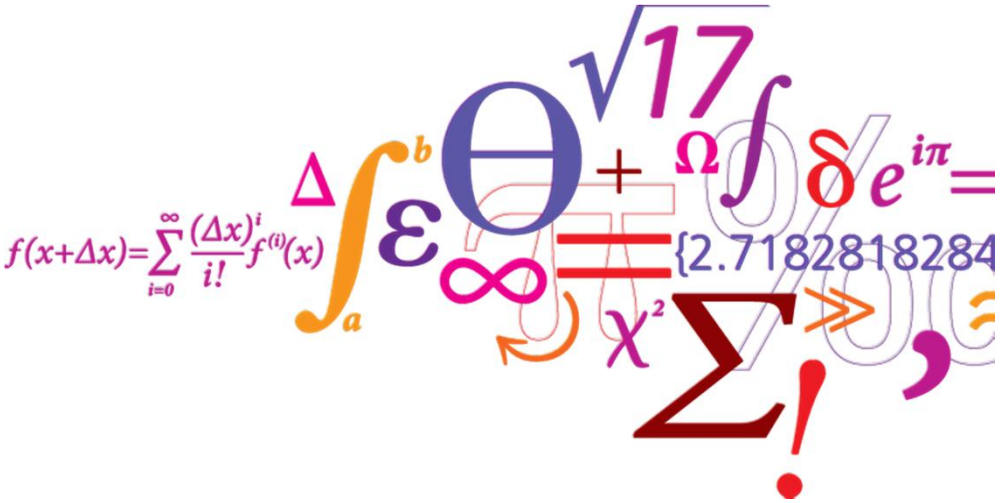

DTU Management Engineering
Department of Management Engineering

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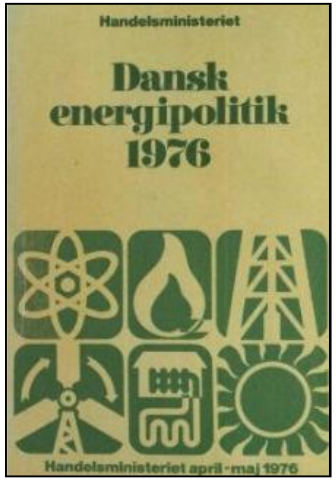
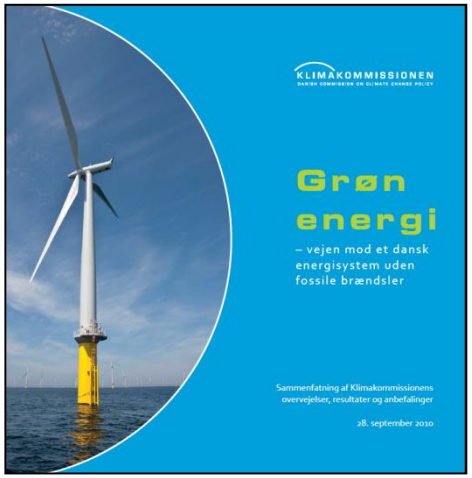
Technical University of Denmark (DTU)

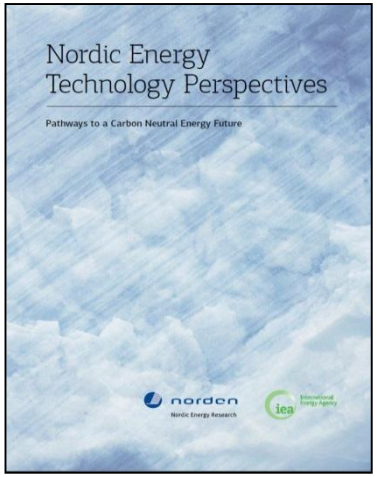
- 5 832 staff, 10 631 students, 1 406 PhD students
- My division: Systems Analysis at Management Engineering dep.
  - 30+ years experience in energy systems modelling and economic assessment of energy technologies
  - working for Danish authorities on forecasts and planning of the energy system, development of energy markets and response to climate change
  - international network: IPCC, EERA, EU Research Programmes, Climate-KIC, Nordic collaboration

What is energy planning?

- Process of developing future energy system setup and policies, focusing on: sustainability, resilience, flexibility, efficiency, affordability etc.
- Incorporates: energy policy, energy economics, engineering, social science
- Energy system modelling allows developing techno-economic scenarios for energy planning facilitation

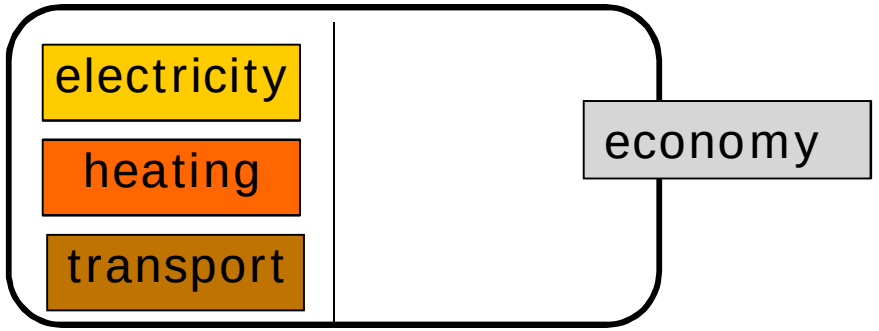






Energy system models

Energy flows in an energy system model



partial equilibrium

Utilize:

- mathematical programming
- engineering process analysis
- econometrics

Can be used to analyse energy system integration

Selected modelling tools

Balmorel

iea Energy Technology Network ETSAP TIMES

TIMES-DK

Energy PLAN

Sifre

energyPRO

Developers and users

	Developers and users
Balmorel	DTU, Danish Energy Association, China National Renewable Energy Centre
EnergyPLAN	Aalborg University, PlanEnergi
energyPRO	EMD, Danish district heating companies
Sifre	Danish TSO Energinet.dk and external collaborators, e.g. DTU
TIMES-DK	DTU, Danish Energy Agency

Sectoral representation and issues solved

	Sectoral representation	E.g. issues solved
Balmorel	Electricity + heat (+ EVs)	Electricity markets; expansion of DH
EnergyPLAN	Electricity+heat+transport	100% RES energy systems; energy storage
energyPRO	Flexible: electricity + heat, (transport as "energy plant“)	CHP plants on the spot market; compressed-air energy storage
Sifre	Electricity+heat+transport+gas	Electrolysis and biomass conversion in Sønderborg, Denmark
TIMES-DK	Electricity+heat+transport	Renewables in heating/cooling systems in 6 EU countries

Implementation and optimization

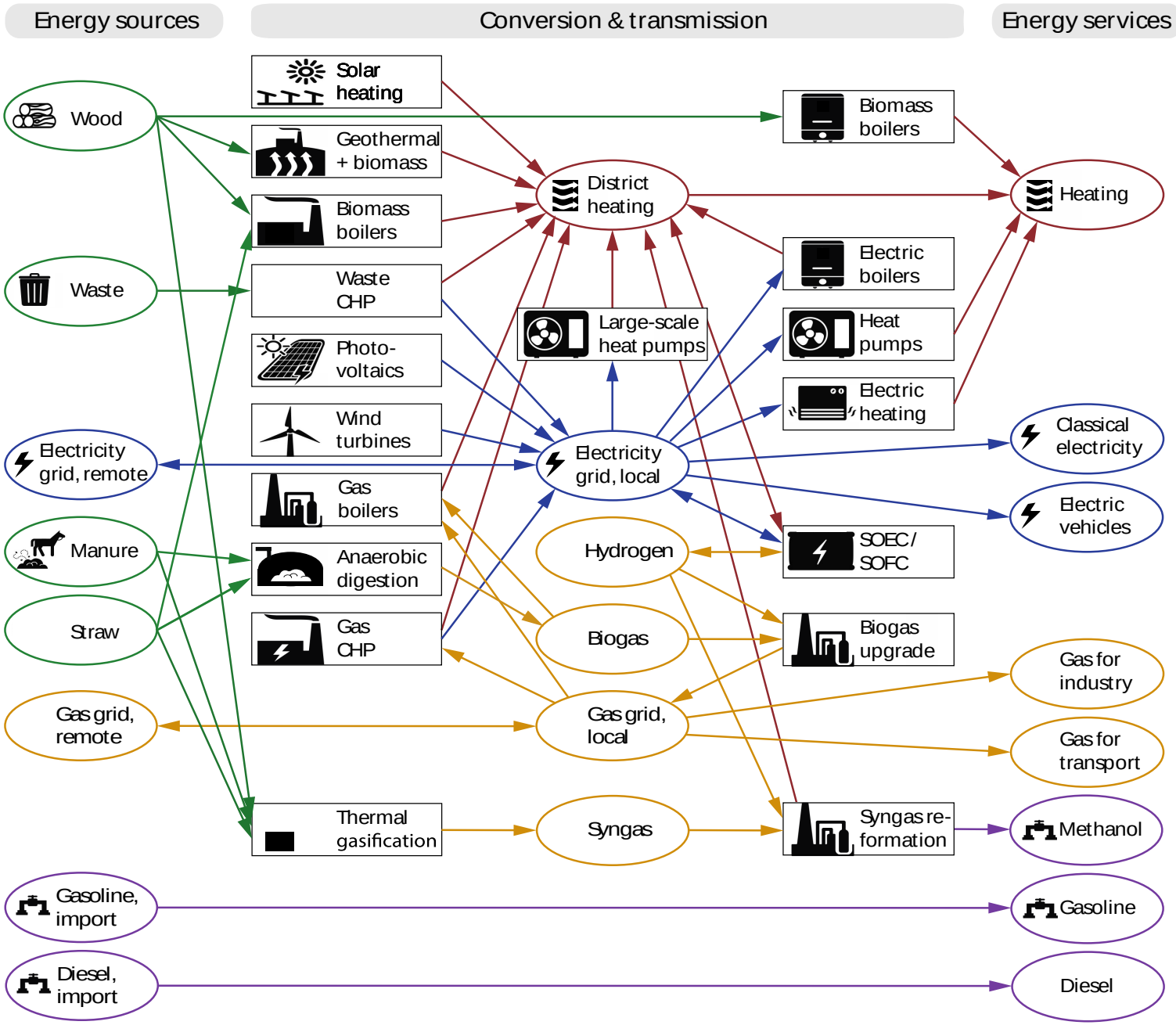
	Implementation	Optimization type
Balmorel	Linear Programming in GAMS, solvers e.g. CPLEX	Total cost minimization
EnergyPLAN	Delphi Pascal	Operation cost minimization; technical or market-economic simulation
energyPRO	Delphi	User-defined or auto-calculated operation strategy
Sifre	Mixed Integer Linear Programming in C#	Operation cost minimization
TIMES-DK	GAMS programming, VEDA front- and back-end, Excel	Total cost minimization

Geographical and temporal representation

	Geographical representation	Temporal representation
Balmorel	Flexible; regions and areas	Hourly over a year - can be aggregated
EnergyPLAN	Flexible	Hourly over a year
energyPRO	Flexible	Calculation steps:10-30 min, 1h; optimisation period: month or year
Sifre	Flexible	Hourly over a year
TIMES-DK	Flexible	32 time slices: depending on availability, demand profiles, electricity import/export

Case study: Sønderborg, Denmark

- Tool: Sifre
- Electricity, heat and transport (as energy service)
- Year 2029, hourly resolution
- RQ: How can Sønderborg become a low-CO_2 emitting municipality in 2029 in an energy efficient and cost-effective way, while limiting biomass use to locally available resources
- Energy system integration:
  - conversion technologies: large-scale heat pumps, biogas production and methanation, thermal gasification, electrolysis and transport fuel synthesis
  - comparison of: total system socio-economic costs, CO_2 emissions, biomass consumption and energy conversion efficiency


Energy sources
Conversion & transmission
Energy services
Wood
Waste
Electricity grid, remote
Manure
Straw
Gas grid, remote
Gasoline, import
Diesel, import
Solar heating
Geothermal + biomass
Biomass boilers
Waste CHP
Photo-voltaics
Wind turbines
Gas boilers
Anaerobic digestion
Gas CHP
Thermal gasification
District heating
Large-scale heat pumps
Electricity grid, local
Hydrogen
Biogas
Gas grid, local
Syngas
Biomass boilers
Electric boilers
Heat pumps
Electric heating
SOEC / SOFC
Biogas upgrade
Syngas re-formation
Heating
Classical electricity
Electric vehicles
Gas for industry
Gas for transport
Methanol
Gasoline
Diesel

Challenges of energy system models

- Demand side optimization rarely modelled (usually by manually changing the demand and analyzing the resulting impact)

- Accounting for air pollution other than CO_2: e.g. particulate matter from biomass

- Global optimization
  - one-way direction: but how to represent and "optimize" prosumers?
  - behaviour: how to model people's choices?

- Developing and soft-linking agent-based models with energy system models?

Summary

- Energy system modelling allows developing techno-economic scenarios for energy planning facilitation

- Main differences:
  - Balmorel and TIMES-DK are investment and operation optimization tools; Sifre, energyPRO and EnergyPLAN are operation optimization tools
  - Various sectoral and technology representation

- Hourly time series suitable for modelling flexibility (intermittent renewables, thermal storage)

- Energy models/modelling tools
  - all are flexible enough for many applications
  - each has its strengths and weaknesses = some more suitable for selected research questions than others

Summary (2)

- Main challenges
  - accounting for demand side flexibility
  - modelling more air pollution types
  - quantifying and modelling people's behavior

- Developing and soft-linking agent-based models with energy system models?

Thank you for your attention!

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