PLANNING TOOLS FOR INTEGRATED ENERGY SYSTEMS

New energy paradigms,

modelling challenges &

personal endeavours

Steve Heinen

CITIES consortium meeting

24th-25th May 2016

Energy planning using mathematical models

Energy planning provides insights on

- Infrastructure (Investment, technology development) and
- Strategy (political alliances, policy and business development, public awareness-building, education)

"Future-now thinking" RAND Corporation

"Planning is bringing the future into the present so that you can do something about it now." Alan Lakein

Mathematical modelling is a tool

- Decision-making support to identify planning challenges and find solutions
- Analytical tool to support human judgement, which is biased and not just driven by logic

"The purpose of computing is insight, not numbers." Richard Hamming

"We're generally overconfident in our opinions and our impressions and judgments." Daniel Kahneman

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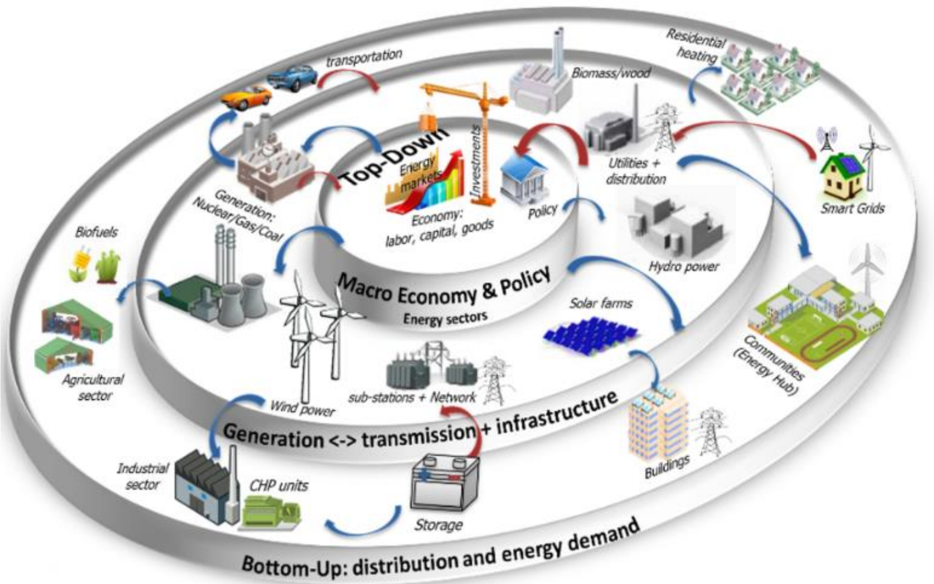
NEW ENERGY PARADIGMS DRIVING DEVELOPMENT OF ENERGY PLANNING TOOLS

New paradigms integrate the energy system across fuels, scales and layers



Flexible demand and consumer participation enabled by ICT technologies and distributed generation

Active demand

Electrification of demand side (heat and transport and penetration of variable renewables

Temporal detail

Distributed resources, renewable resource potential and networks (electricity, heat, biogas)

Spatial detail

Rapid tech innovation, market liberalisation and regulation

Uncertainty

Unlike detailed sector-specific models, an integrated model captures couplings and interactions and, if those are significant, it reveals integration challenges and opportunities

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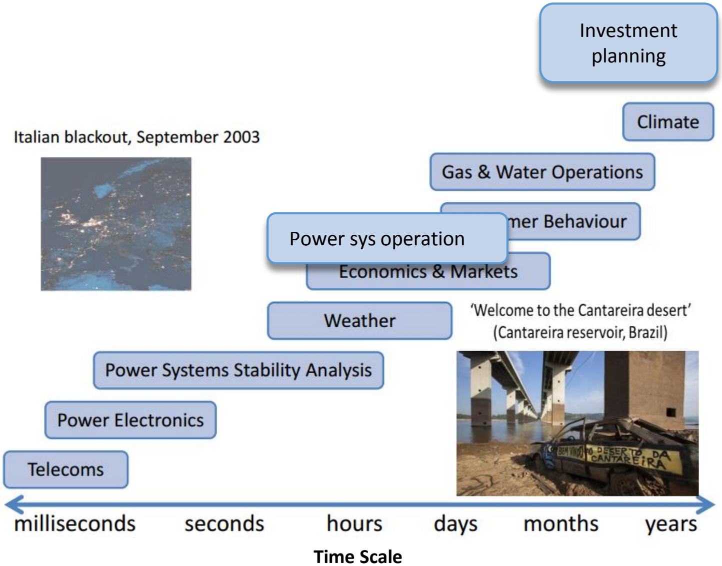
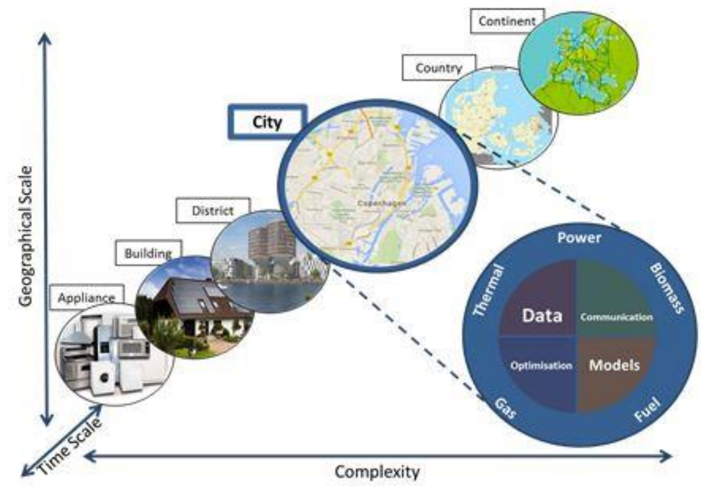
Modelling challenge:
Resolve temporal and spatial resolutions





Temporal resolution **Spatial resolution**

Interdependencies between scales and layers impact planning

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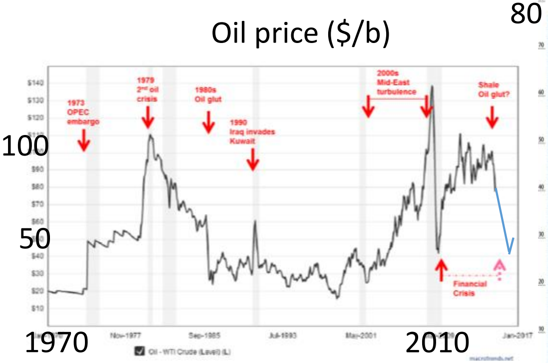
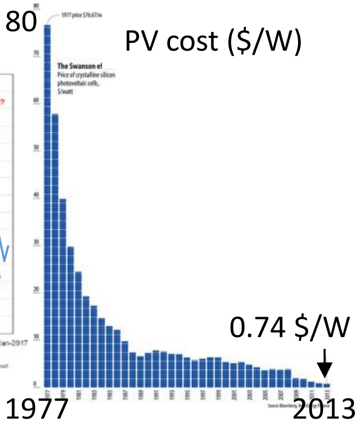
Modelling challenge
…and long-term planning uncertainties

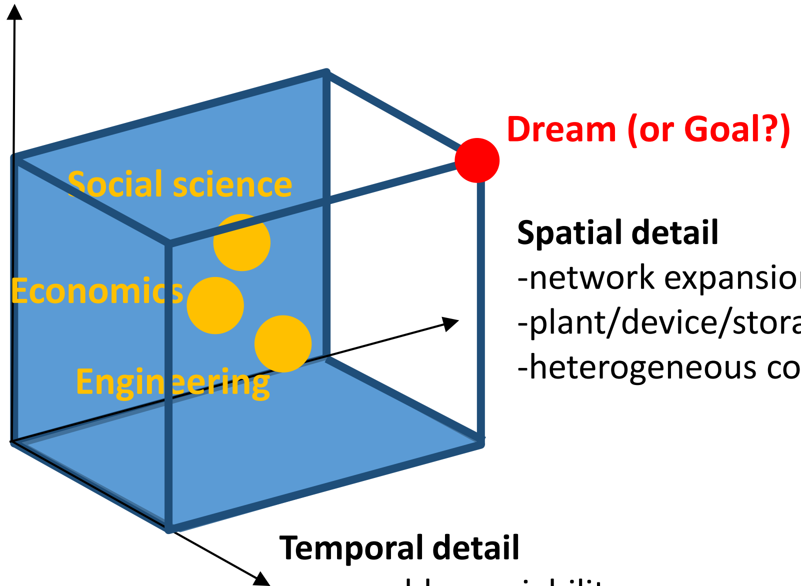
- Policy and regulation
  - Technology-specific grant
  - Feed-in tariffs
  - Market design
- Population growth and lifestyle
- Economic development
- Geopolitics
- Fuel prices
- Carbon prices
- Technology development
- Technology acceptability
- Climate





The modelling trilemma

Long-term uncertainty
-fuel prices
-policies
-public acceptability
-technology development



Spatial detail
-network expansion
-plant/device/storage location
-heterogeneous consumer

Temporal detail
-renewables variability
-demand variability

No model can cover it all, approximations needed
But approximations can only be made by understanding the details

"The art of being wise is the art of knowing what to overlook." William James

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Model categorisations

- **Simulation/forecasts →** predictive
  - EnergyPlan, LEAP, NEMS
  - Challenge: designing control variables
- **Optimization/scenarios →** normative
  - Investment planning/Capacity expansion: TIMES, Markal, Balmoral, Netplan, WASP
  - Operations planning: Plexos, WILMAR
  - Challenge: balancing model temporal and spatial resolution with data availability and computational tractability
- **Market/strategic stakeholder behaviour**
  - Agent-based models: EMCAS
  - Challenge: limited representation of physical energy system, computational tractability for larger systems

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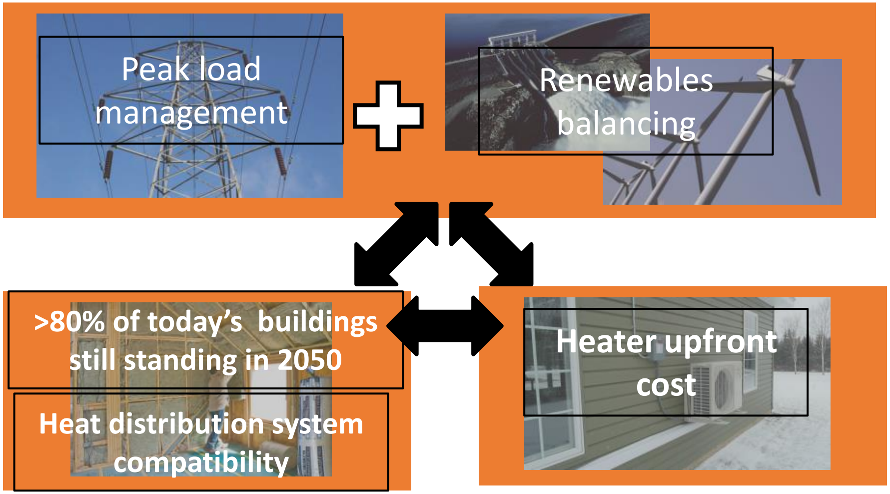
PERSONAL ENDEAVOURS

Scope: Electrifying heat in Irish domestic sector



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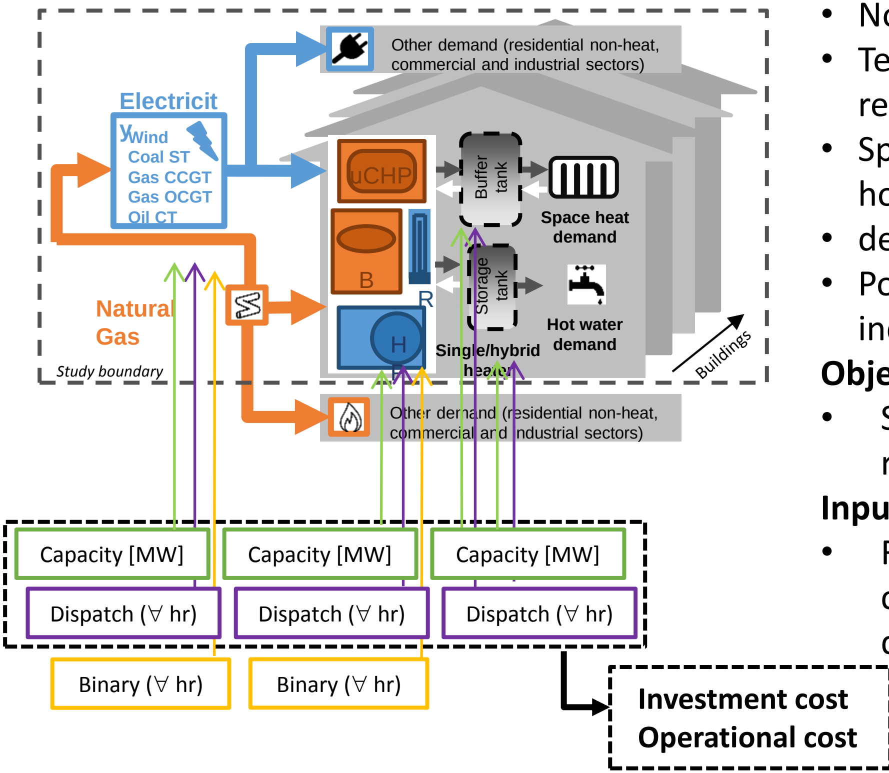
Model overview

Started off with simulation model (proof-of-principle) and grew into optimisation model…



Description:

- Planning stage: 1-stage
- Normative: Optimisation
- Temporal resolution: full hourly representation a year
- Spatial representation: representative houses using RC model
- deterministic or stochastic
- Power plants. Group dispatch (LP) or individual units (MILP)

Objective:

- System cost minimisation (or risk/CVaR minimisation)

Inputs:

- Fuel prices, technology characteristics and cost, demand data

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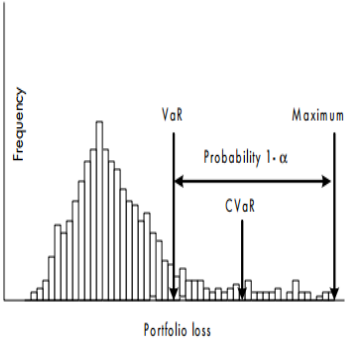
Capturing planning uncertainties

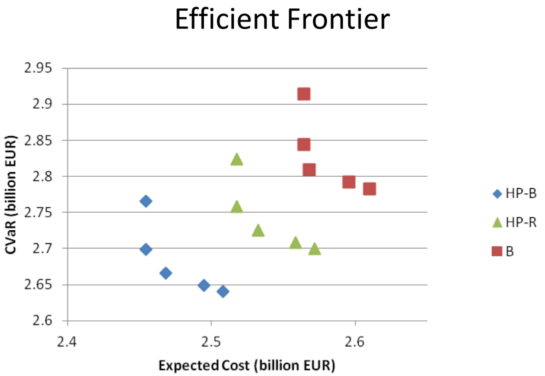
1. Deterministic. Vast number of scenarios

- Natural gas price (3x)
- Carbon price (3x)
- Domestic heat technology (6x)
- Heater investment cost (6x2)
- Thermal storage cost (2x)
- Building insulation (3x)
- Temperature and wind profile (2x2)

~15 000 scenarios

2. Stochastic. Optimising conditional value at risk for stochastic gas prices





Conditional VaR (CVaR)

- Represents downside risk and risk averseness of decision-makers (losses loom larger than gains)
- Convex (can be formulated as LP)

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Challenges for Energy System Planning as a discipline

- Availability and openness of code
  - Code may not be available in publications, which makes it difficult to compare to other results and guarantee reproducibility
- Data
  - Data used in a study may not be publically available or confidential for commercial reasons
- Validation
  - Establish test systems, benchmarking, Monte-Carlo simulations
- Modelling consumer behaviour
  - Consumer role is often too simplified.
  - Consumers are heterogeneous groups of active agents that do not behave fully rationally, but are driven by a variety of other emotional, social and circumstantial parameters.

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"Plans are useless, Planning is indispensable."

Dwight D. Eisenhower

Thank you for your attention

Thanks to Prof. Mark O'Malley
Supported by

- CITIES project, Denmark (Project Ref. 1305-00027B/DSF)
- Fonds National de la Recherche, Luxembourg (Project Ref. 6018454)

Fonds National de la Recherche Luxembourg

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Centre for IT Intelligent Energy Systems

Further reading

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