# THERMOS

## Accelerating the development of low-carbon heating & cooling networks

Energy system modelling concepts

Kamal Kuriyan, Imperial College

National Inspire Event, Aalborg, December 14, 2018

# Urban energy system model

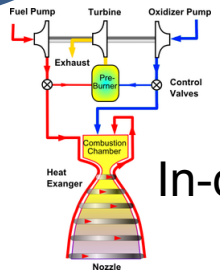
A formal system that represents the combined processes of acquiring and using energy to satisfy the energy service demands of a given urban area

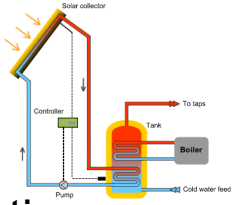
- Ex-urban processes for resource extraction, energy generation and transportation
- Associated costs and greenhouse gas emissions
- Potential processes for in-city energy generation and conversion
- Improve understanding of urban energy use.
- Analyse policy initiatives, infrastructure investments.

Ex-urban generation

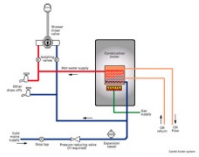
thermos-project.eu

Transportation

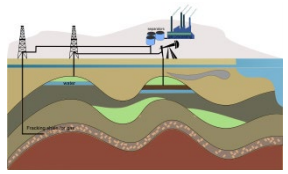



In-city generation



Extraction



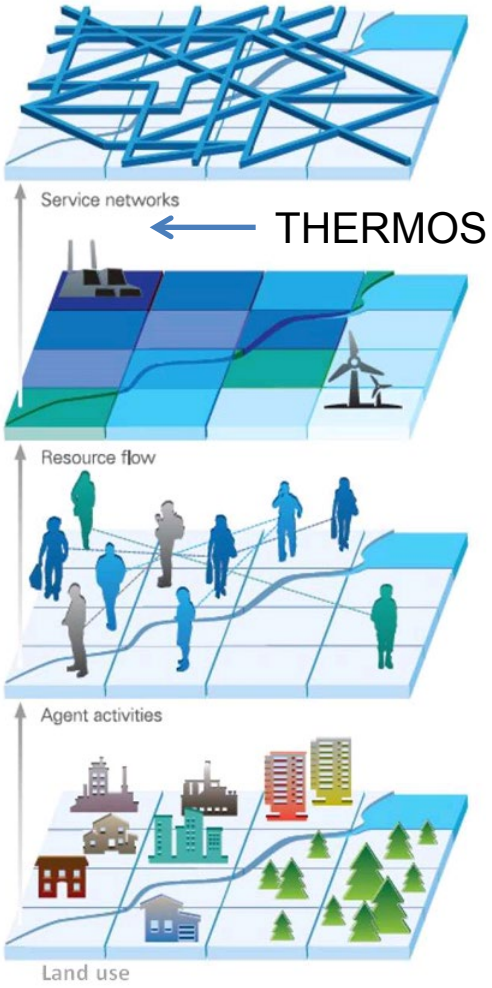
Transportation

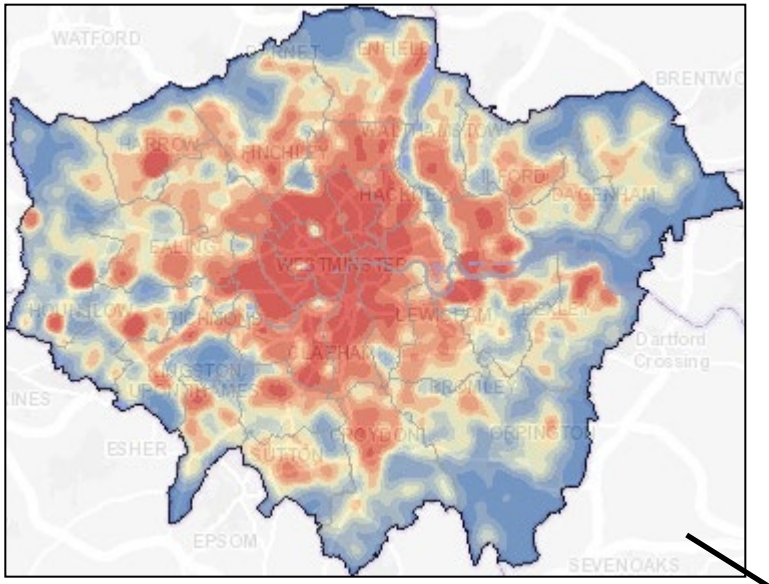
# Modelling complex systems

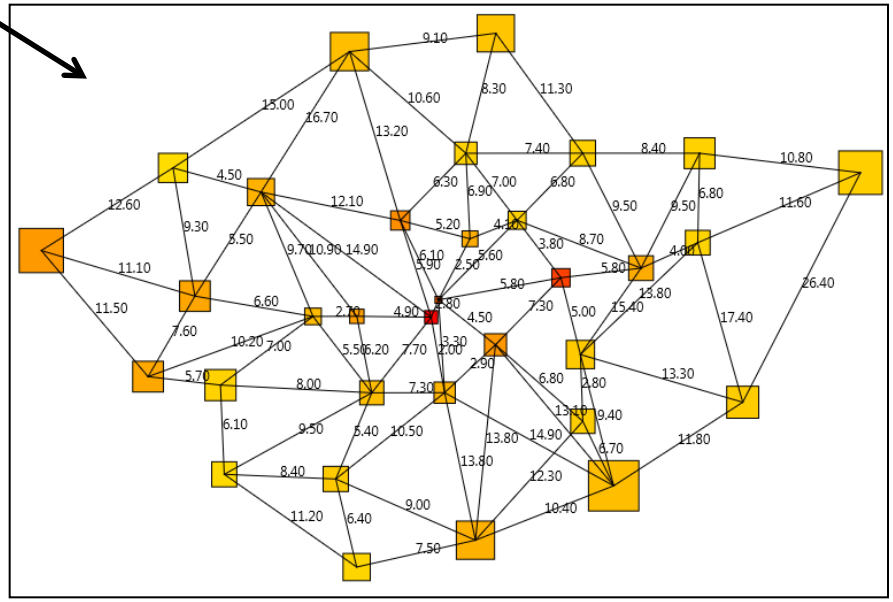
- Urban systems are complex systems
  - Decompose into sub-models
  - Include all relevant interactions between sub-models
  - Abstraction to create formal network-based models
  - Adjust level of detail to scale of model
    - City ↔ District ↔ Neighbourhood

# Sub-models for urban energy systems

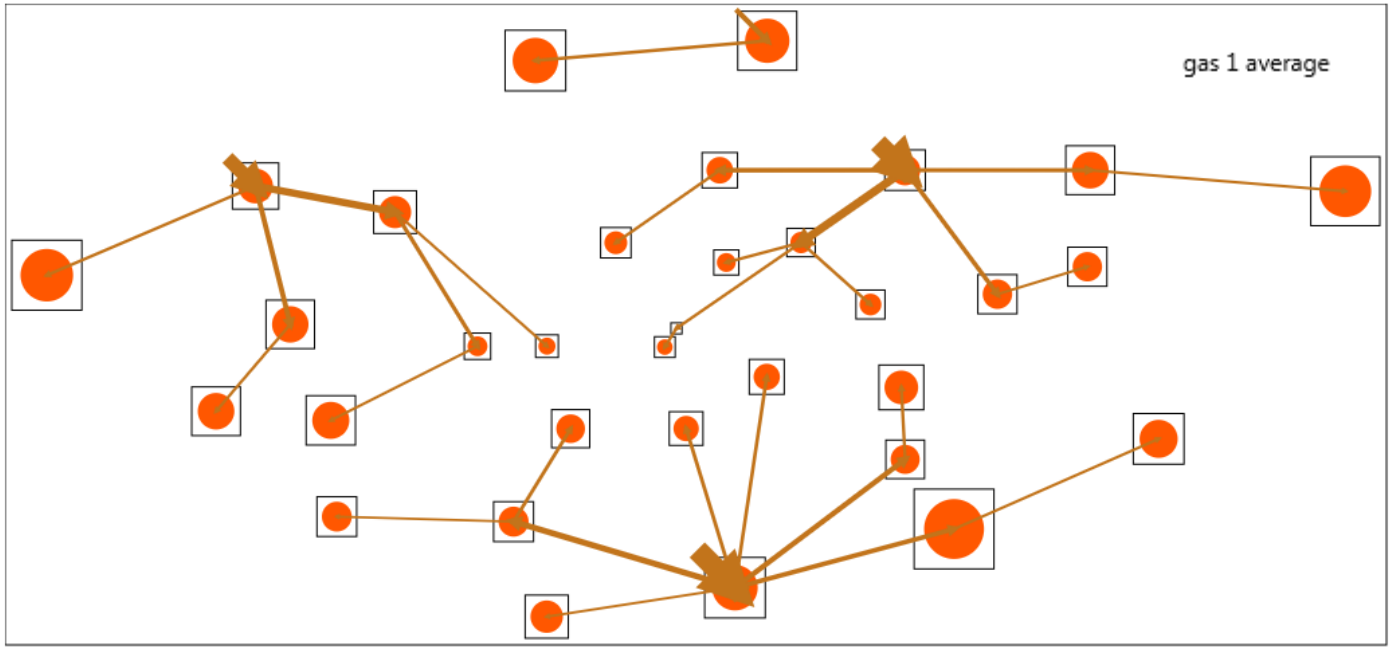
- Service network models
  - Networks to transport energy flows
- Multi-energy models
  - Flows of multiple resources
  - Heat, gas, electricity, biomass
  - Network interactions
- Behavioural models of agent activities
  - Impact of demographics, preferences, agent activities and movements on energy demands
- Land use models
  - Impact of building density, location, transport links on energy demands





Abstraction to create formal network model



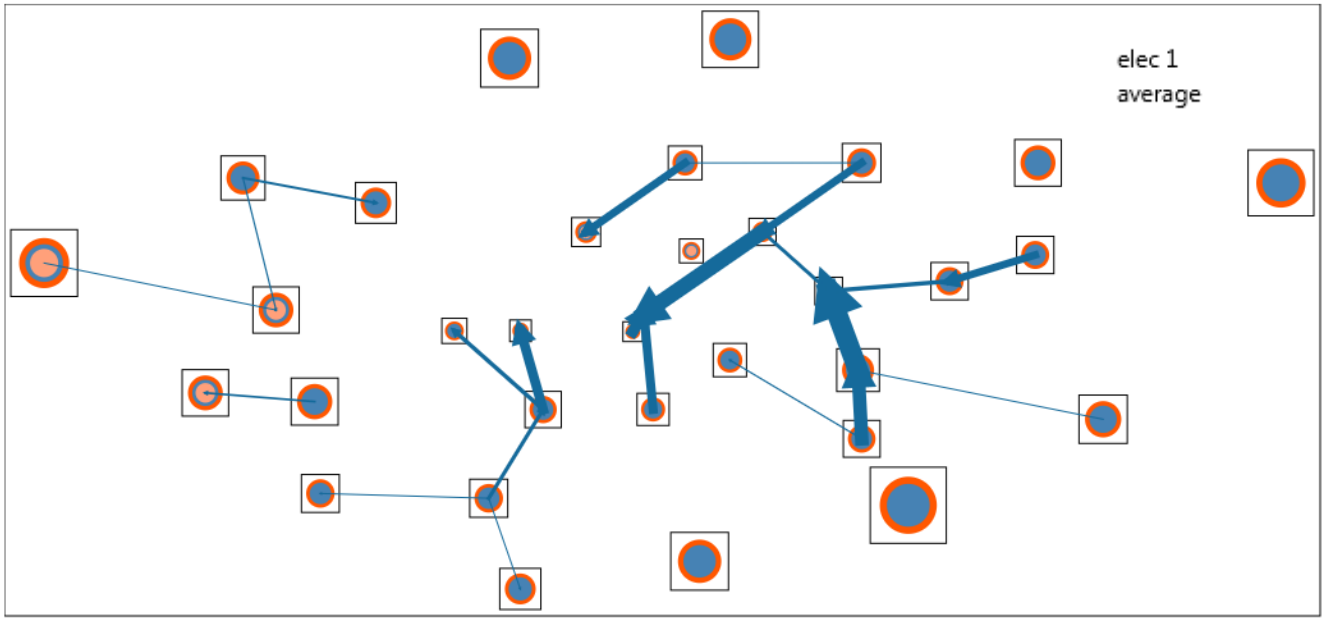

nos-project.eu

Gas import and distribution for CHP

eheater
large_chp
spaceGSHP-h
wind_med

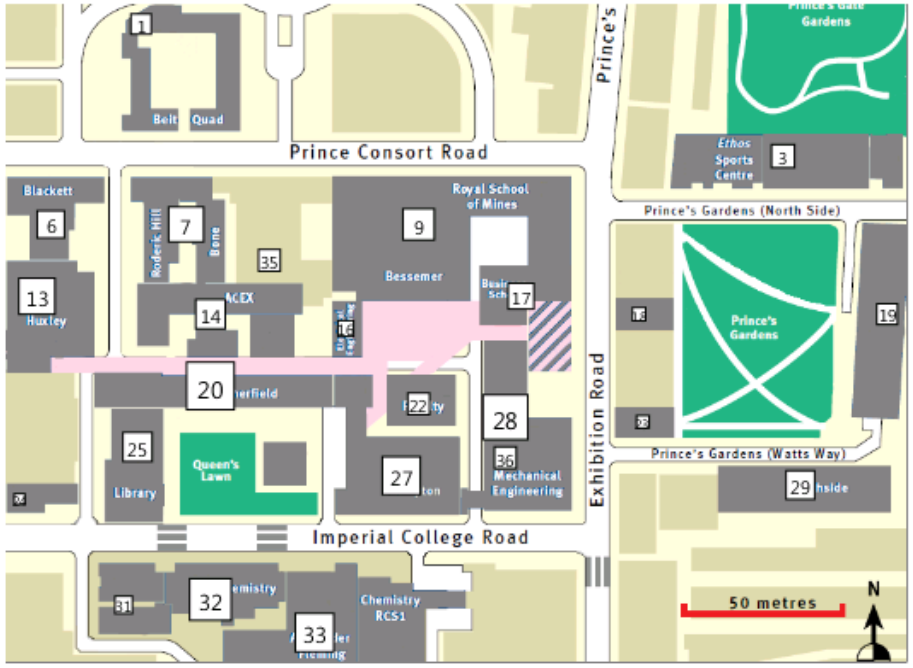
# Network interactions

Distribution of electricity generated locally

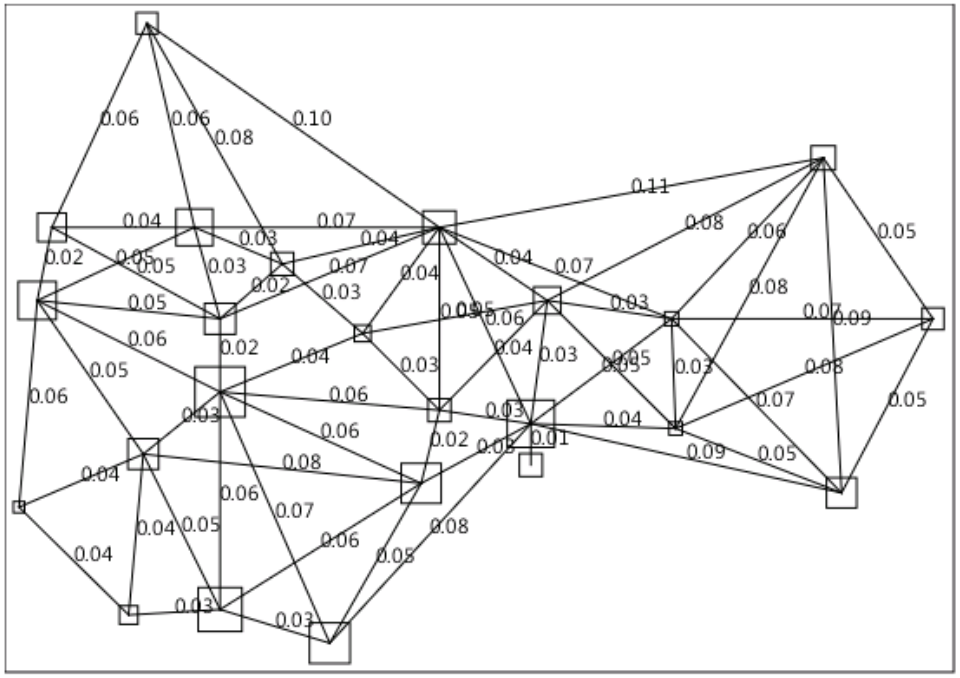


# Neighbourhood level model

Imperial College, South Kensington Campus




Grid cells



Network

# Systems methods and outcomes

- Holistic model with quantified metrics
  - Economics
  - Environmental impact
- Assessment of supply options
  - Renewables, poly-generation, heat-recovery, energy cascading
- Business models and policy options
  - Tariffs, rebates, emissions targets
  - Learning and technology improvement

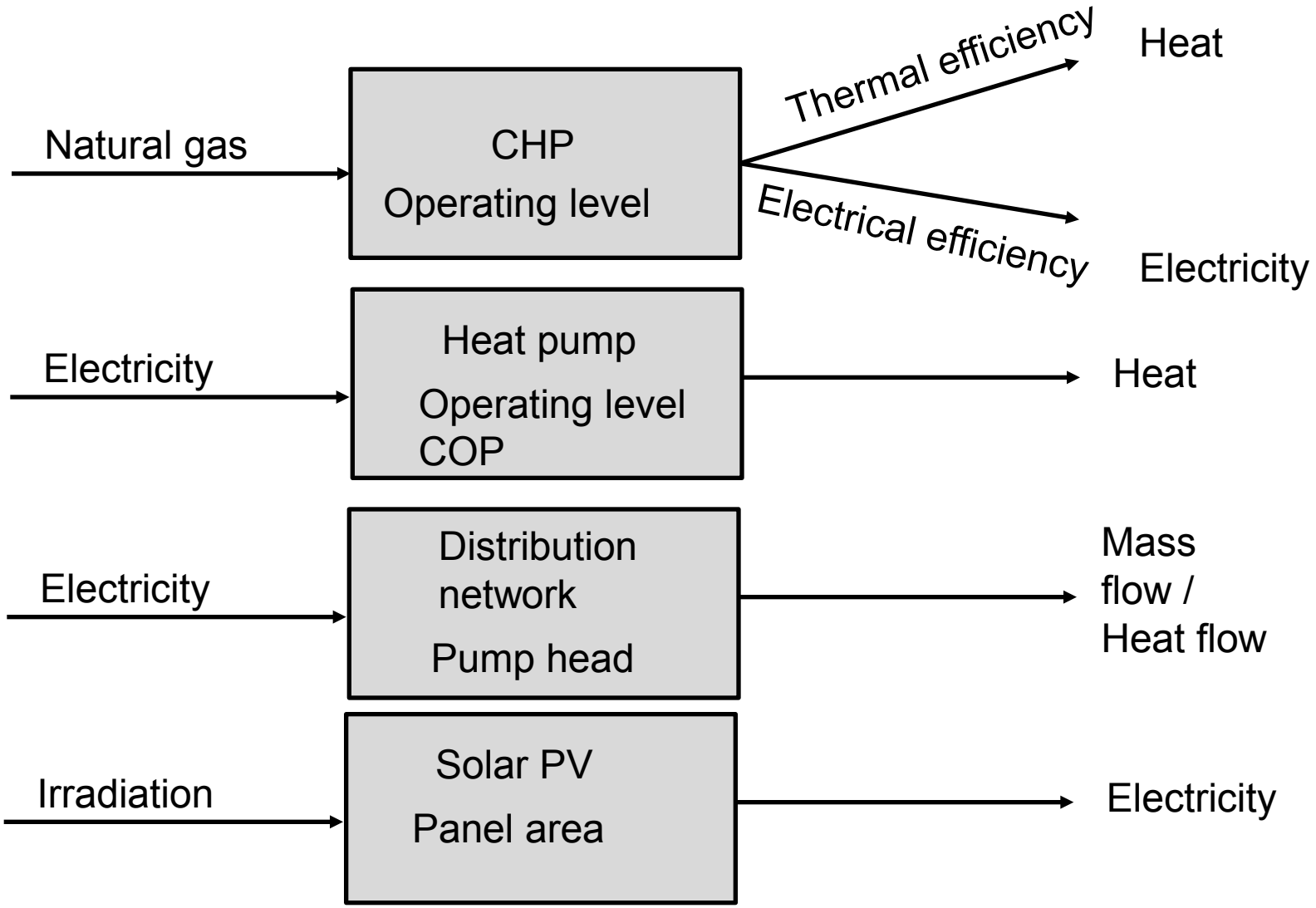
# Optimisation models

- Selection of technology type, scale, location
  - Large techs: Build out heat network from primary supply location
  - Small techs: Close to multiple demand locations
  - Emissions targets (biomass, renewables)
  - Combined heat, power, cooling
    - Electricity imports vs local generation
    - Revenues from electricity exports
    - Heat pump electricity requirements
- Ensure feasibility
  - Sufficient generation and transport capacity, emissions targets
- Performance metrics
  - Operating costs, carbon costs, investment costs

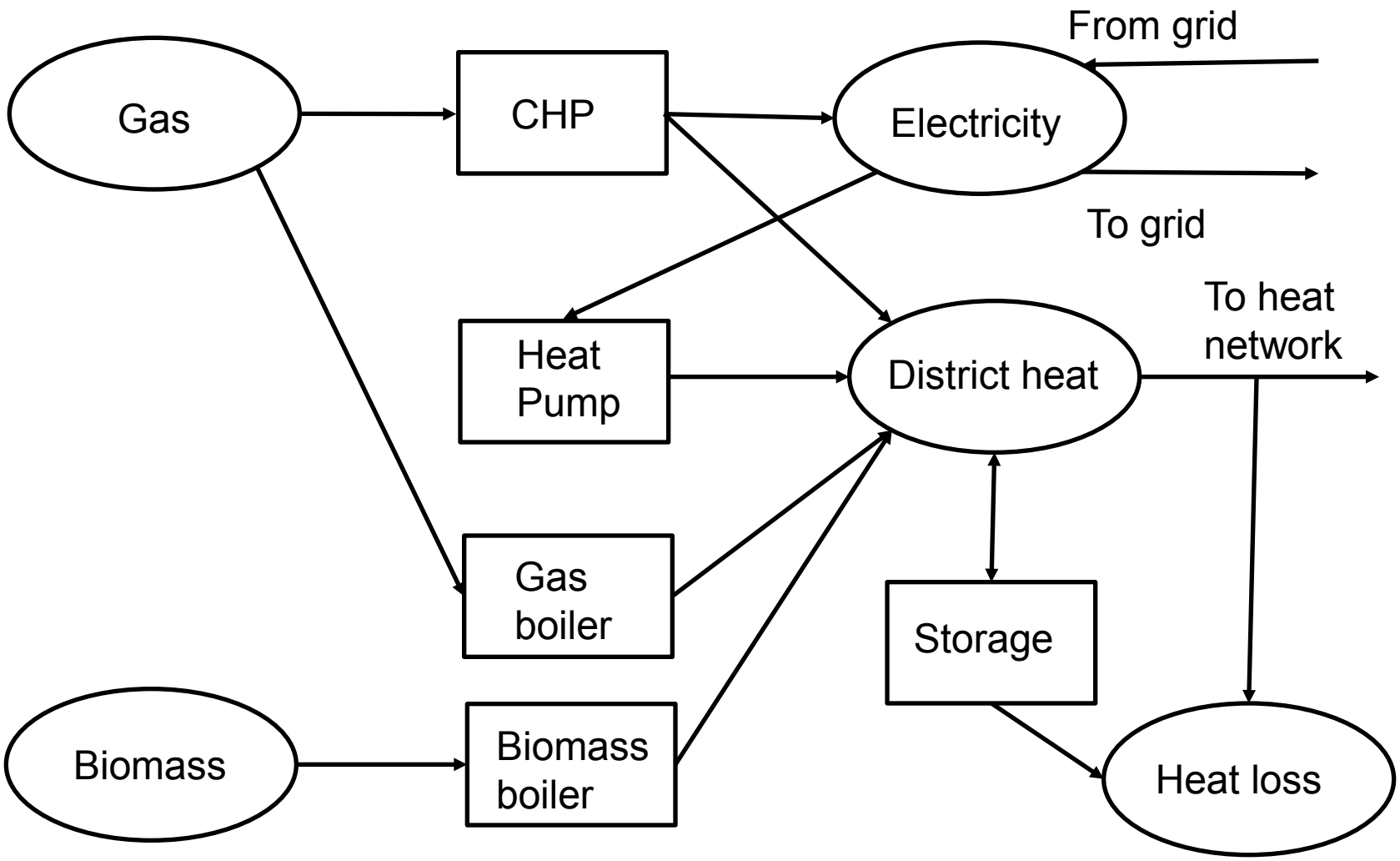
# Multi-period models

- Minor periods can be used to capture the impact of temporal variations in model parameters
  - Hourly, daily, and seasonal variations in energy demands
  - Hourly variations in electricity prices
  - Seasonal variations in natural gas/biomass prices
  - Variations in grid emissions factors with load
- Major periods (e.g. year or decade)
  - Define staged investments and capture  long term variations in prices

# Individual technology models



# Technology combinations




Energy Centre, Barkantine District Heating Network

# Data requirements

- Economic
  - Import/export prices, tariffs, operational costs
  - Investment costs, annuity factor (period, rate)
- Environmental factors
  - GHG, Other ($NO_x$, $PM_{10}$, $PM_{2.5}$)
- Technological
  - Conversion factors, minimum, maximum operating levels
- Spatial
  - Location constraints (allowed/disallowed)
- Temporal
  - Demand variations
  - Representative set of demand periods

# Summary

- Energy systems are complex systems
- Sub-models for land use and transport, agent activities, service networks, network interactions
- Optimisation models can be used to select between alternatives based on environmental and economic metrics

# Acknowledgments

*Imperial College*
Prof. Nilay Shah
James Keirstead
Nouri Samsatli
Sara Giarola
Clemence Morlet
Romain Lambert
Koen H. van Dam
Salvador Acha
Axelle Delangle
Mark Jennings
Kostas Zavitsas
Miles Loeber
Marko Aunedi

*CSE Bristol*
Josh Thumim
Tom Hinton
Richard Tiffin
Glenn Searby

# THERMOS

| | |
|---|---|
| web | thermos-project.eu |
| email | info@thermos-project.eu |
| twitter | @THERMOS_eu |
| linkedin | THERMOS project |

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 723636. The sole responsibility for the content of this presentation lies with its author and in no way reflects the views of the European Union.