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Urban Energy Systems

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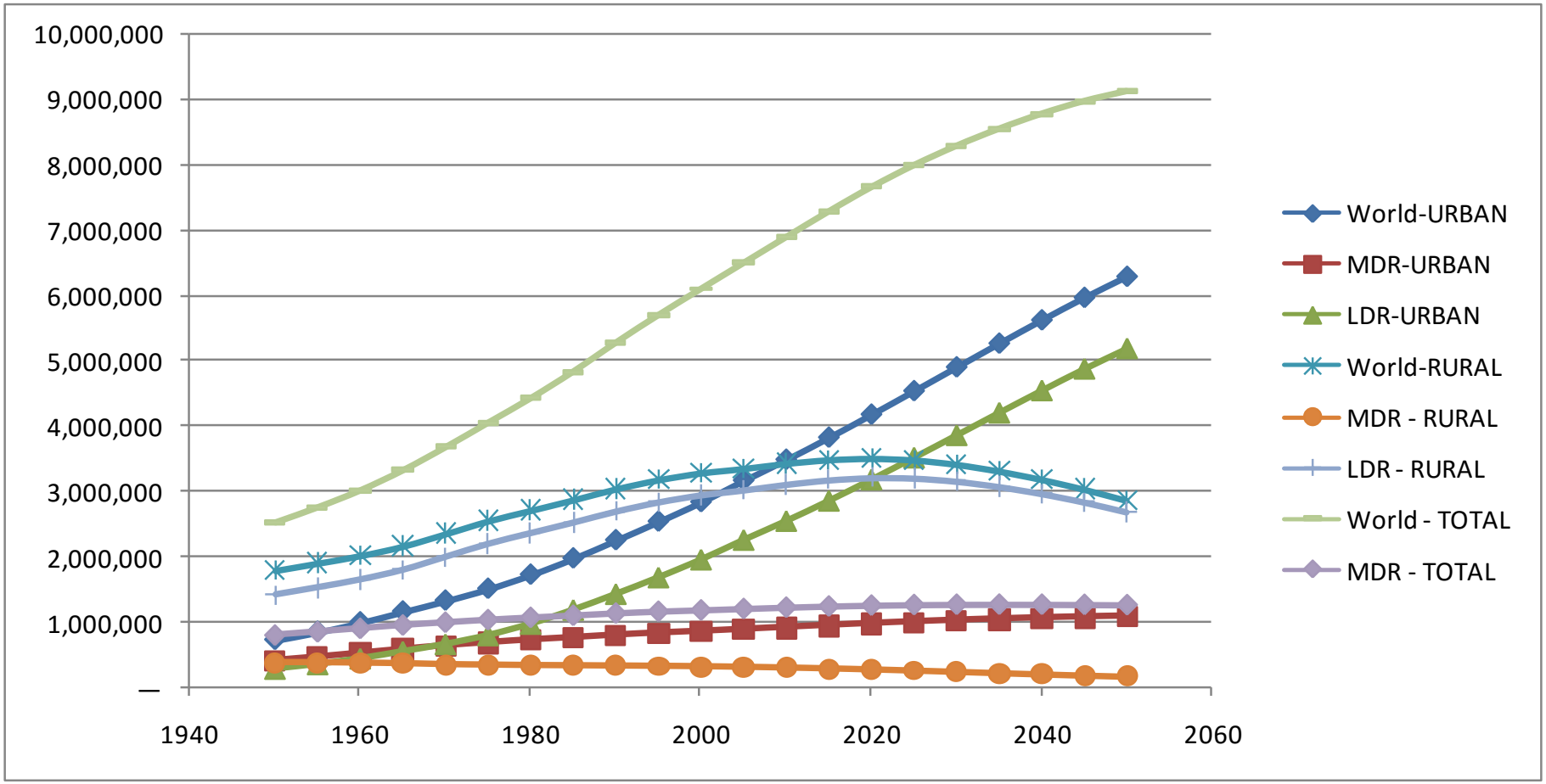
Why cities? Urbanisation trends



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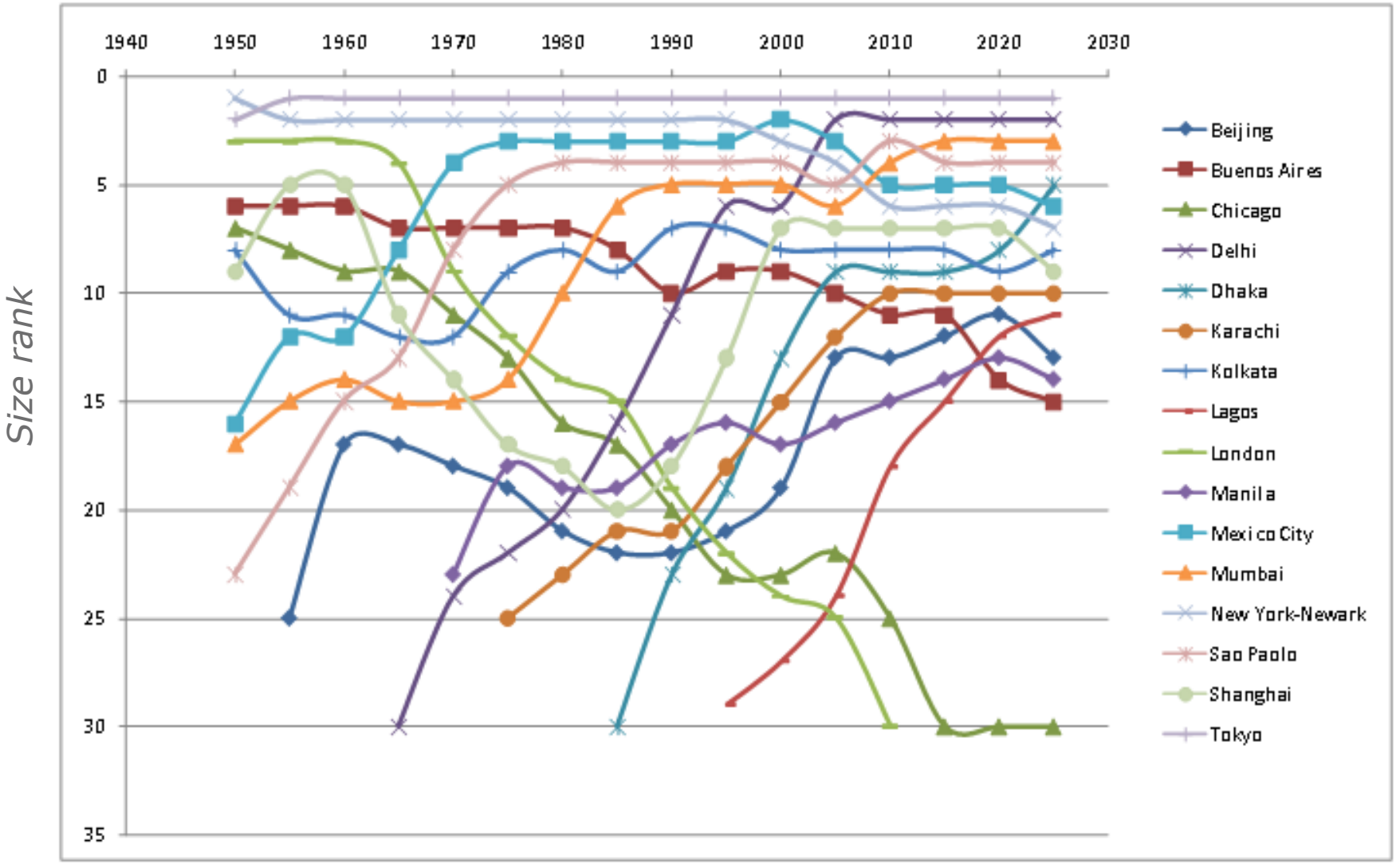
Why cities? Cities are in flux and compete



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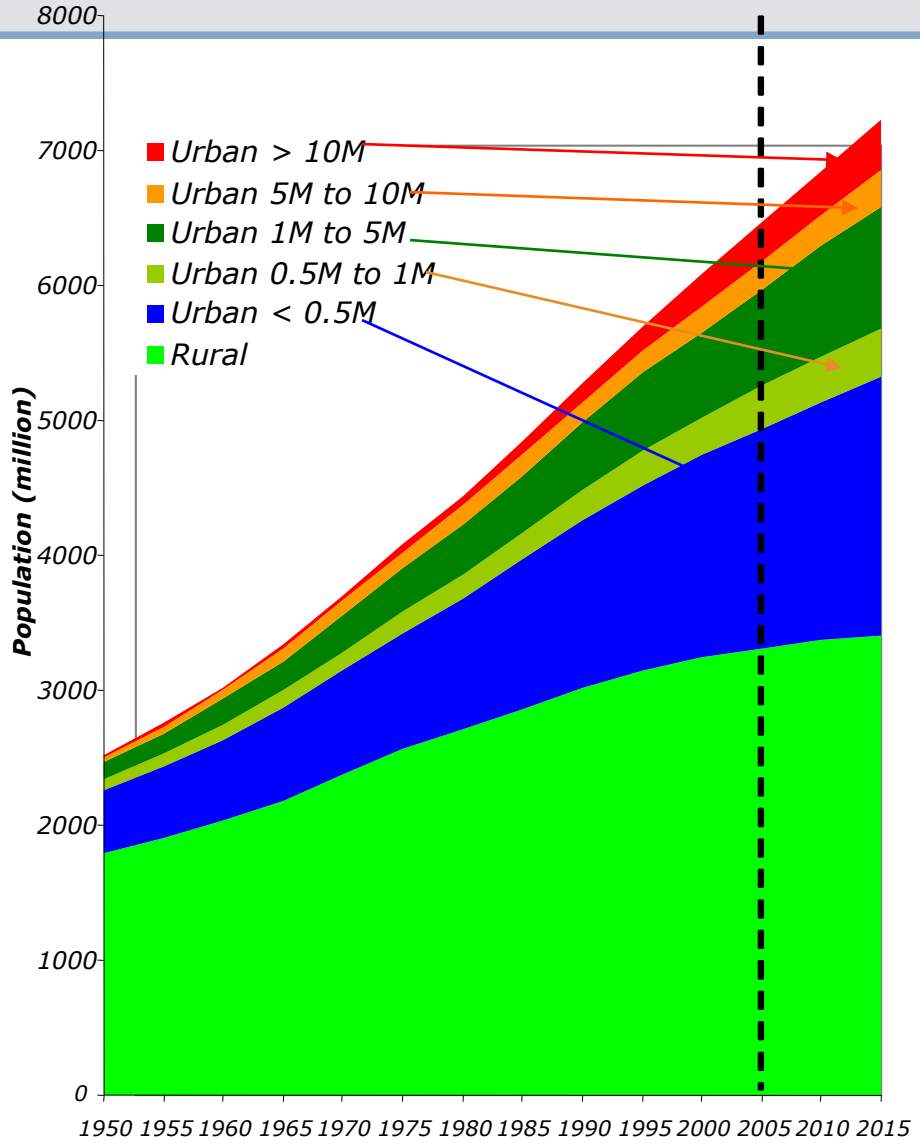
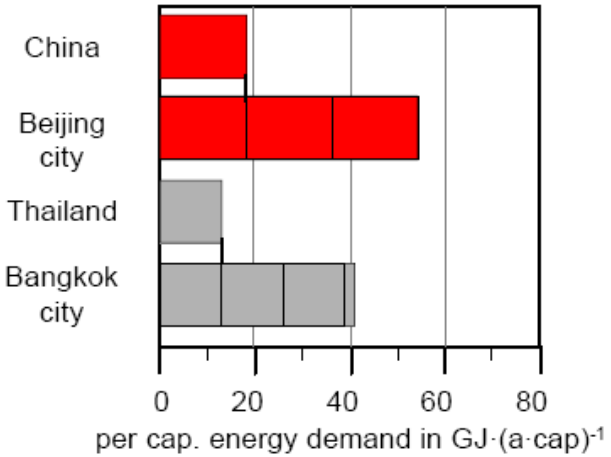
Population by Residence and Settlement Size; Urban Energy





- Few Mega-cities with <10% of urban population
- Urban settlements with less than half-million >50% of urban population
- LDR city dwellers use 3 x more energy than rural dwellers

*Source: **Dhakal, 2008,** based on: United Nations, Department of Economic and Social Affairs, Population Division (2006). World Urbanization Prospects: The 2005 Revision. Working Paper No. ESA/P/WP/200.*

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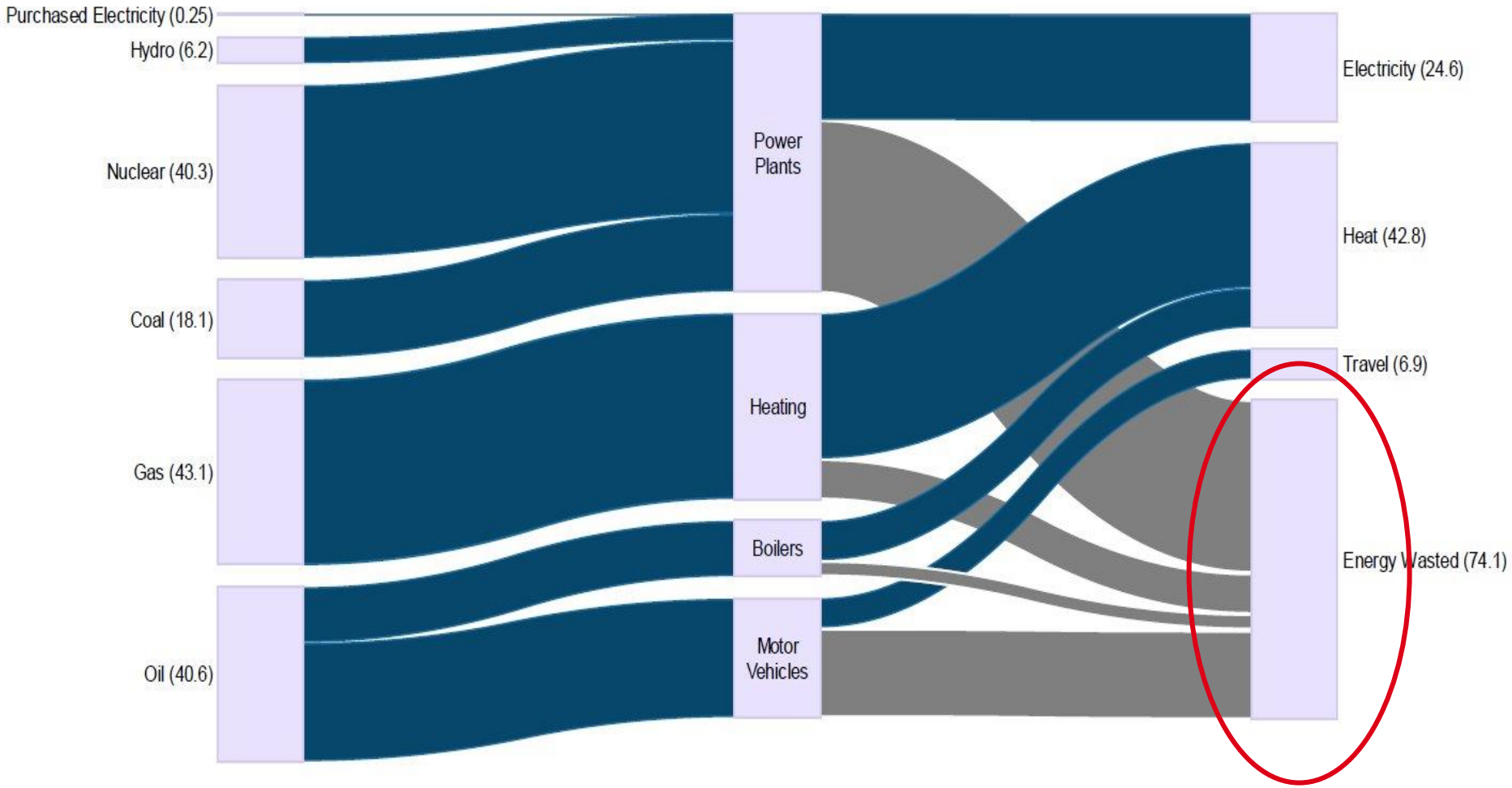
Today's cities are inefficient



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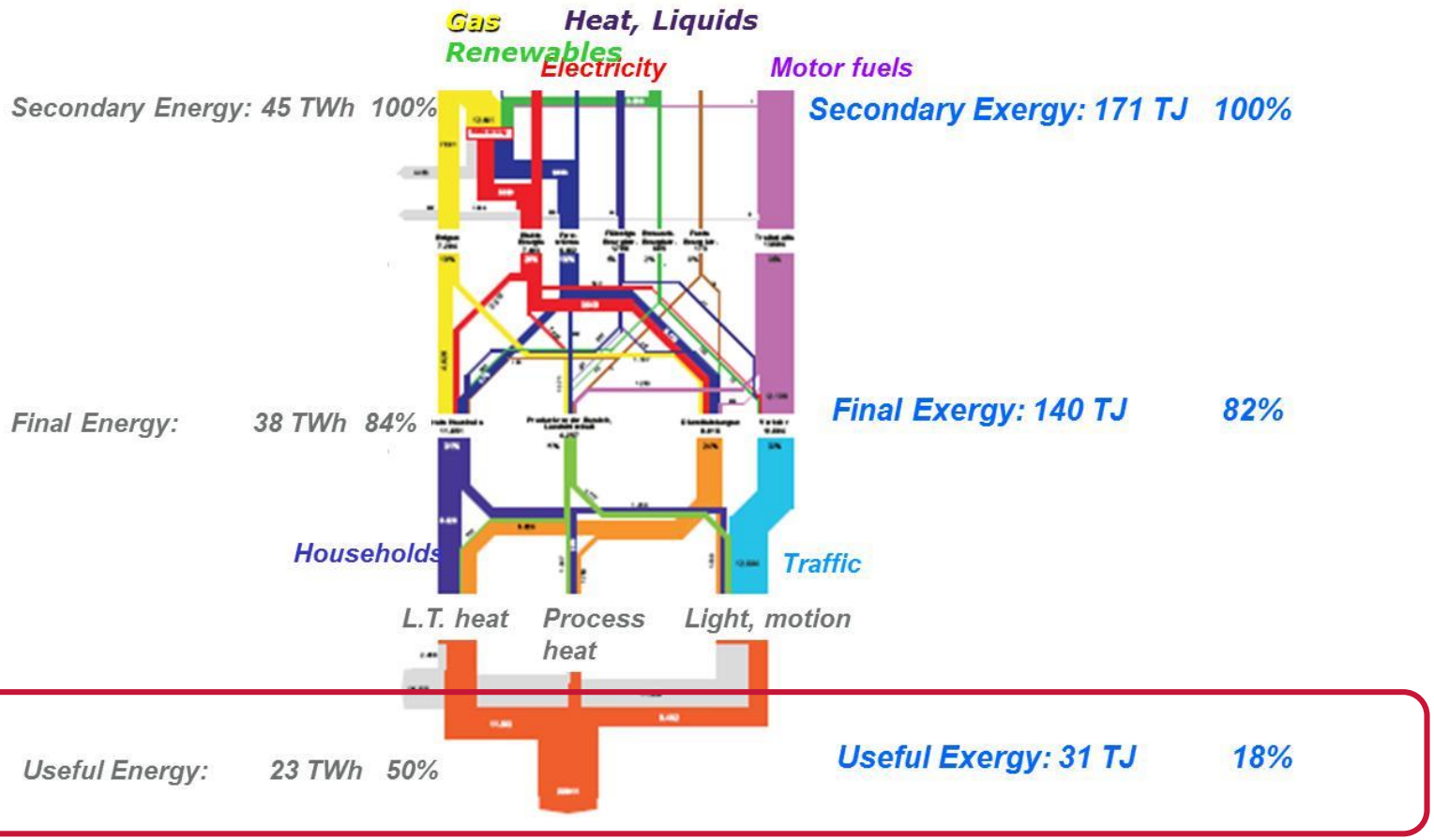
Energy and Exergy Flows Vienna 2006



Source: Gruebler, 2012; Wien Energie, 2009; (rough) exergy efficiencies based on Gilli et al., 1996.

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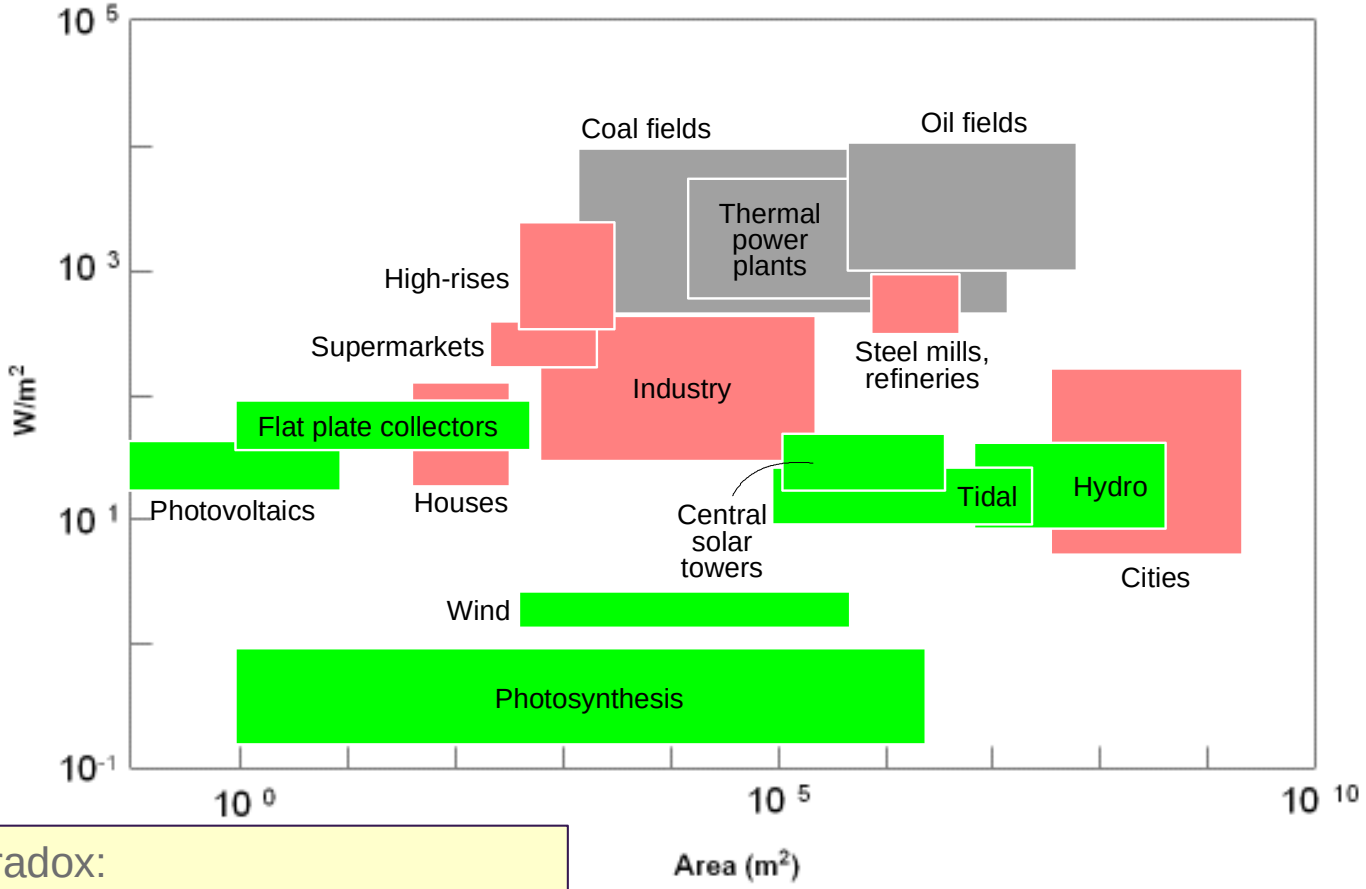
But energy density provides opportunities



Policy paradox:
- largest leverage from systems integration, but
- most difficult due to policy fragmentation

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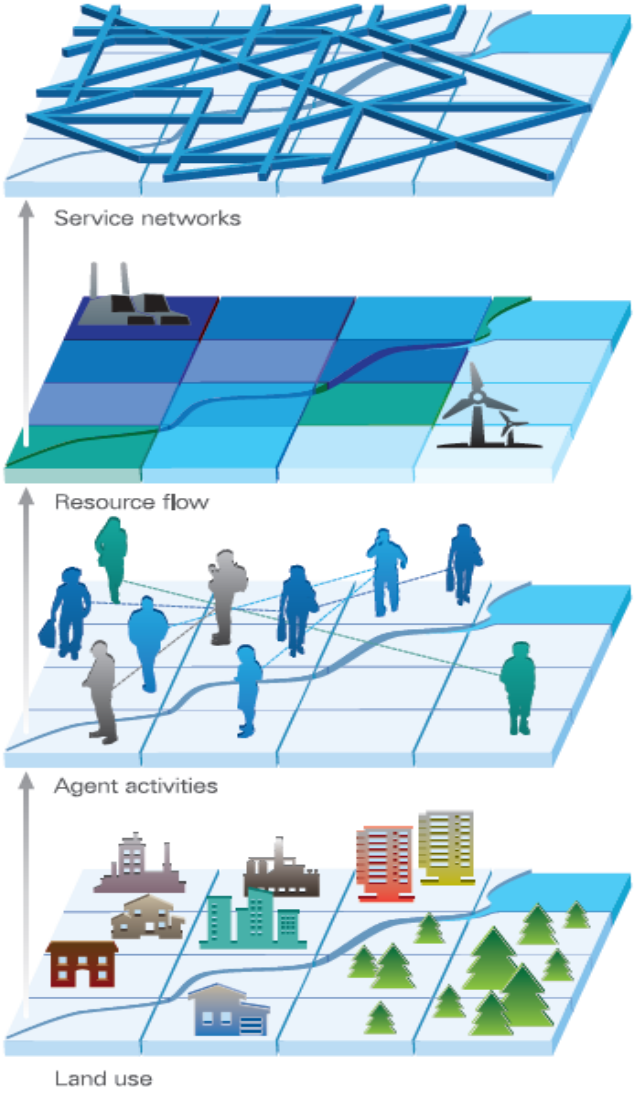
Solution: Structured, systematic approach



Smart service systems

Resource flow optimisation

People and behaviour

Land use/built environment

Our integrated modelling approach looks at two key questions:

- How does resource demand arise and how can it be reduced? E.g. Land use changes, technology, policy
- How to design systems to supply (reduced) resource demands in effective, integrated ways?

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What do we model in a city?

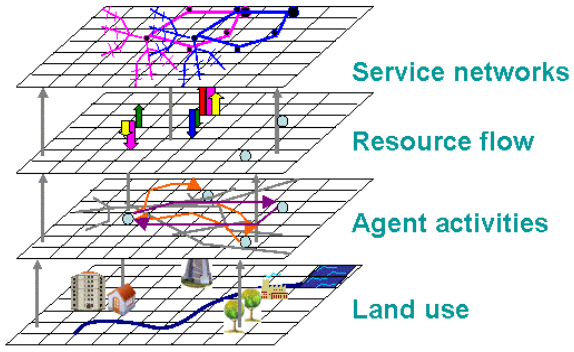
How the space is organised: built environment and its functions (activity locations); transport system

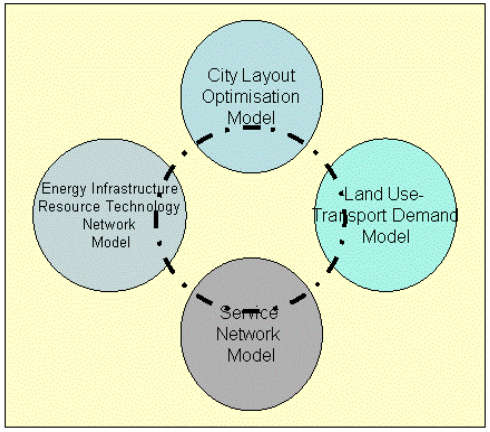
How agents use the space

How resource demands vary in space and time

What is the best resource interconversion technology and flow network?

What is the best engineering service network?





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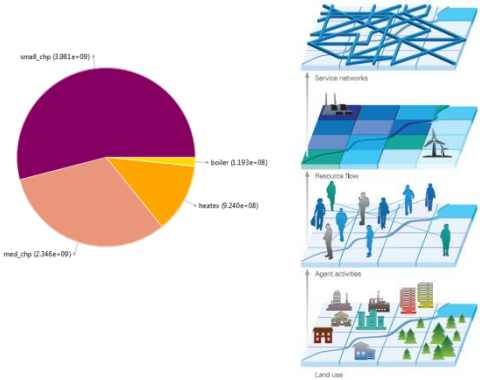
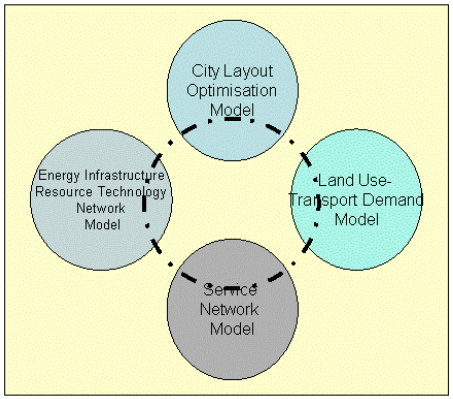
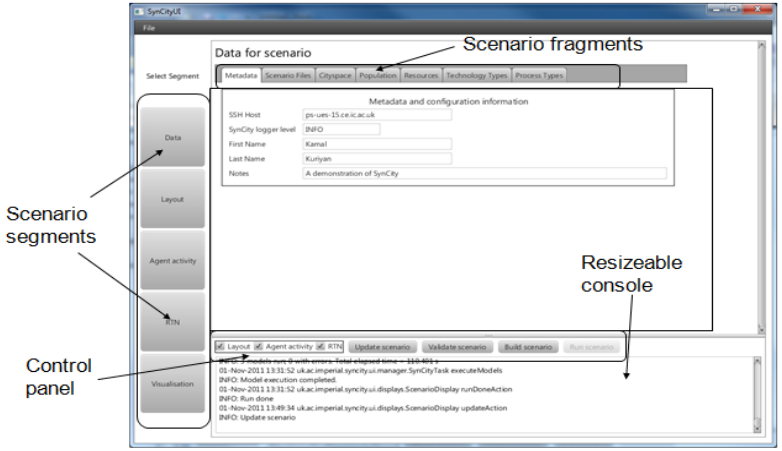
UrbEn – integrated modelling framework

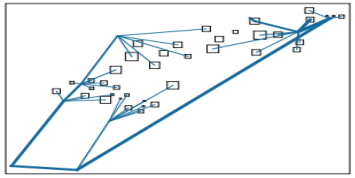
The system is composed of four integrated models:

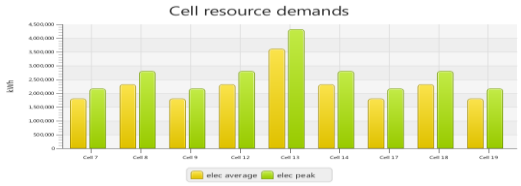
1. Layout model – optimises or describes how the space is organised
2. Active agent model – establishes how agents are likely to use the space over time and estimates resource demands by location and time
3. Resource-Technology Network model – determines the best resource interconversion technology and flow network (i.e. the core energy system)
4. Service Network Model – establishes the engineering service network configuration appropriate for the resource flow











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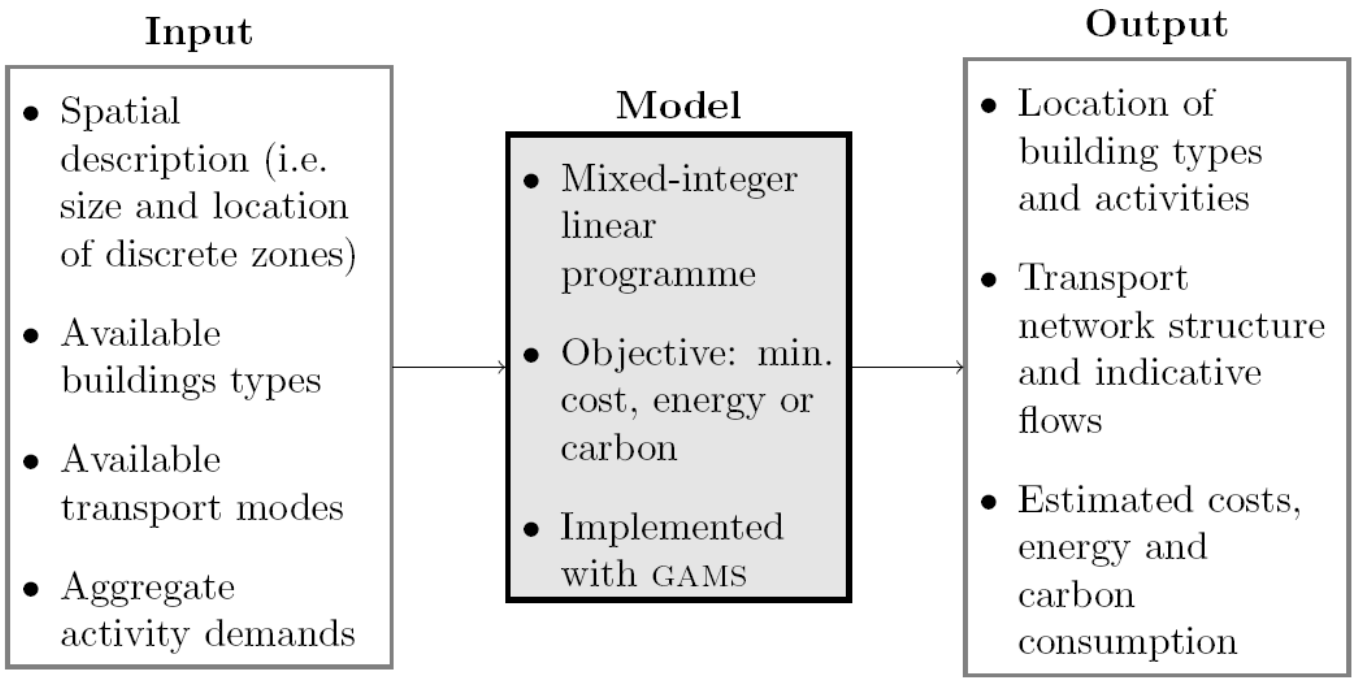
Layout model

Combinatorial optimisation (*cf.* VLSI & chip design)
Proxy for transport energy consumption and clustering benefit
- To be revisited once many studies complete

Generates gross layout
Ensures "well-connectedness" of cities and access to activities
Can incorporate a wealth of constraints
Various objective functions possible
Solution can be starting point for urban designer



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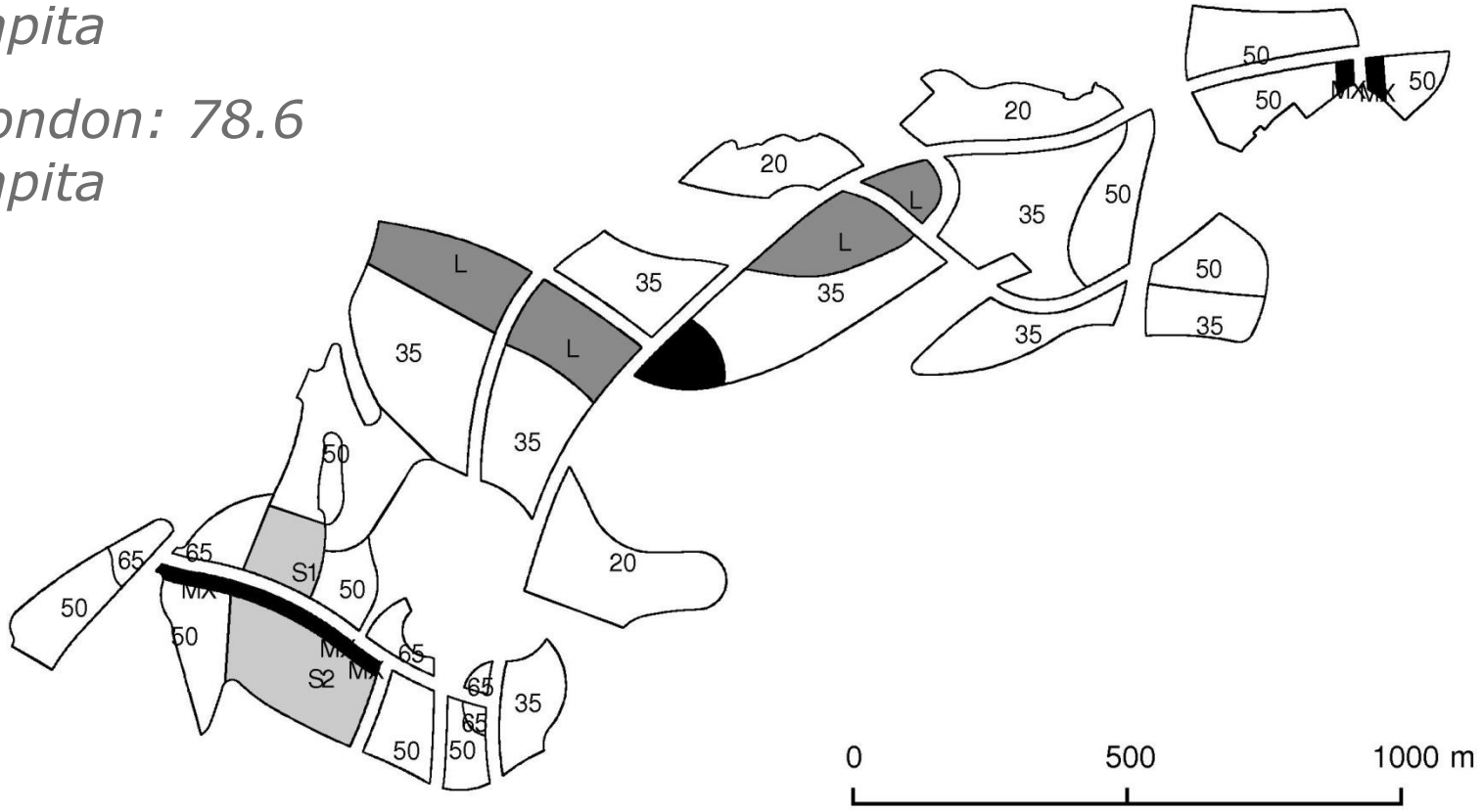
Smart design: layout and built environment
UK eco-town: original master plan

Annual energy: 23.8 GJ/capita

Cf. London: 78.6 GJ/capita



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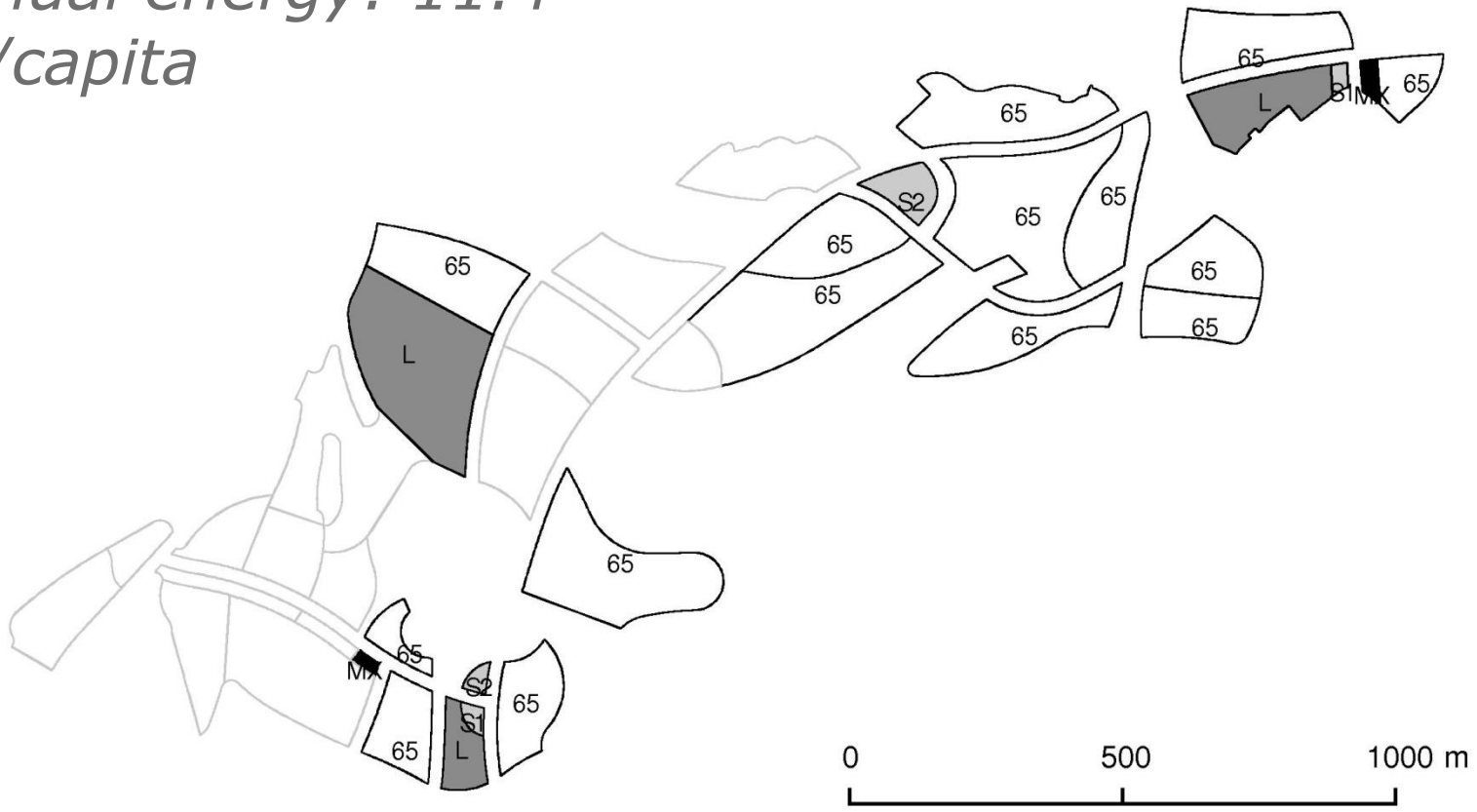
Layout Model

UK eco-town: unconstrained low energy design

Annual energy: 11.4 GJ/capita



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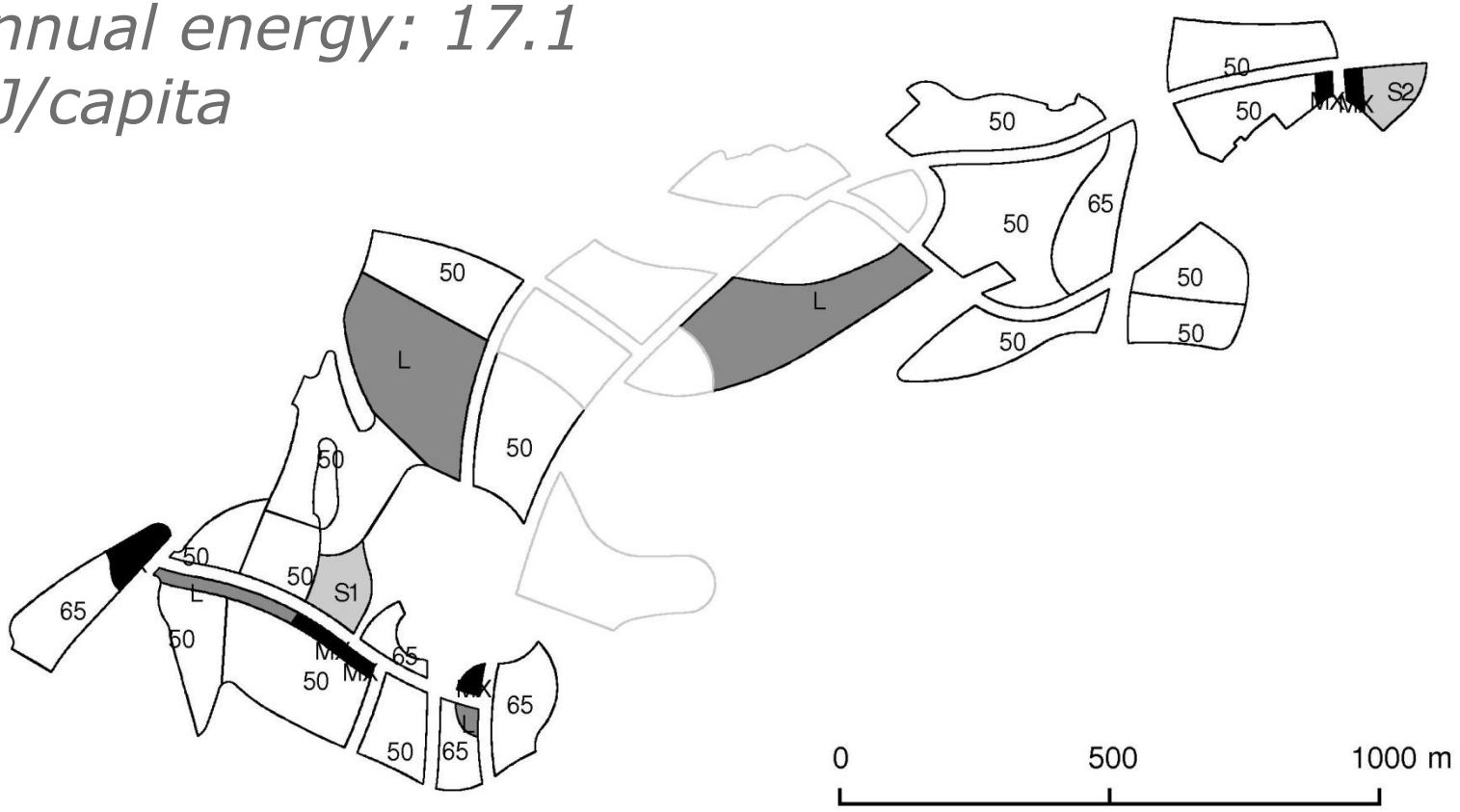
UK eco-town: constrained, "livable" low energy design

Annual energy: 17.1 GJ/capita



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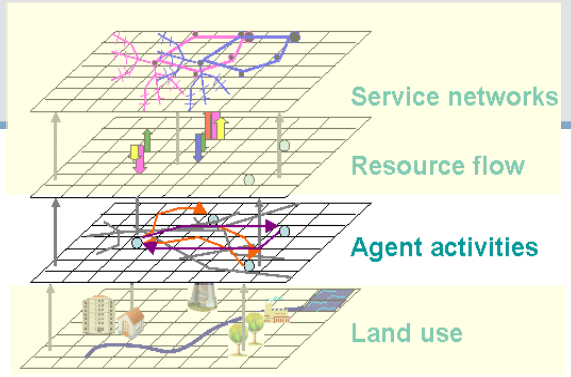
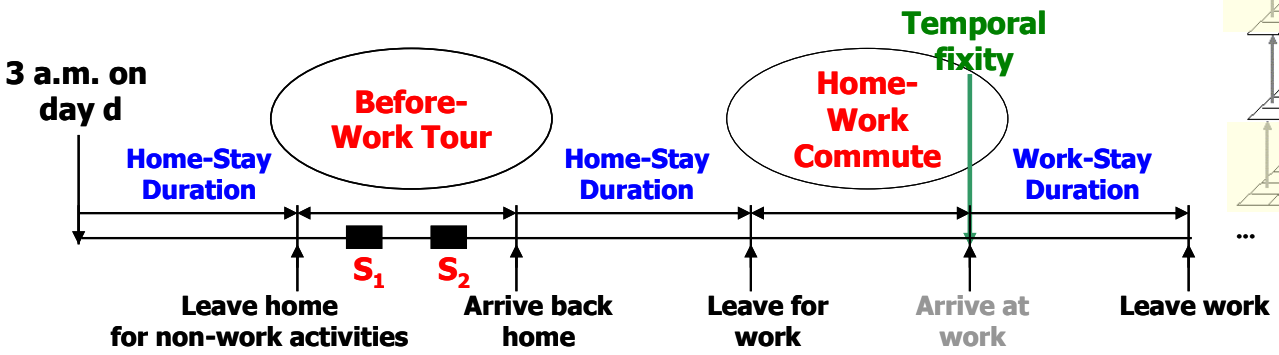
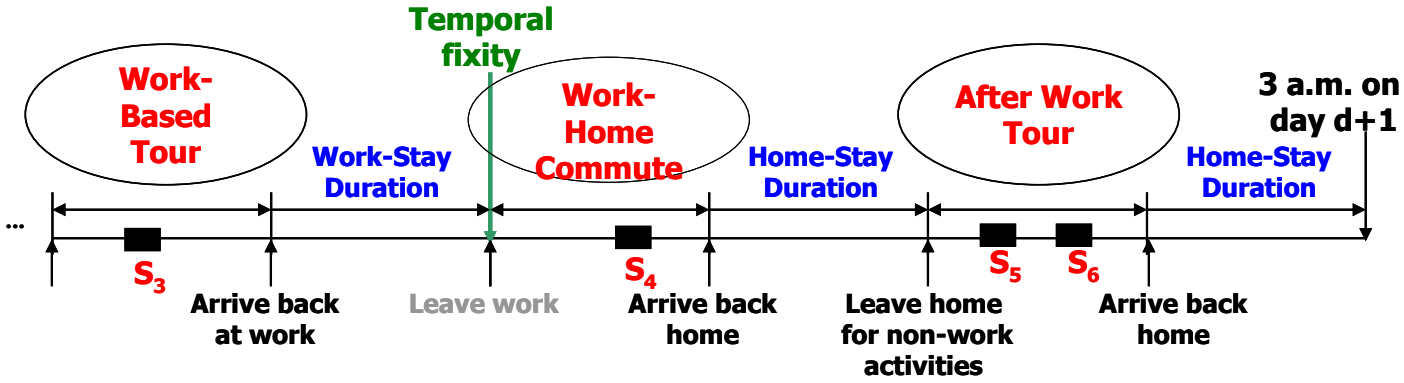
ABMS: Land use and transport







How do citizens use the 2D/3D space?

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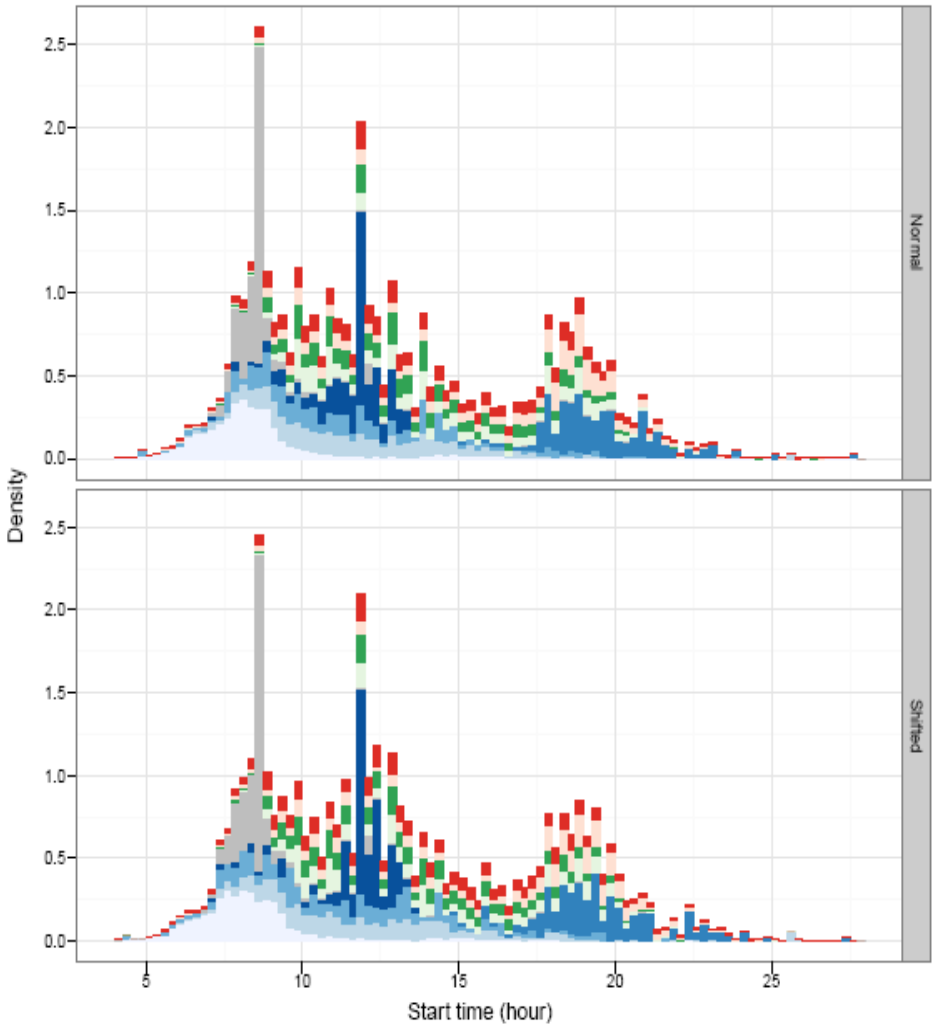
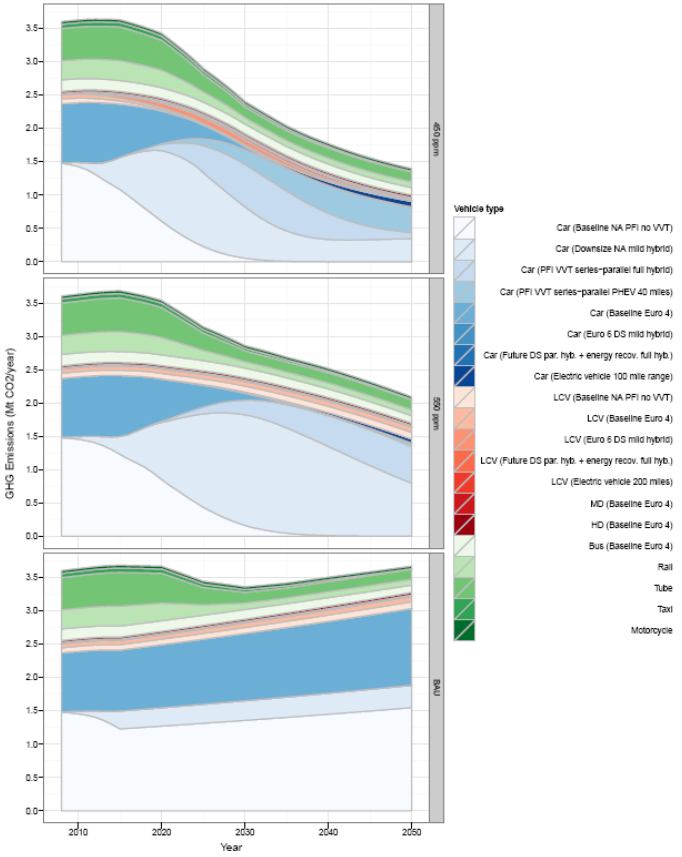
People: Results of London Travel Study





RESOURCE FLOW/CONVERSION OPTIMISATION

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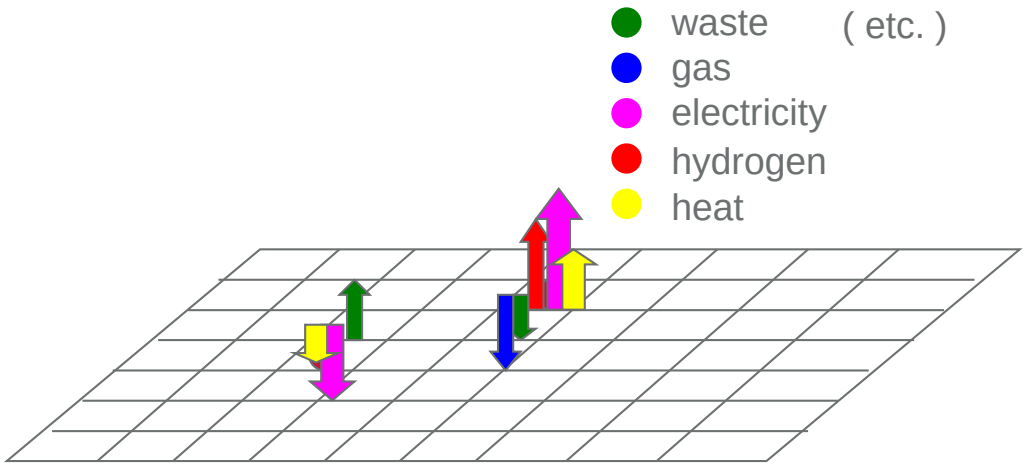
Resource (service) demands



Known for every location and every time point
(season, day of week, part of day)

How to supply optimally:
Resource Technology Network model

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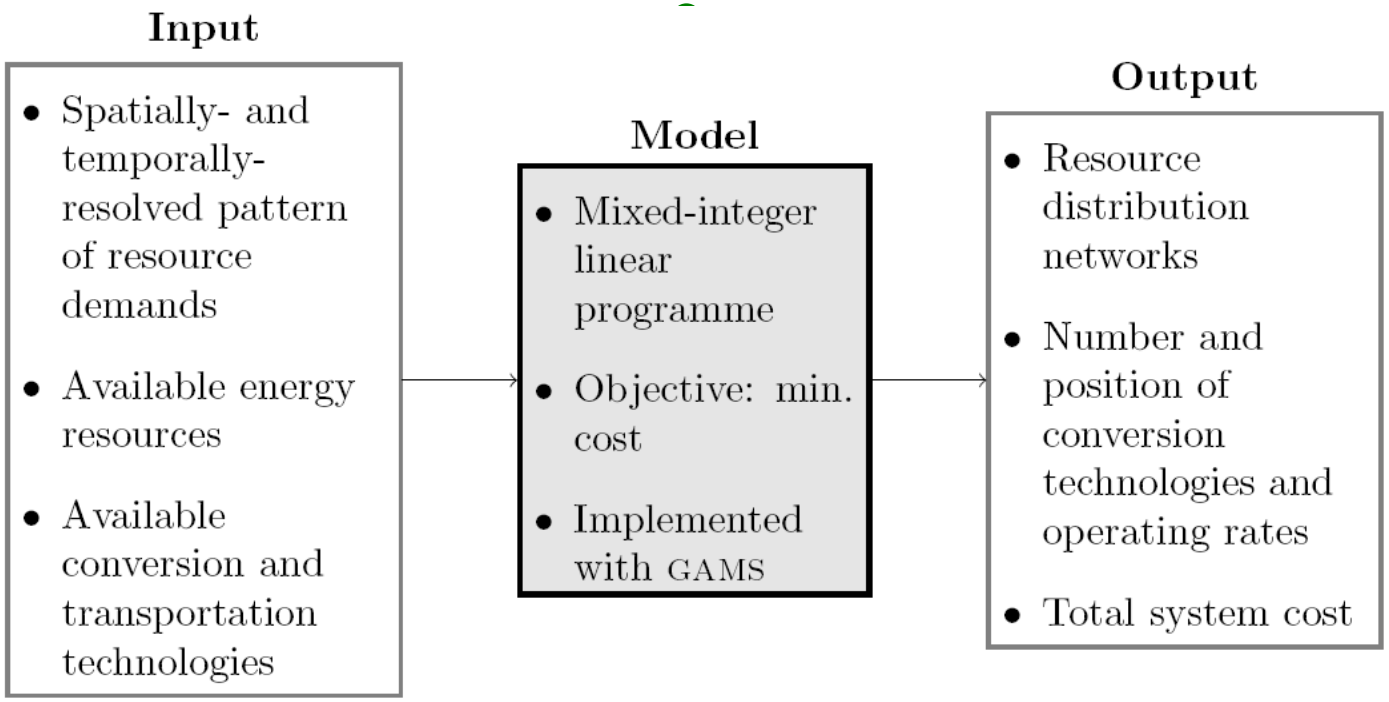
RTN model



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Key elements

Space

Time

Resources

Technologies

Infrastructure/Networks

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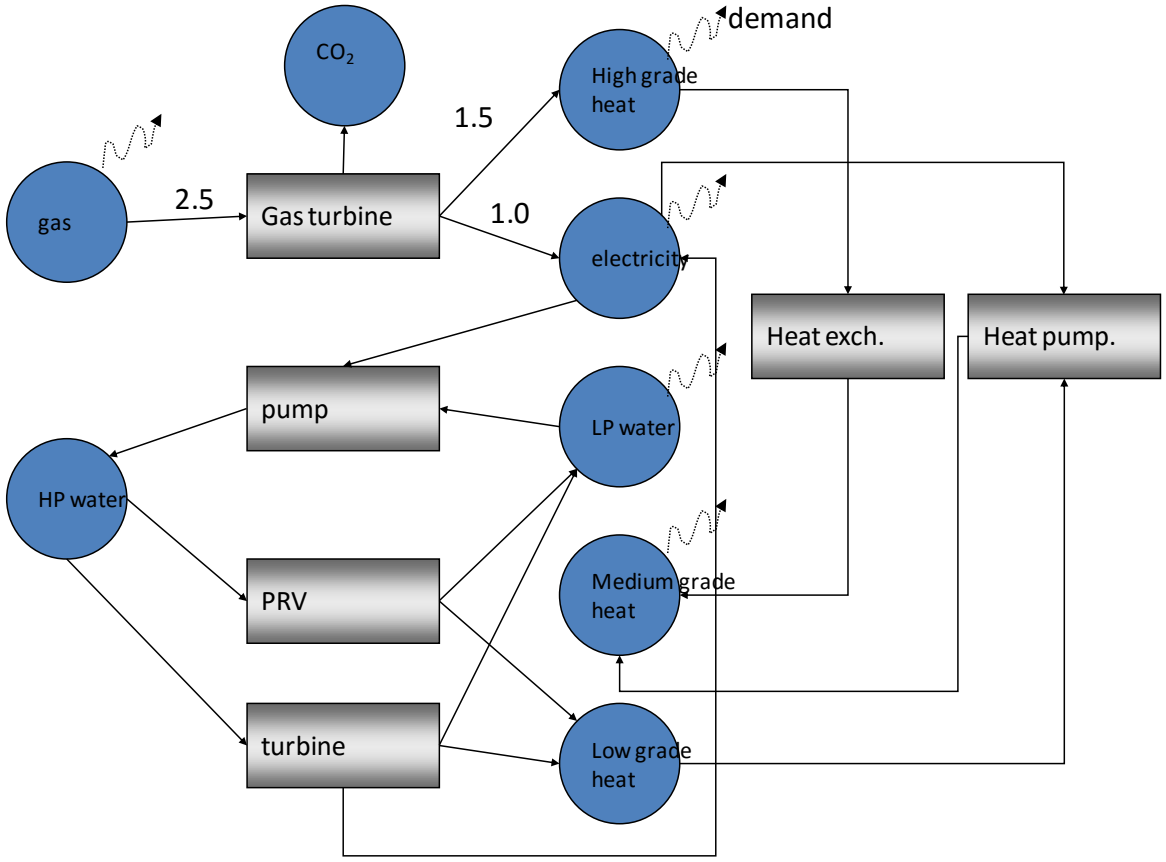
Resource Technology Network: Example



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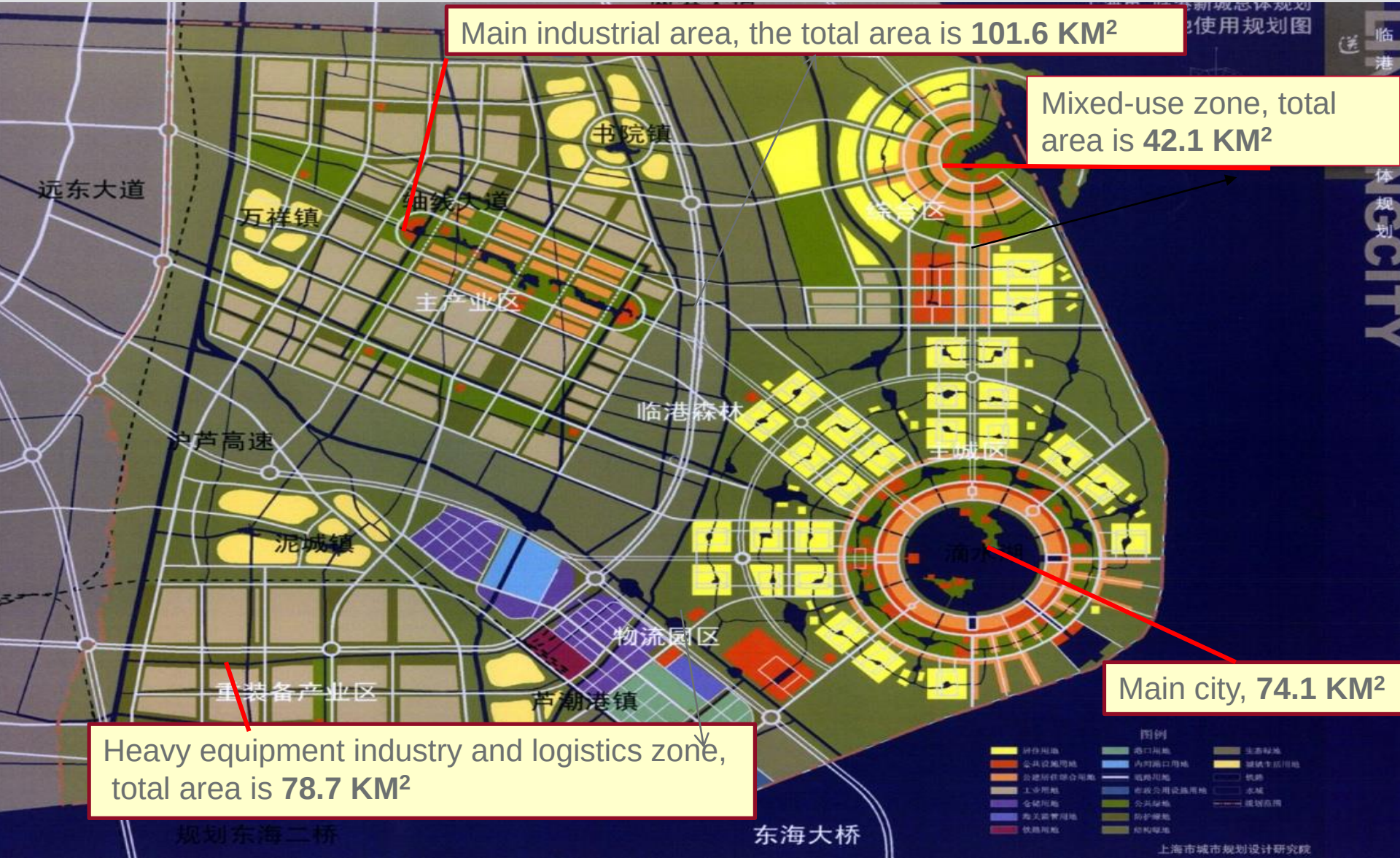
Lingang New City



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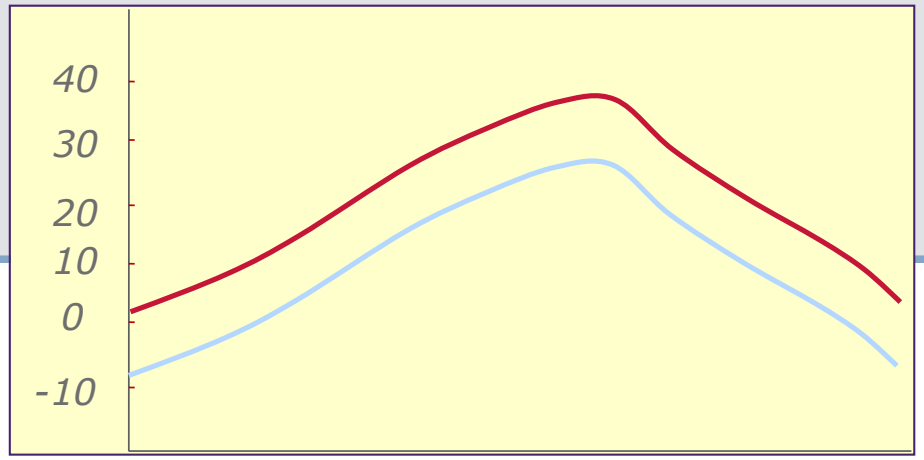
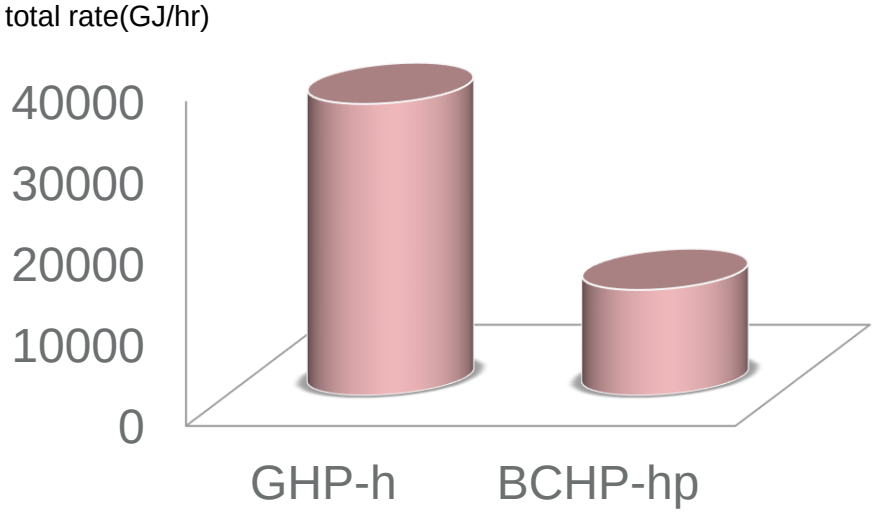
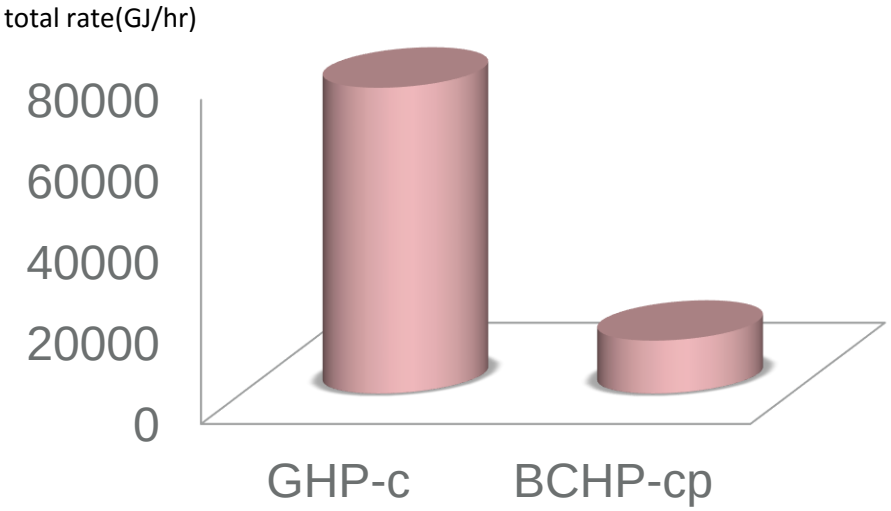
Energy System Optimisation





Energy supply pattern in winter



Energy supply pattern in summer

>50% GHG reductions compared to BAU

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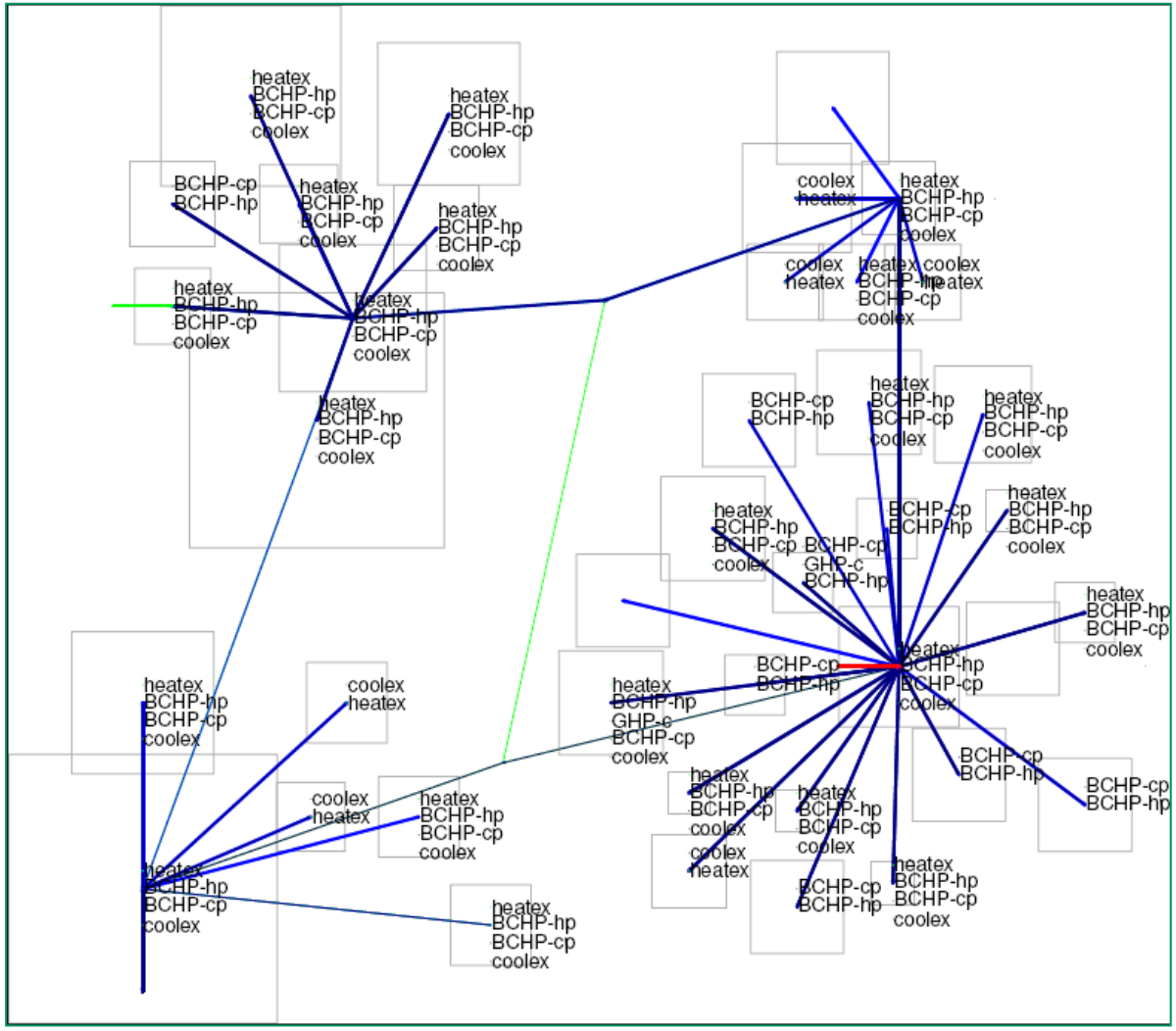
Overall System Design



Network provides:

- *Heating in winter*
- *Cooling in summer*

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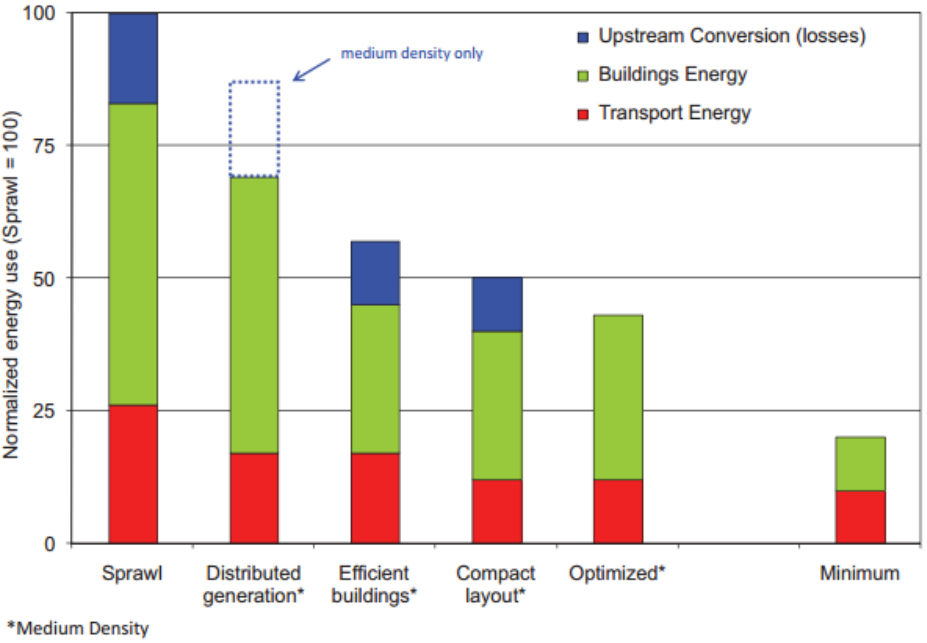
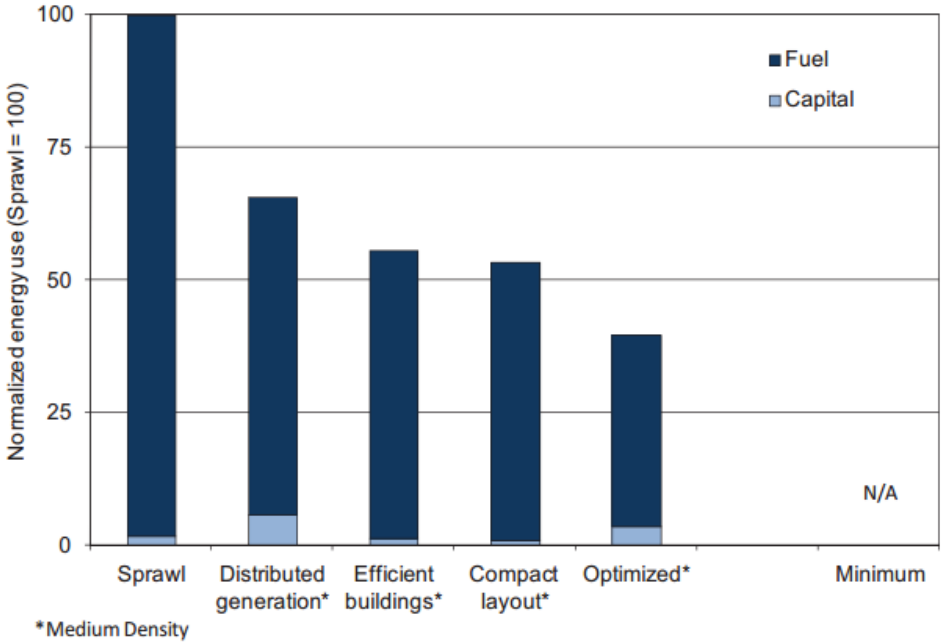
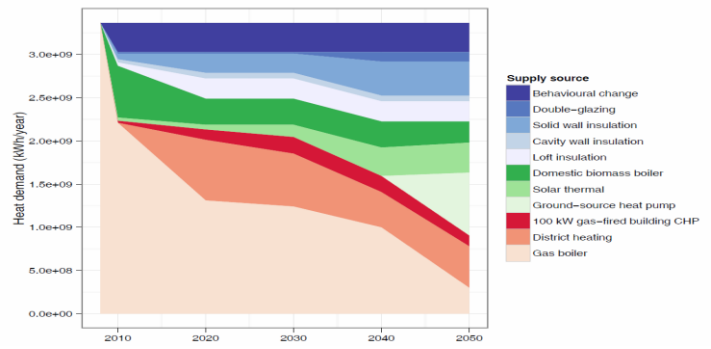
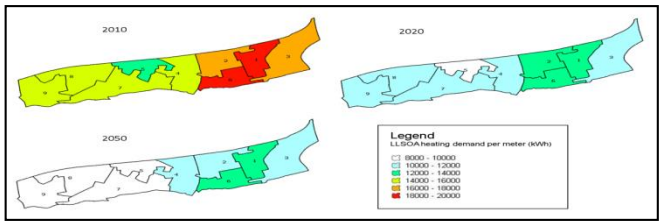
UK studies – 50% reduction cost effecive









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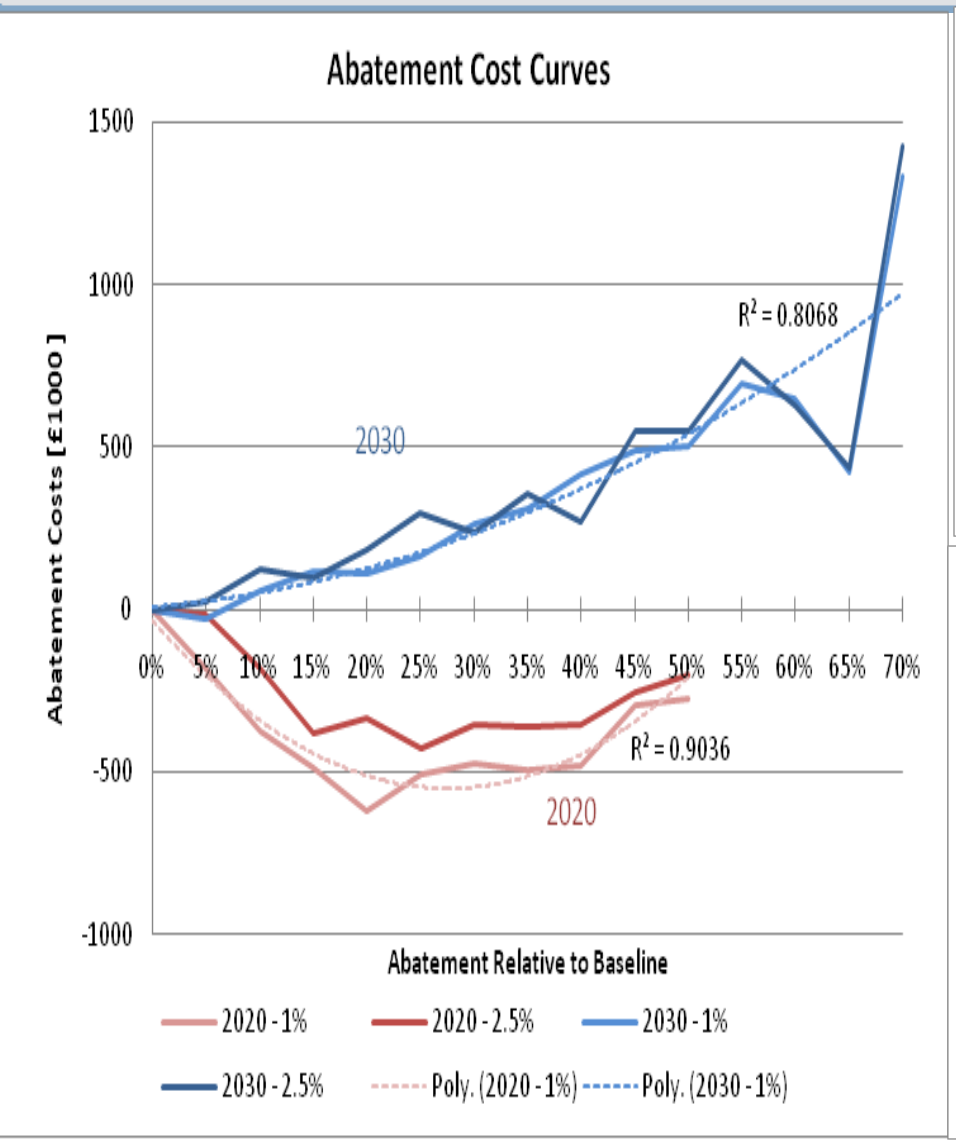
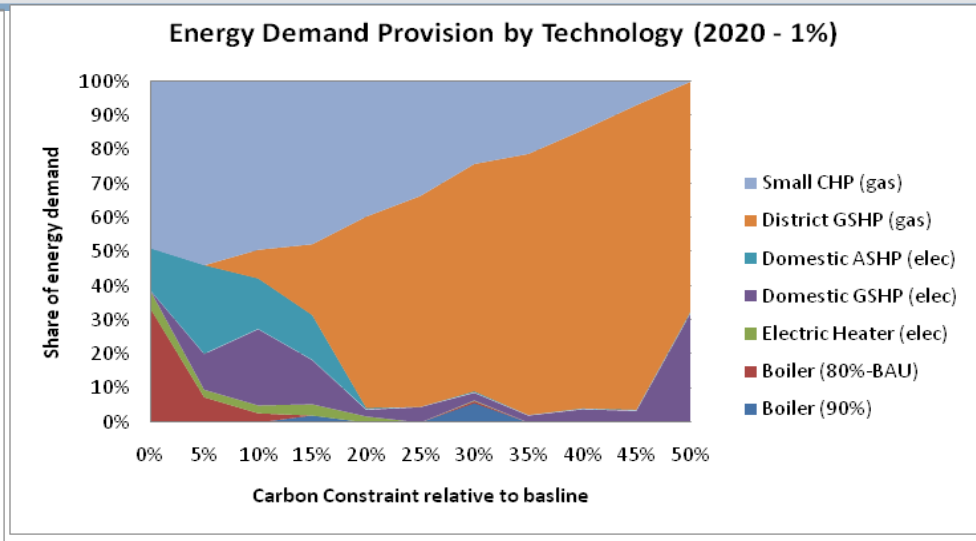
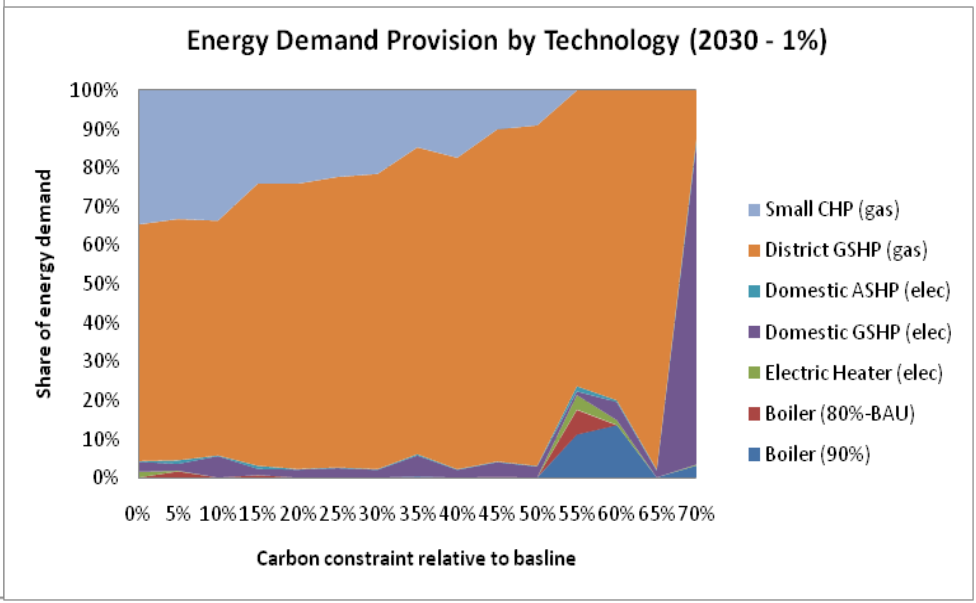
City MACCs and urban energy transitions







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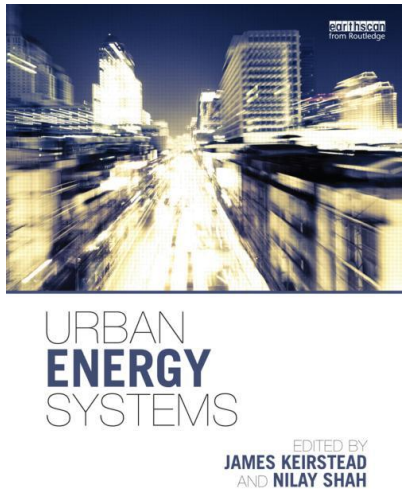
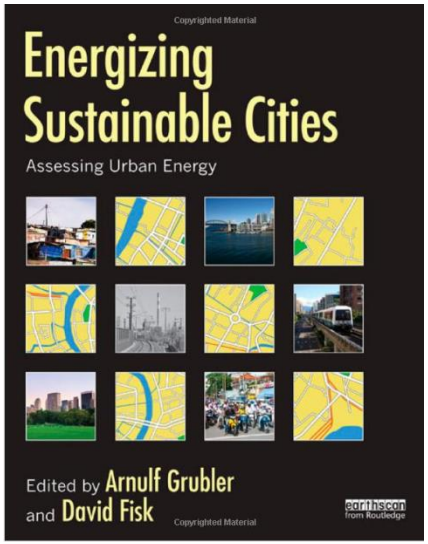
Summary

- **Cities** provide massive opportunities for climate change mitigation
- **Cities** at the forefront of innovation; often more aspirational than nation states
- **Tools** for smart and systematic design of urban energy systems becoming available





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