UCCRN Symposium

10th-11th May 2007, Columbia University, New York

The critical role of modelling in urban energy and climate policymaking

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Outline: Urban Energy Systems (UES) Modelling

1. The UES project at Imperial College (IC) London
2. Rationale and objectives for UES modelling
3. Existing Methods
4. Need for improved understanding of UES
5. Proposed outcomes for the IC UES model
6. Challenges of UES modelling

1.1 The Imperial College UES project

"By 2030 it is estimated that over half the world's population will be living in cities. So reducing the amount of urban energy wasted is critical in tackling diminishing natural resources and climate change. Our Urban Energy Project at Imperial College London is exploring how cities could be more efficient with their use of power, heating and transport – for example harnessing previously wasted heat from power stations to heat offices and homes"

bp advertisement, The Times, 8 June 2006

The BP Urban Energy Systems project at Imperial will identify the benefits of a systematic, integrated approach to the design and operation of urban energy systems, in the context of the dynamic evolution of cities.

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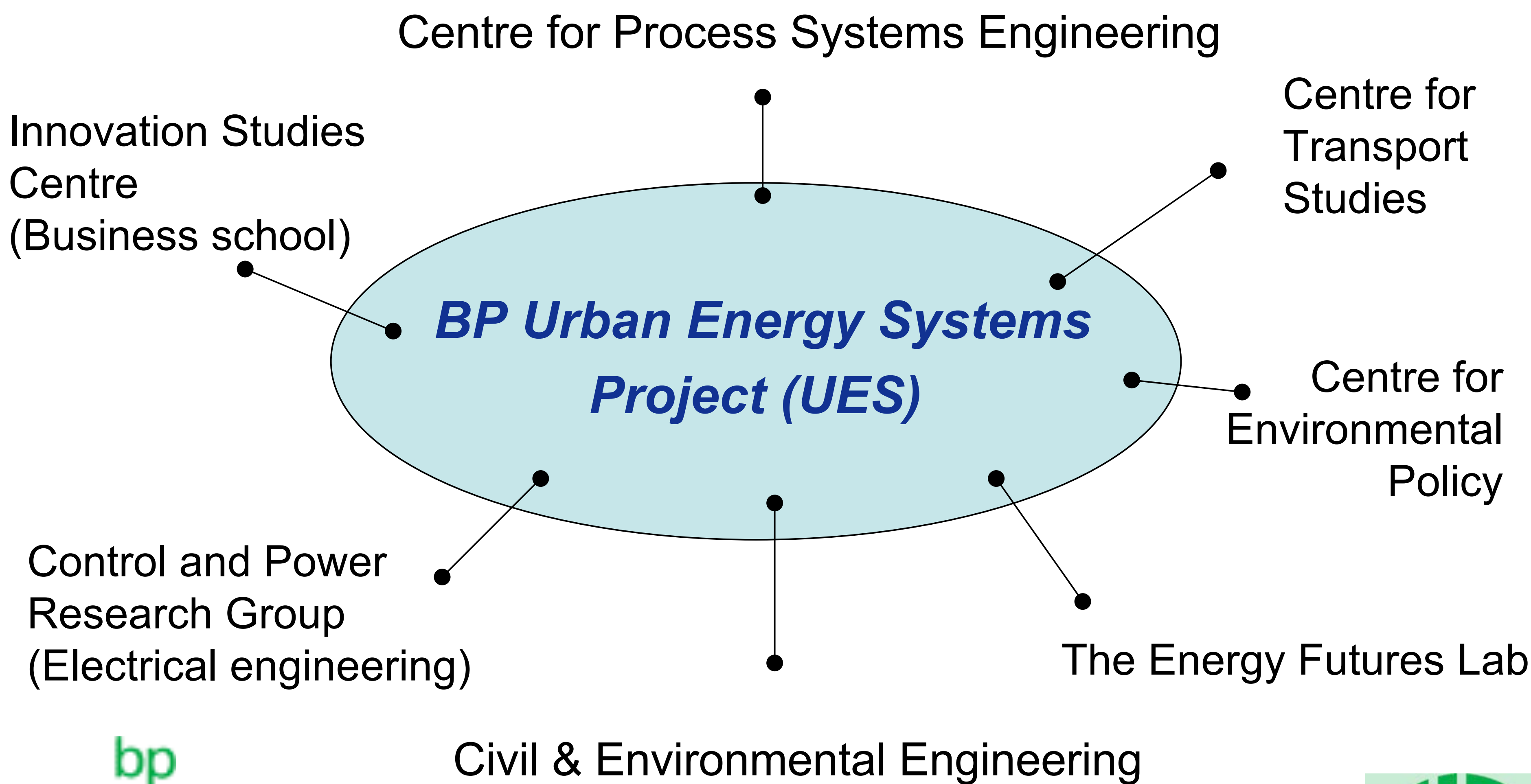
1.2 The Imperial College UES project

- Core funded by BP
- Hosted in energy futures lab
- MSc and PhD opportunities in sustainable energy futures
- 12 year project, phase 1: 2006 - 2010
- Multidisciplinary, cross faculty initiative
- 8 fulltime researchers, extensive team of part-time, associates, advisors
- Involves: process systems engineering, electrical engineering, civil and environmental engineering, transport studies, environmental policy, innovations study centre / business school

1.3 Urban Energy Systems project at IC



2. Objectives for UES modelling

- Analyse and understand the current state of urban energy systems (UES) in existing and new cities
- Predict prescribe and invent the urban energy systems of the future
- Provide detailed understanding of supply system and end-use (energy service) delivery
  - Improve knowledge on system interactions
    - across end use sectors
    - and across energy supply vectors
- Improve understanding of risks of energy supply disruptions
- Improve understanding of opportunities of supply innovation
- identify options for system integration and efficiency improvements

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3.1 Model classes

- Static/Dynamic:
  - Not all information can be captured in a static system
    - Short/medium term variations (e.g. day/night, seasonal)
    - Long term trends: city development and growth
    - Some use established tools: e.g. cellular automata, increasingly agent based modelling
    - Many do mainly extrapolate historical trends
- Partial/General UES
- Aggregate/Disaggregate
  - RES/MARKAL are typical for national systems
  - Disadvantage: no spatial disaggregation; unable to take advantage of urban features
- Deterministic/Stochastic

3.2 Existing energy models

- General lack of understanding about the spatial and temporal heterogeneity of urban energy systems
  - Important details of energy systems operate on individual/ small scale (e.g. energy efficient equipment, timing demand)
  - Detailed models of buildings / building types and their interaction with urban texture, granularity are required
- Also the model assumption of interactions between demographic drivers of activities (workplace, residential, leisure, transport) and energy demand need improvements in detail and coherence
- Multi criteria models are necessary to address interactions with social-, environmental- and health parameters (externalities of the energy system at various scales)
- New data sources (real time monitors, ICT networks) and computing capabilities provide opportunity for improvement

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4. Elements of optimisation

- Demand optimisation
  - Building refurbishment, PV, low energy equipment, city compaction etc.
  - Demand management
- Supply optimisation
  - New conversion, efficient distribution, production technologies, renewables, integrated systems
  - Network design, storage
- Objective functions/constraints
  - Costs (total social cost?)
  - Primary energy demand (renewable/non renewable)
  - Emissions
  - Other environmental/sustainability indicators

5. Outcomes: IC UES model

- Scenarios and validated models for energy demand evolution and supply innovation for developed and developing cities
  - Potential solutions – supply innovation and demand management strategies
  - Early sight of the local and global benefits of novel approaches
  - Impacts for the energy supply industry
  - Inputs to academic- and public policy debate
- Quantitative assessment of current and future alternative technology options in an urban context
- New approaches to optimisation in large self-organising systems
- Innovative engineering possibilities for energy conversion, storage and transport
- Blueprints for new approaches to expanding urban energy systems
  - New business models
  - Methodologies and tools
  - Trained personnel

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6.1 Challenges:

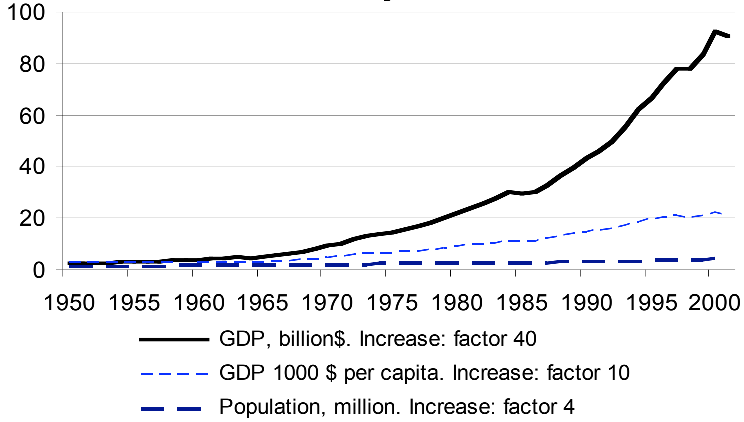
- Integration of sectoral models on different scales (temporal and spatial) and variation in topology
- Multi criteria modelling (modelling energy, carbon, heat flows: limited or unknown commensurability, conversion or substitution)
- Spatial/administrative versus functional system boundary definition
  - data challenge at metropolitan scale
  - Production versus consumption based measures (LCA rationale)
  - open system characteristics
- Static versus dynamic system perception
  - urban growth
  - urban environmental transition
  - non-equilibrium models

6.2 Environmental Impact models:

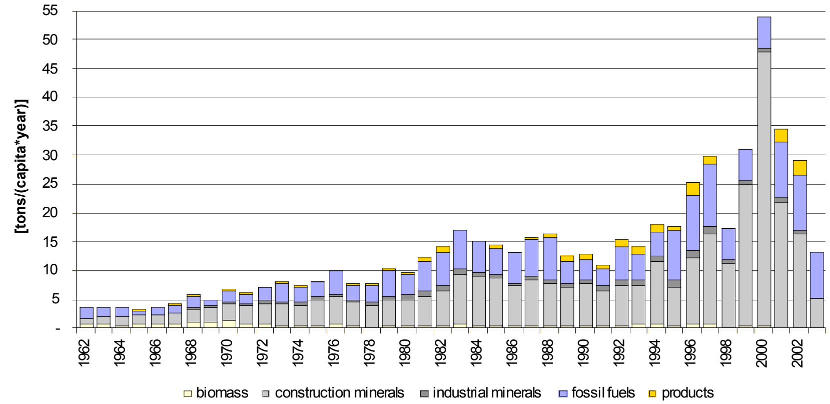
- Urban energy system should include the use of biomass (for nutrition etc.) as integral component of UES
- Not only direct, but also indirect energy uses such as
  - Production and transport of energy carriers
  - Transport of other resources to (and waste from) cities
  - Induced energy consumption due to production of goods and services ‘elsewhere’ that are consumed in cities
- Open character of urban systems requires life cycle approach (such as MFA)
- Boundary definitions and impact assessment is methodologically challenging
  - LCA software tools like SIMA, Ecoindicator

6.3 Urban metabolism: Singapore

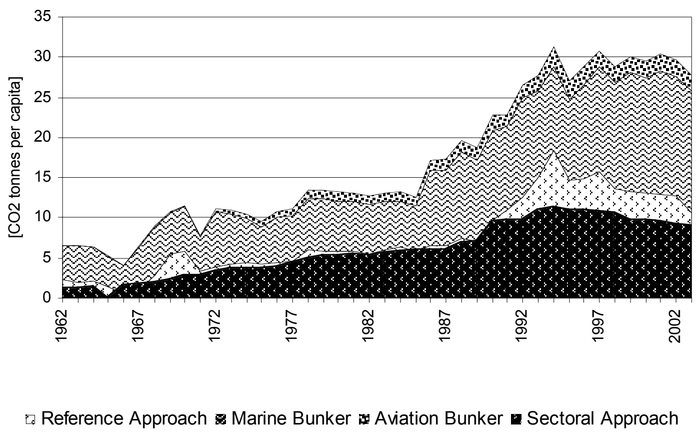
economy



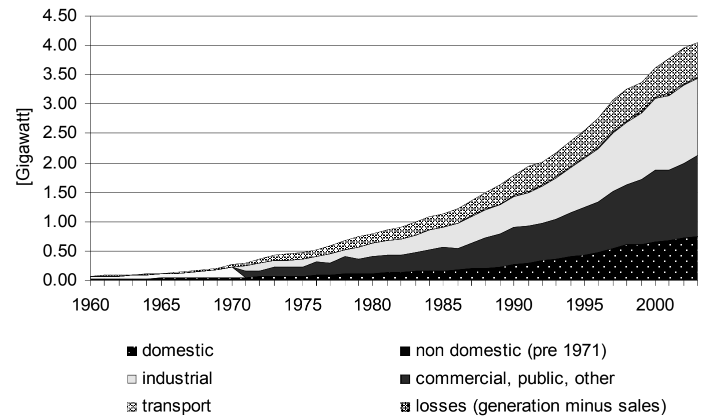
material use (DMC)



emissions



electricity use



Schulz 2006, 2007

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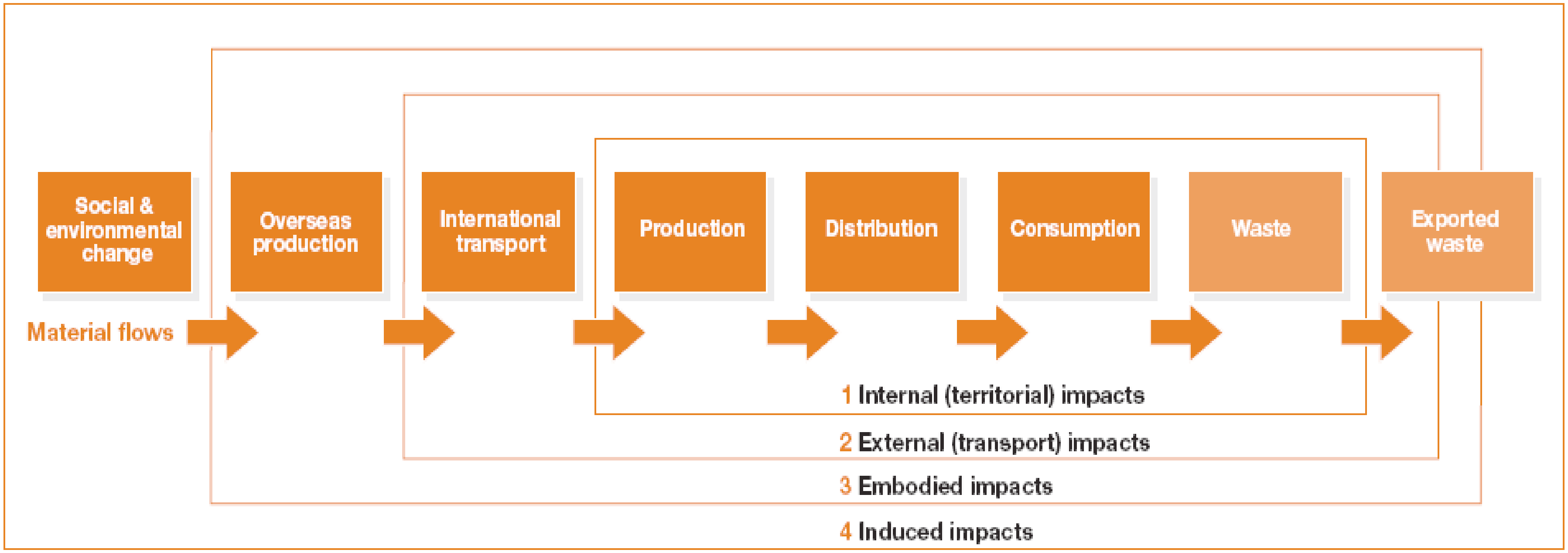
6.4 Ecologic contextualisation of cities



Source: WWF-UK 2006

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Thank you for your attention

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www.imperial.ac.uk/urbanenergysystems
(Online 1st June 2007)