The University of Manchester
Sustainable Consumption Institute

Future Energy and Water Demand: Interdisciplinary insights, methods, critiques

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Based on an article in review: Maria Sharmina, Dana Abi Ghanem, Alison Browne, Sarah Hall, Josephone Mylan, Saska Petrova, & Ruth Wood (in review). Future energy and water demand: Interdisciplinary insights, methods and critiques. Technological Forecasting & Social Change

INTERDEW Project

- Overarching aim: *to define a research agenda to better understand and explore how change in demand for water [and energy] can be projected on a 20 year + horizon*

- People involved: Ruth Wood, Maria Sharmina, Dana Abi-Ghanem (Tyndall Centre, UoM); Ali Browne (SCI/Geography) et al

Our Agenda

- Exploring the types of methods and models that are currently used to understand future demand
- Exploring their ability to provide insights into the paradigm shift challenges (i.e. Environmental, social, technological challenges etc)
- Problematizing the idea of ‘deep uncertainties’
- Bringing interdisciplinary demand modelling in conversation with other disciplinary perspectives on demand

Our Starting Point

- ***Interlinked*** Water/Energy Uncertainties
  - Changing Climate
  - Tipping points
  - Societal responses/adaptations
  - Wider changes in modes of provision e.g., decentralisation, industry reform
  - Wider changes in patterns of use/demand
  - Modernising decaying urban and rural infrastructures e.g., New technologies, infrastructures
- Learning across approaches being developed in the water and energy sectors

WE Nexus Research: Opportunities/Challenges

- Connected to increased research and policy attention to the interlinked issues of Water/Energy
- Opportunities for learning and reflections
- But also a recognition that challenges remain for methodological innovation within the field of energy and water demand
  - Development of shared languages (Bracken & Oughton, 2006; Cairns & Krzywoskzynska, 2016).
  - Integration of methods across ontological divides (Bazilian et al, 2011; Nair et al., 2014; Sharp et al., 2011)

What do <u>we</u> mean by modelling?

- Modelling framed as a way of imagining future demand (not necessarily forecasting)
  - Usually quantitative and programmable machines
  - BUT also can be qualitative, mixed methods
  - Do not necessarily provide ‘one’ answer often provide a range of plausible representations of future demand
- Not all strategic decision making based on modelling but it’s increasingly being used to support planning

What is an interdisciplinary approach to Uncertainty?

- Dominance of particular types of modelling evident (Asdal, 2008, 2014; Barry & Slater, 2002)
- Poor representations of:
  - Rapid change
  - Diversity of behaviour and practices that currently exist (i.e., averaging of demand)
  - Societal responses to uncertainty
  - Demand side uncertainties

Four Attributes of Deep Uncertainty

What qualities (attributes) of the human and natural systems can be used to represent uncertainty of future demand in planning and decision support tools for energy and water sectors?

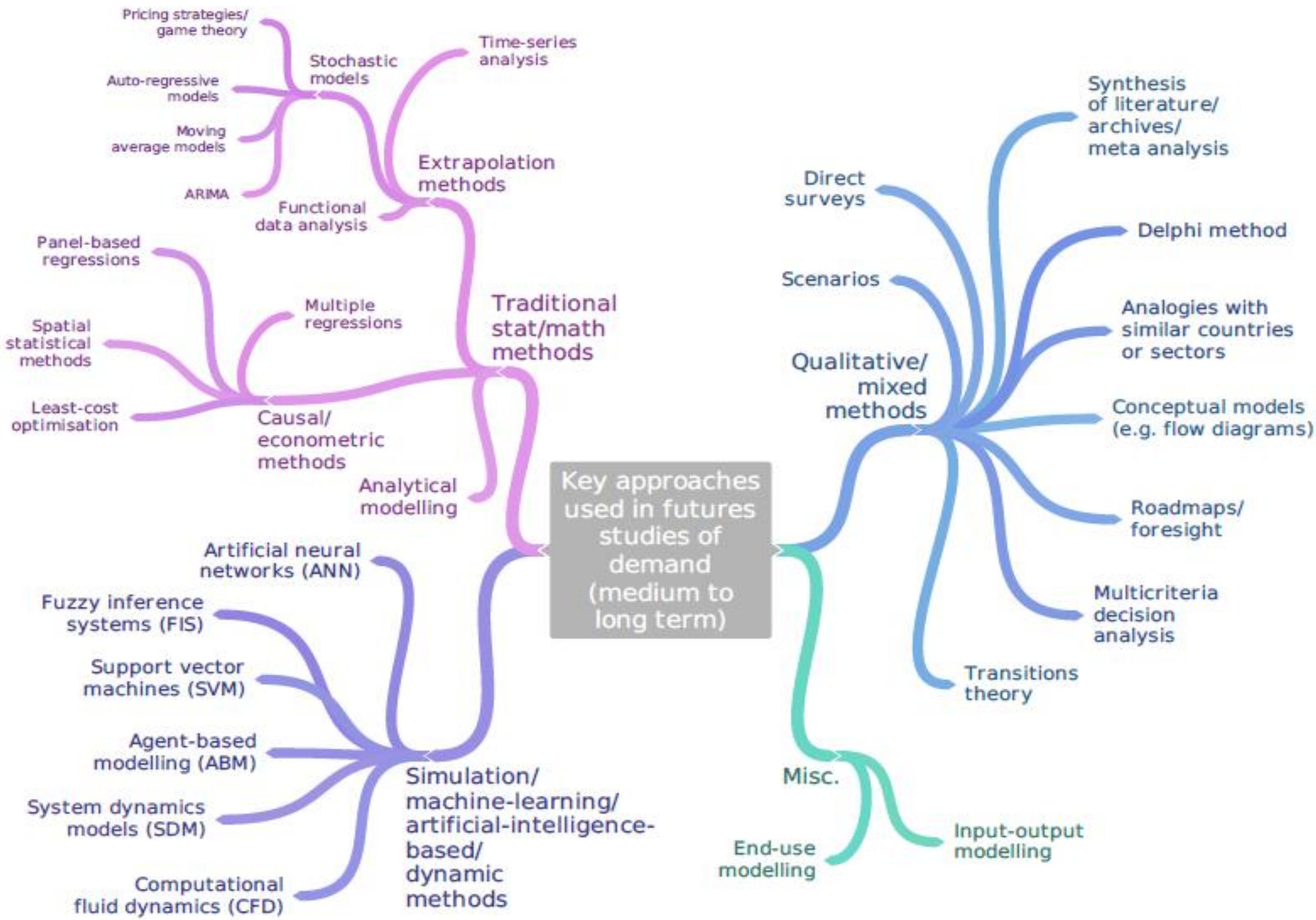
- Stochastic Events
- The Diversity of Behaviour
- Policy Interventions
- Co-Evolution

Table 1. The four attributes of socio-natural systems with examples of variables that models could represent as proxies for sources of uncertainty (Source: own analysis)

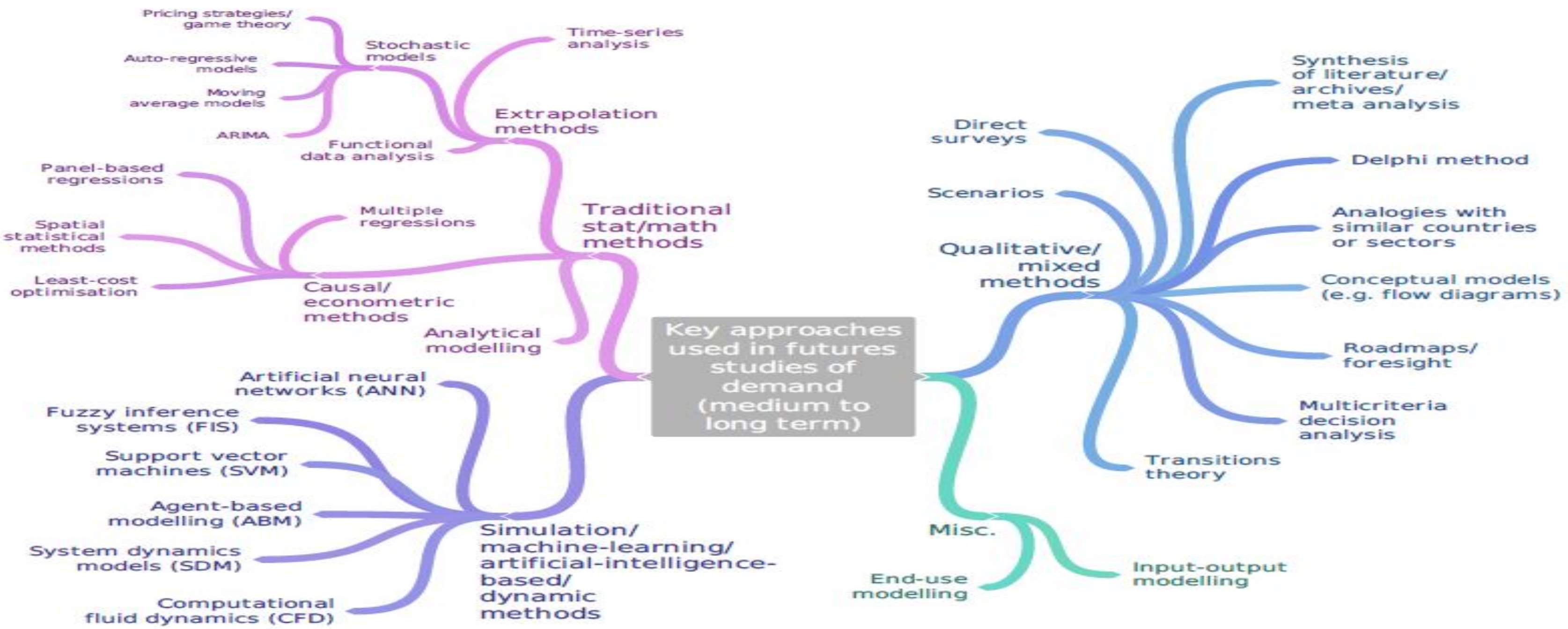
Attribute	Sources of uncertainty captured	Examples of variables to be represented in models
Stochastic events	Unpredictability, randomness, emergent qualities	A stochastic (as opposed to deterministic) representation of climate change impacts, technological breakthroughs, social unrest, economic crises
Diversity of behaviour	Human behaviour (from individual behaviour to behavioural patterns and practices at a population/systems level)	Social networks exerting group/peer pressure; attitudes towards energy and water conservation, consumer classifications, diffusion of information, social and cultural norms
Policy interventions	Planned 'shocks' with unpredictable, particularly unintended, consequences	Standards for fuel and water efficiency, a feed-in tariff, a carbon tax, changes in levels of service provision
Co-evolution	Interactions and feedback loops, path dependency, spatial and temporal scales and levels, non-linear developments	Key relationships and interactions between the variables specified within the other three attributes

Interdisciplinary, intersectoral typology of methods for WE Demand

- Our method in developing a new typology that addresses these attributes we:
- Consolidated methods typologies from the literature
- Expert survey
- Expert workshops (2 workshops with academic and non-academic experts)



Key approaches used in futures studies of demand (medium to long term)
Traditional stat/math methods
Extrapolation methods
Time-series analysis
Stochastic models
Pricing strategies/ game theory
Auto-regressive models
Moving average models
ARIMA
Functional data analysis
Causal/ econometric methods
Panel-based regressions
Multiple regressions
Spatial statistical methods
Least-cost optimisation
Analytical modelling
Simulation/ machine-learning/ artificial-intelligence-based/ dynamic methods
Artificial neural networks (ANN)
Fuzzy inference systems (FIS)
Support vector machines (SVM)
Agent-based modelling (ABM)
System dynamics models (SDM)
Computational fluid dynamics (CFD)
Qualitative/ mixed methods
Direct surveys
Synthesis of literature/ archives/ meta analysis
Delphi method
Scenarios
Analogies with similar countries or sectors
Conceptual models (e.g. flow diagrams)
Roadmaps/ foresight
Multicriteria decision analysis
Transitions theory
Misc.
End-use modelling
Input-output modelling



Typical typologies focus on i) traditional statistical/mathematical methods and ii) machine learning methods occasionally adding in Delphi technique and conceptual models

Augmenting with complementary qualitative and mixed methods approaches; and also other types of methods

Typology is not uniform, clearly demarcated, indicative of all complexity of managing WE resources. Methods overlap substantially. But still a useful heuristic.

What does this new typology 'do'?

- It highlights:
  - what approaches to modelling dominate within the WE sectors (e.g., traditional statistical methods)
  - What approaches are yet to be fully integrated (e.g., machine learning methods, qualitative)
  - what 'knowledges' underpin our current understandings of uncertainty and planning
  - what biases exist in the way that research questions are being asked within WE sectors (i.e., shared technical interests see Shove, 2011; Asdal, 2011)
  - A dominance on only some of the attributes of uncertainty (e.g., stochastic events, linear approach to policy intervention, reductionist incorporation of 'behavioural' features and rational choices) over others (e.g., diversity of behaviour, co-evolution, dynamic and non-linear policy intervention effects)
  - Least represented in the reviewed modelling methods is 'co-evolution' i.e., feedback loops, interrelationships between demand/supply systems and insights from the critical social sciences

Opportunities: Explore machine learning methods

- Machine learning methods – increasing focus should be paid to this approach given ability to capture dynamic processes, non-linear interactions, behavioural patterns (House-Peters & Chang, 2011; Kandil et al., 2001)
  - Disadvantages: complexity and data intensity compromises transparency of models and obscure interpretation of results

Opportunities: Explore Qualitative and Mixed Methods Category

- Moving beyond methodological individualism of psychological approaches to demand (Jackson, 2005)
- Exploring population level changes as a system dynamic
  - e.g., response of behaviour within stochastic events,
  - e.g., exploring the co-evolution of systems of practices (practices/demand, wider factors of technological and infrastructural change)
  - Paying greater attention to ideas of difference and unevenness of WE within and across societies and space (inequalities, justice, gender, class, intergenerational)

Opportunities: Modelling Demand as Co-Evolution

- What do we mean by co-evolution?
  - Social nature of demand (e.g., cultural norms around cleanliness or good life in gardens)
  - Material nature of demand (e.g., infrastructures and technologies at various scales and how they configure demand
  - How demand is 'done' (e.g., how demand is performed – or disrupted – on the day to day)

  - Scaling up from an understanding of the diversity of behaviour to what happens to all of these factors at a population level ….

How to do this is still a challenge across water/energy sectors

Final Reflections:

"What this research highlights in relation to 'futures', particularly in light of modelling, is that the past-present-future is not an evenly shared or homogeneous entity to be modelled as a singular 'demand' outcome. The challenge for futures studies is to understand the way that water and energy supply-demand systems vary across time and space" (Sharmina et al., under review).

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Questions?

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New approaches to Diversity of Behaviour Patterns of Water Project (beyond the averages with a focus on diversity across performance of water practices)