UCL

UNIVERSITY OF CAMBRIDGE

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wholeSEM

A seminar to key UK energy policy stakeholders:
BEIS, CCC, Ofgem, ESC

Energy Modelling for UK Policy Insights:
Successes, failures, lessons and future directions

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EPSRC
Pioneering research and skills

Seminar Overview

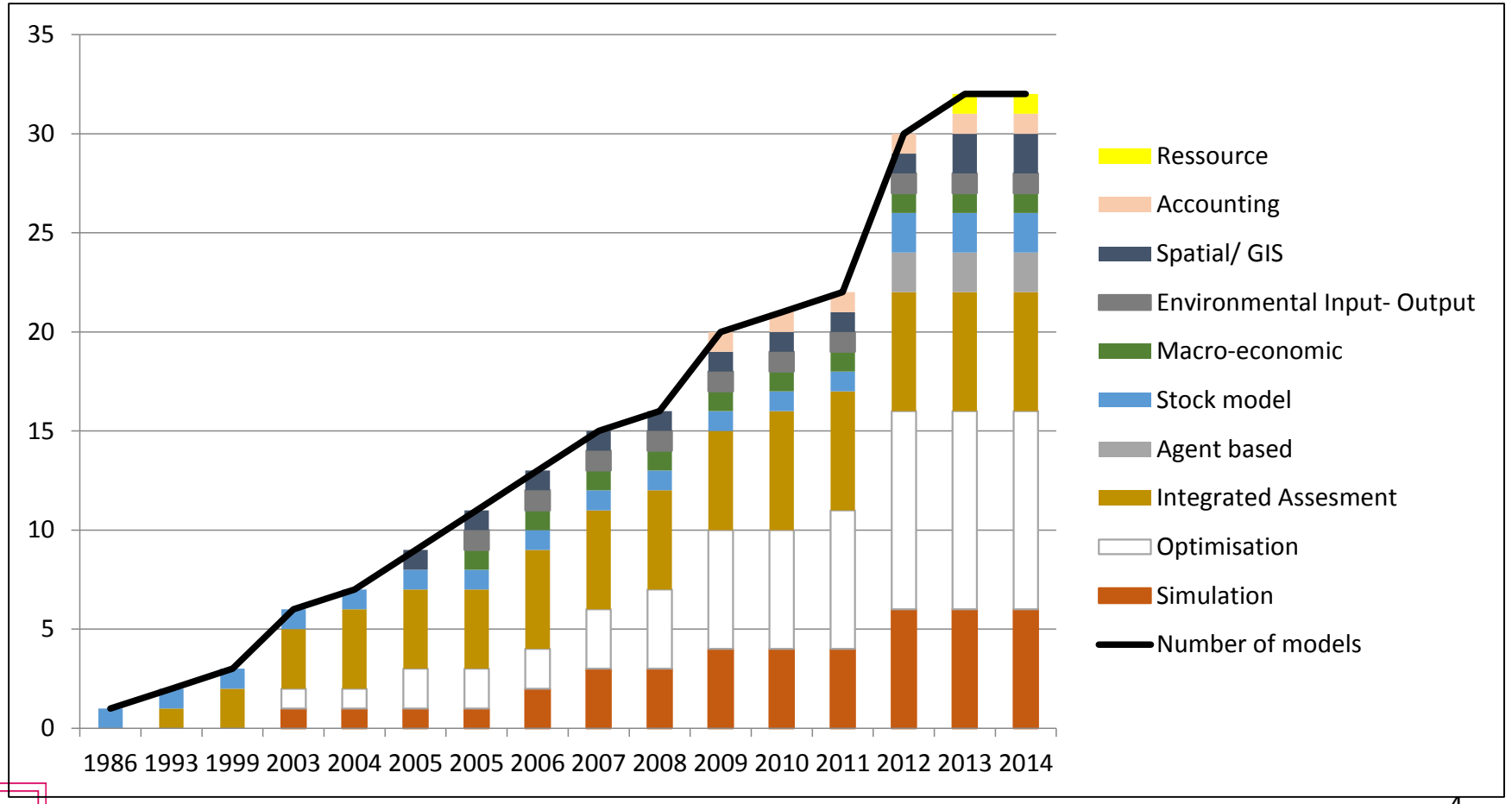
A personal view of the lessons from the successes (and failures) of the Whole Systems Energy Modelling consortium (www.wholesem.ac.uk)

1. A little energy modelling history
2. WholeSEM's disciplinary and hybrid energy modelling
3. Practical advice for energy model developers and users
4. Future research and future outreach

Energy modellers have been working diligently for decades to provide insights to decision makers

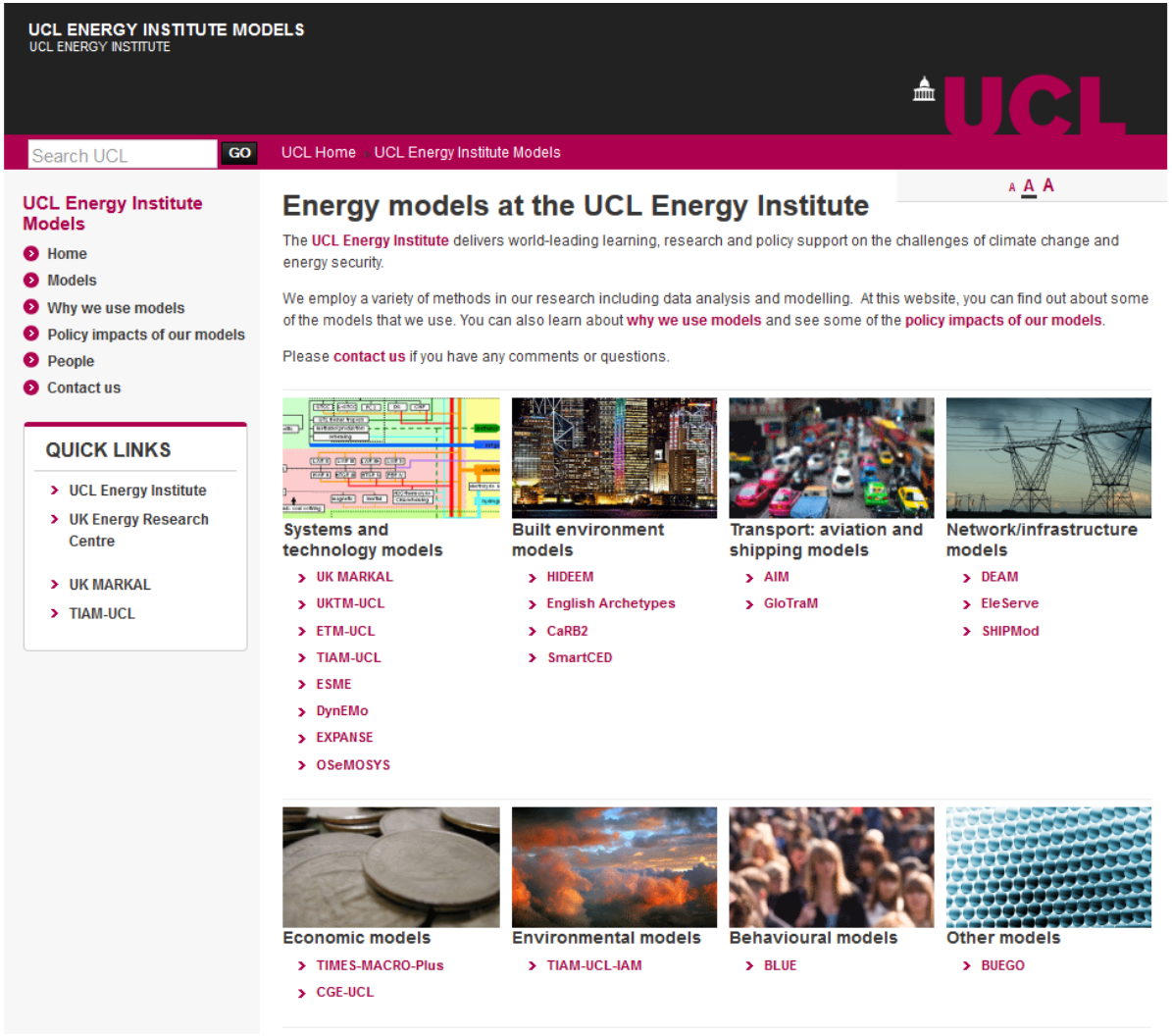
- Huntington, H., J. Weyant and J. Sweeney (1982). *Modeling for insights, not numbers: the experiences of the energy modeling forum,* Omega 10(5): 449-462

Number of UK Energy models 1986-2014
(Zeyringer, 2014)



Intentionally wide range of models
(formulation, spatial scale, temporal scale and purpose)

UCL-Energy Models:
www.ucl.ac.uk/energy-models



We are only OK are getting broad trends and quantities correct

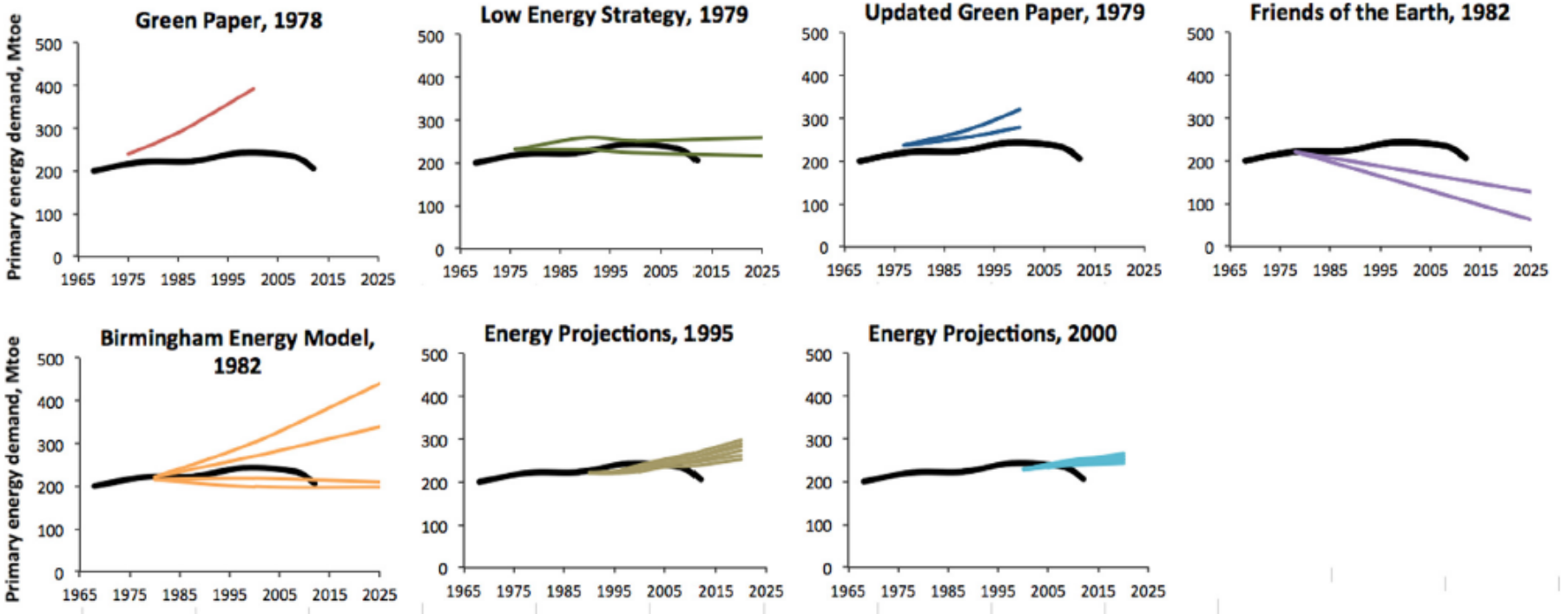
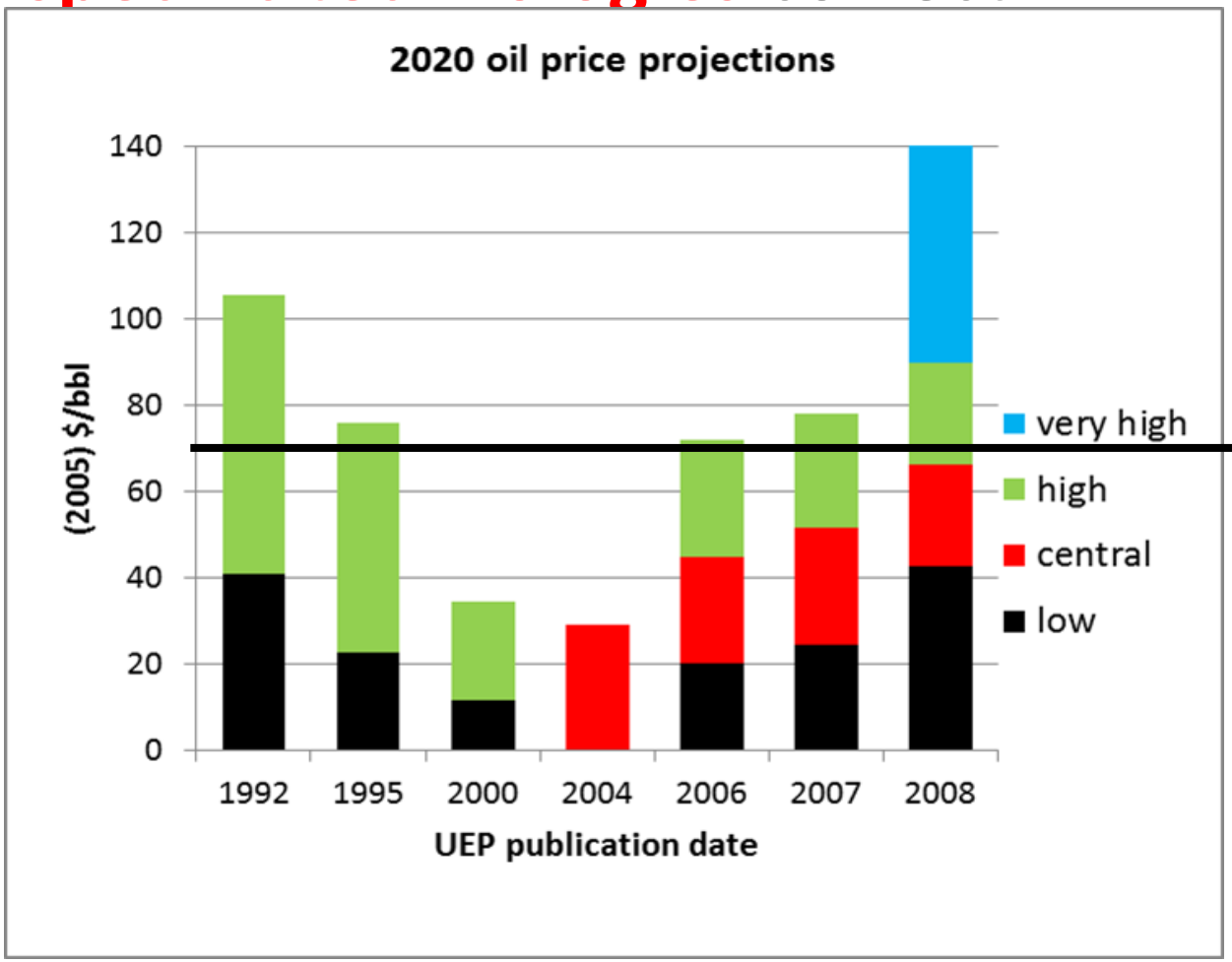


Fig. 2. Comparison of the actual primary demand transition (black line) and selected past UK energy scenarios in terms of primary energy demand, Mtoe.

We are poorer at getting prices and specific technologies correct



Brent crude oil price on 30/01/18: $68.62

Source: Strachan, N. (2011). *Business-as-Unusual: Existing policies in energy model baselines*, Energy Economics 33(2): 153-160.

I could also have given examples of industrial CCS deployment, cost reductions in PV and wind, residential energy efficiency uptake, hydrogen freight vehicles etc.

2. Disciplinary and hybrid energy modelling – key insights

wholeSEM proposal objectives

- **EPSRC gave us £4.6 million over 4 years**
- **Main objectives of the wholeSEM consortium were:**

1. Undertake internationally cutting edge research on prioritised energy system topics;
2. Integrate whole energy systems modelling approaches across disciplinary boundaries;
3. Build bilateral engagement mechanisms with the wider UK energy systems community in academia, government and industry.

WholeSEM babies: A tangible outcome!

- UCL
  - Kate, Hannah, Marianne, Ilkka
- Cambridge
  - Sandy, (and Sandy), Dennis, Rick
- Surrey
  - Maria, Tom
- Imperial
  - Meysam, Marko

Selected wholeSEM insights from disciplinary modelling

- Flexible electricity technology deployment could give cumulative savings of £17 – 40bn in the UK electricity system
  - Strbac G. , M. Aunedi and D. Pudjianto (2016), *An analysis of electricity system flexibility for Great Britain*, report to the Carbon Trust
- Myopia in strategic investments, or a focus on -80% rather than net-zero CO_2 emission targets could entail very large infrastructure costs
  - Fuso-Nerini F, I. Keppo, N. Strachan (2017), *Myopic decision making in energy system decarbonisation pathways. A UK case study*. Energy Strategy Reviews, 17: 19–26
  - Pye S., Li F., Price J., Fais B.(2017) *Achieving net-zero emissions through the reframing of UK national targets in the post-Paris Agreement era*, Nature Energy, 2(17024)
- UK decarbonisation pathways are unlikely to have no-regret options for land/water, and/or to export these wider environmental impact
  - Konadu D., Zenaida S., Allwood J. et al., (2015) Land use implications of future energy system trajectories—The case of the UK 2050 Carbon Plan, Energy Policy, 86: 328-337
- 82% of people have regretted purchasing goods in the UK, worth £5–25bn per year, equivalent to 2–10% of annual consumer spending
  - Roberts T., Hope A , Skelton A. (2017) *Why on earth did I buy that? A study of regretted appliance purchases*. The Royal Society Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 375

Our research and policy impact

- Models (all with summary documentation)
  - Extended: UKTM, FORSEER; WeSIM [linked to SUC, PriceDSP, DTIM, DistPlan and CGEN]
  - New: STeMES, highRES, BLUE, HOPES
- Journal papers
  - 43 as of July 2017, with lots more to come…!
- Stakeholder engagement
  - BEIS/DECC, CCC, ETI/ESC, Ofgem, DDPP (Paris Agreement) etc
  - Major contributions to Clean Growth Strategy, Industrial Strategy; CCC's 5th budget assessment
  - Missing other stakeholders and industrial decision makers?

Proposal outreach mechanisms

Mechanism	Notes
High profile advisory board	Sustained and deep engagement
Innovative fellowship programme (12 Fellows)	**7 out**: IEA, LBNL (USA, X2), CCC, DECC, UC Berkeley (USA), E3M (Greece) **6 in**: Simon Fraser university (Canada), NC State (USA), KIT (Germany), DECC, Aalto university (Finland), PSI (Switzerland)
Annual workshops (4)	>120 attendees per event; high profile keynotes; excellent feedback; PhD sessions; modelling cafes
Technical (24) and stakeholder (12) workshop	23 in total, including BE4, Myopic, Household energy, Social practices, IQ Scene, Land-energy nexus, Water-energy nexus, Spatial/temporal, Flexibility, Deep uncertainty
Detailed and transparent model documentation	Summaries on our website; Innovative model animations
Provision of training in modelling techniques	ABM courses; Selected training to key stakeholders (eg National Grid)
Interactive web-based information	Popular website, Twitter
Journal papers	43 as of July 2017; Many more to come…!
Curation of energy modelling data	
Model access via expert user group	Only UKTM?

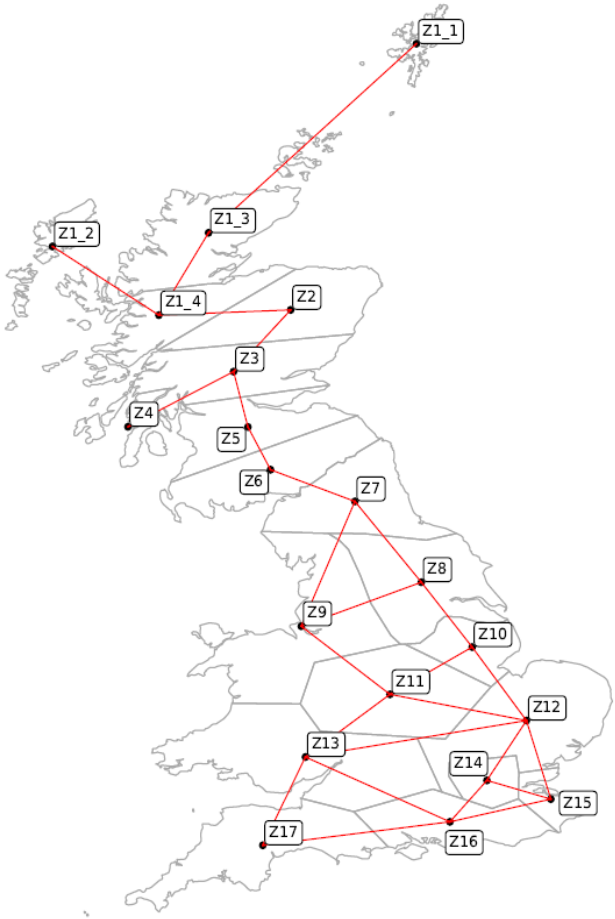
The 5 Stages of Interdisciplinary energy modelling

wholeSEM

Stage	Reaction/Response by Consortium Members
#1: Denial	I can't believe my colleagues don't know: a) Neoclassical Economics b) Elementary Psychology c) Basic Engineering Principles d) The Laws of Thermodynamics
#2: Anger	Why does "inter-disciplinary research" mean **I** need to adjust **my** thinking and change **my** modelling approach ??
#3: Bargaining	I'd be OK if only my colleagues would use my methodology / underlying tenet / words I actually understand !!
#4: Depression	Have you seen the Gantt chart and all the deliverables we've promised EPSRC / our Advisory Board / wider stakeholders ….
#5: Acceptance	This multi-disciplinarity and model linking really does allow us to generate and communicate new insights on whole energy systems analysis ☺

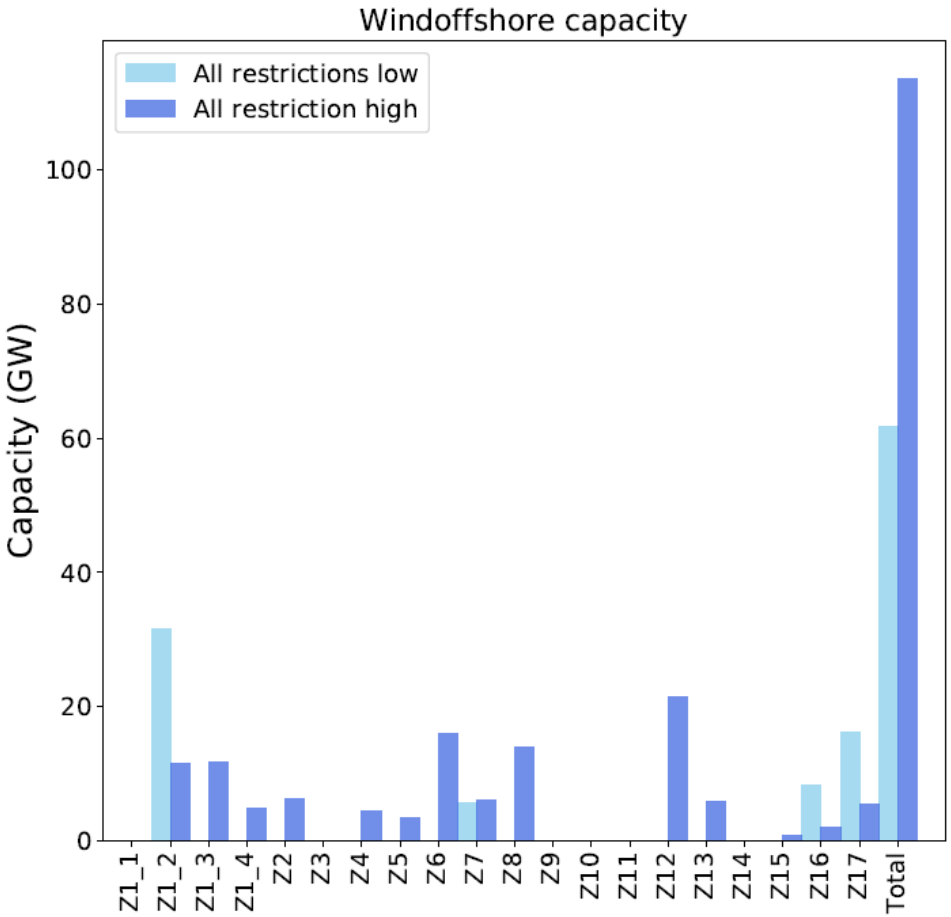
Hybrid modelling:
"TopDIP" Nexus case study

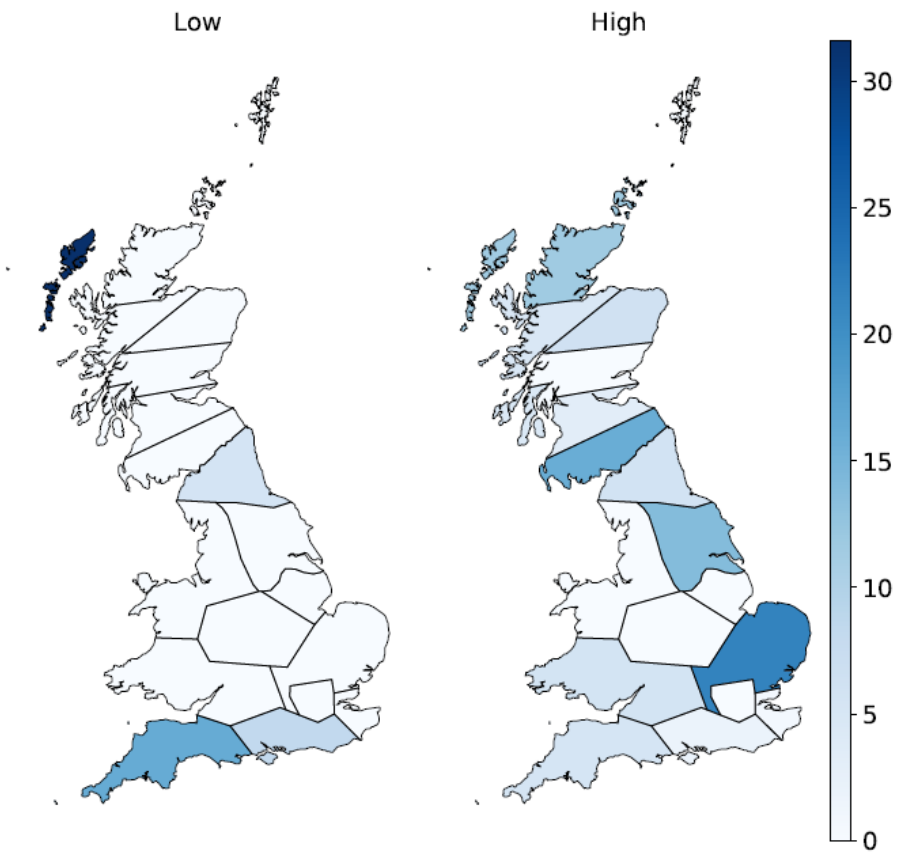
- Aim
  - Represent spatial factors for variable renewables, nuclear and fossil generation
- Models
  - High spatial and temporal resolution electricity system model (highRES) – runs for one "snapshot" year
    - Makes capacity investment (annualised costs) and operational (dispatch) decisions
  - Soft linked to UK TIMES (UKTM)
    - Cost optimising, long time horizon model of the whole UK energy system
  - Here integrated with Foreseer
    - Estimates land & water availability based on future demand by different sectors at high spatial resolution



Offshore wind deployment

(extreme low and high constraints: Land, Water, Nuclear, VRE)





3. Practical advice for energy model developers and users

How an energy modelling team works (should work) in practice

- General
  - Give the model a name
  - The “Strachan 3-person rule”
  - Ask yourselves every year whether the model should be retired
- Prioritise uncertainty analysis
  - Alternate scenarios/narratives
  - Model diagnostic runs
  - Establish and test key parameters (sensitivities or Monte Carlo)
  - Investigate/compare model structural uncertainty (few teams do this well or at all)
- Go open source
  - Full documentation (online), including data (very hard to keep updated)
  - Model source code and software environment (if practical)
- Peer reviewed
  - Journal papers (academia and other experts)
  - Dedicated reports and outreach (government, industry and civil society)
- Expert user group
  - Model developers and users in government, industry, consultancies and academia
  - International support network

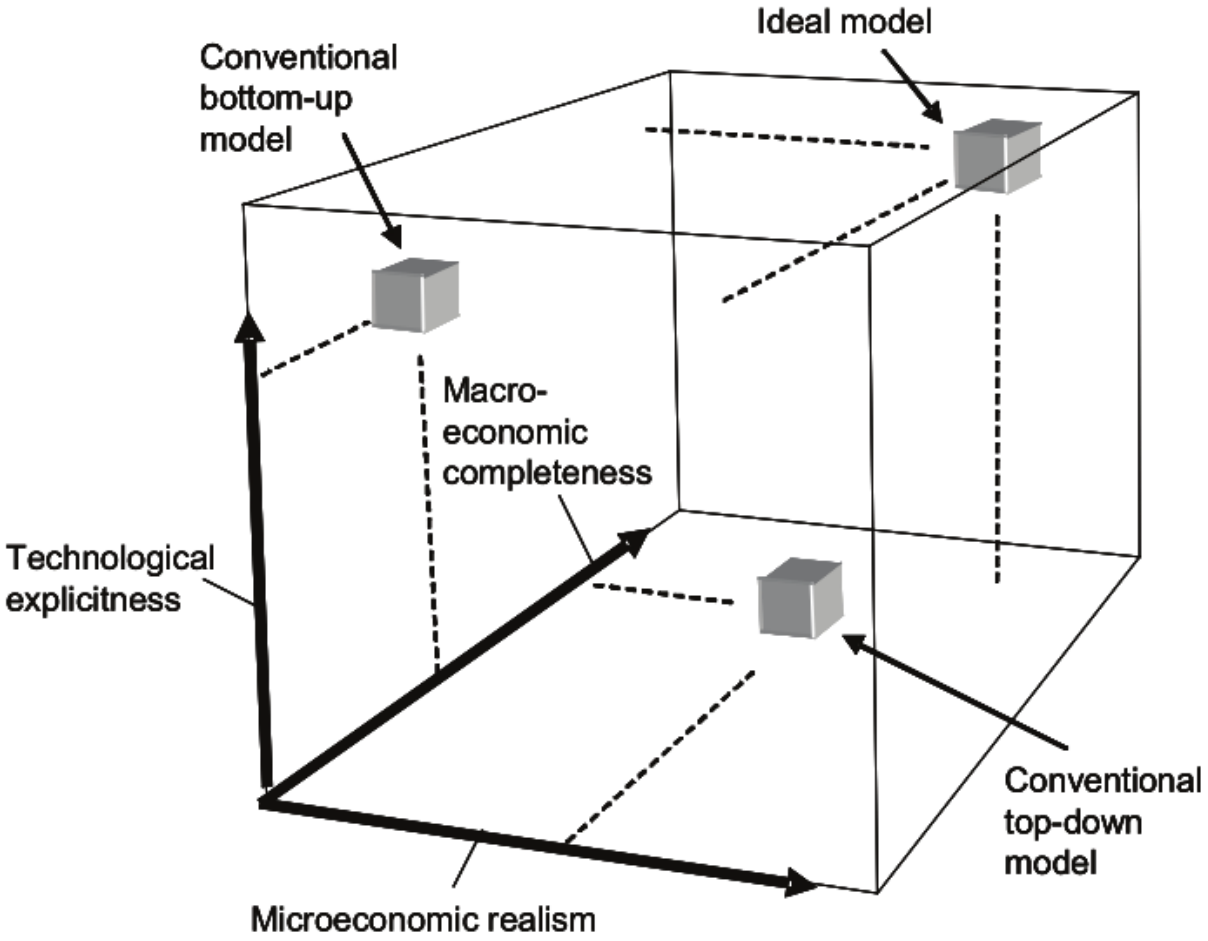
Reinventing the energy modelling-policy interface

Category	Current Limitation	Proposed Improvement
Enabling	Uneven path dependant development	Coupling to funding and policy cycles
Coordination	Incumbency advantage	Platform based expert user groups
Review	Modelling silos	Interdisciplinary external stakeholder review
Transparency	Lacking incentives for quality assurance, version control and documentation	Targeted resourcing for these model process tasks

Source: Strachan, N., B. Fais and H. Daly (2016). *Reinventing the energy modelling–policy interface.* Nature Energy 1(3): 16012.

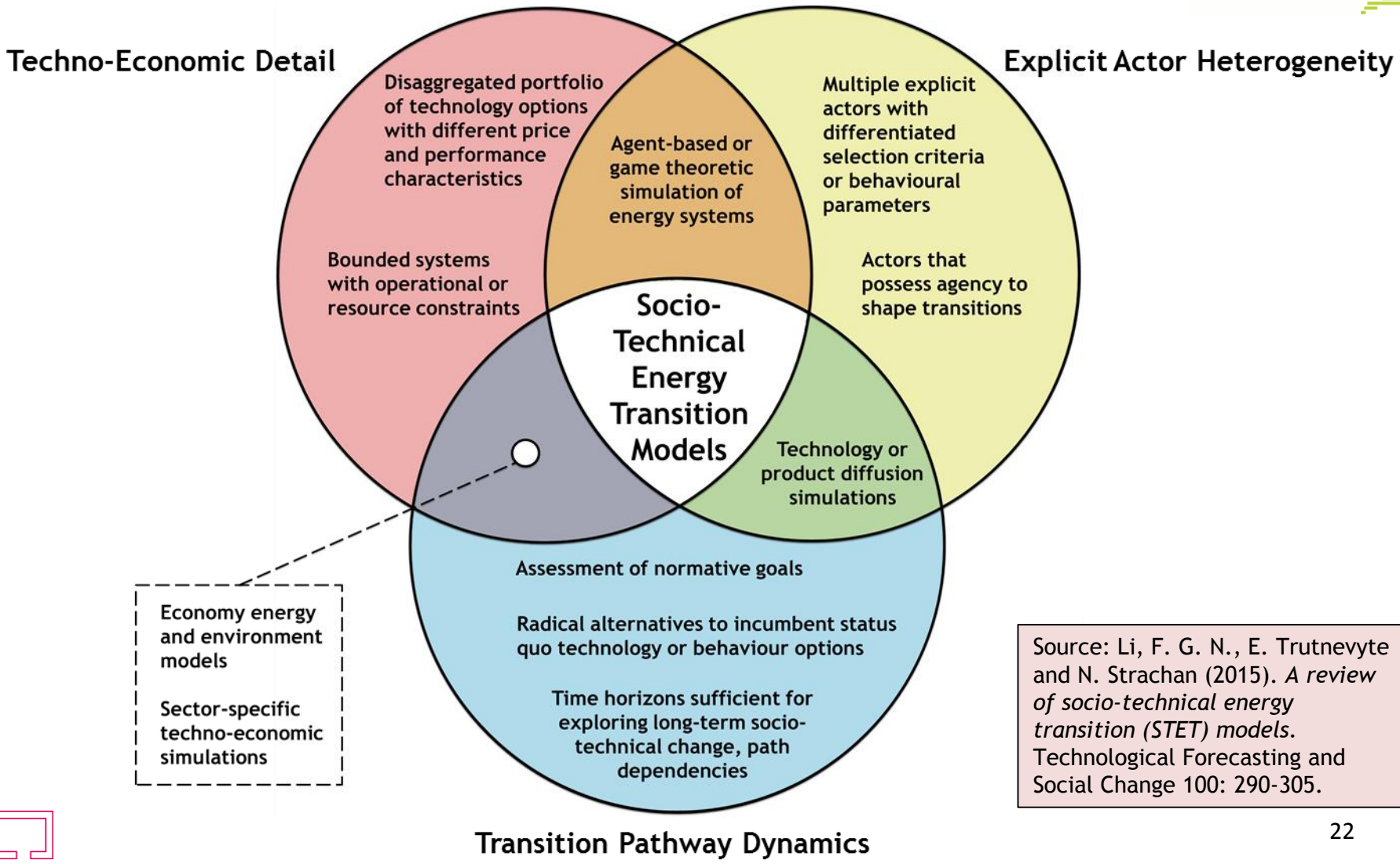
4. Future research and future outreach

Hybrid energy models:
Conventional typology



Hourcade 2006, Hybrid Modelling: New Answers to Old Challenges
doi: 10.5547/ISSN0195-6574-EJ-VolSI2006-NoSI2-1

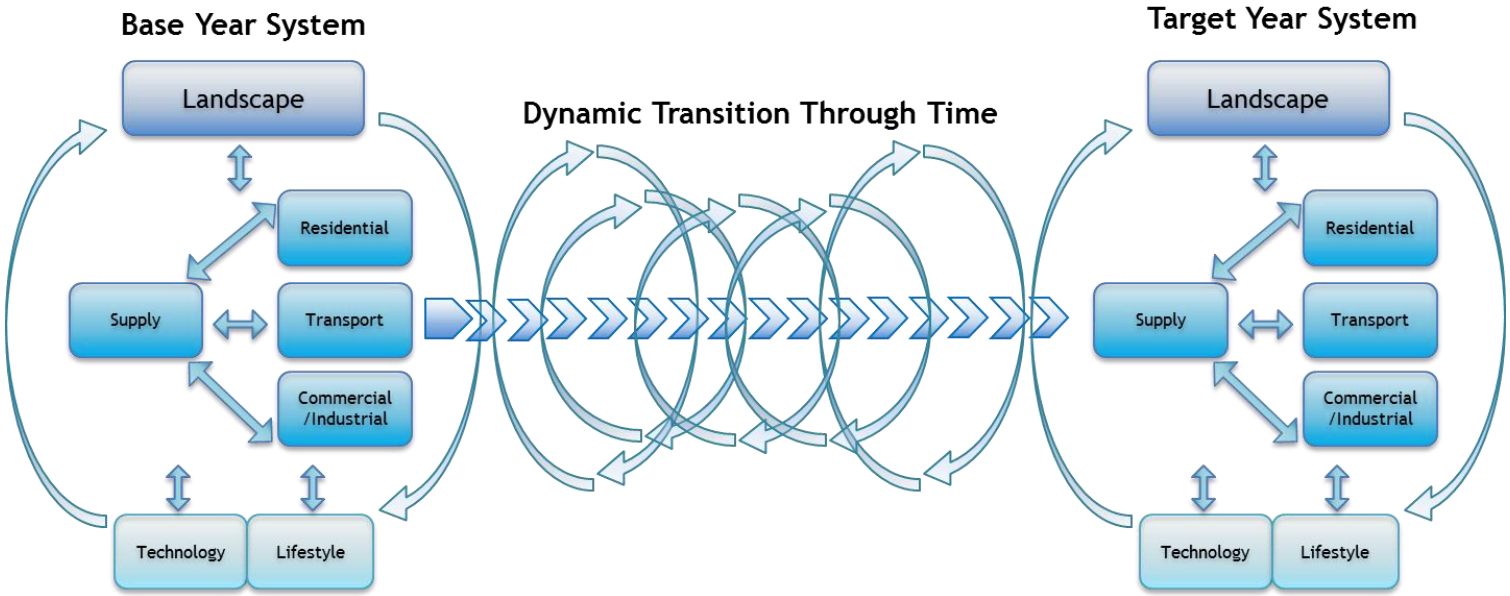
Socio-Technical Energy Transition (STET) Modelling



Source: Li, F. G. N., E. Trutnevyte and N. Strachan (2015). *A review of socio-technical energy transition (STET) models.* Technological Forecasting and Social Change 100: 290-305.

blue Behaviour Lifestyles and Uncertainty Model

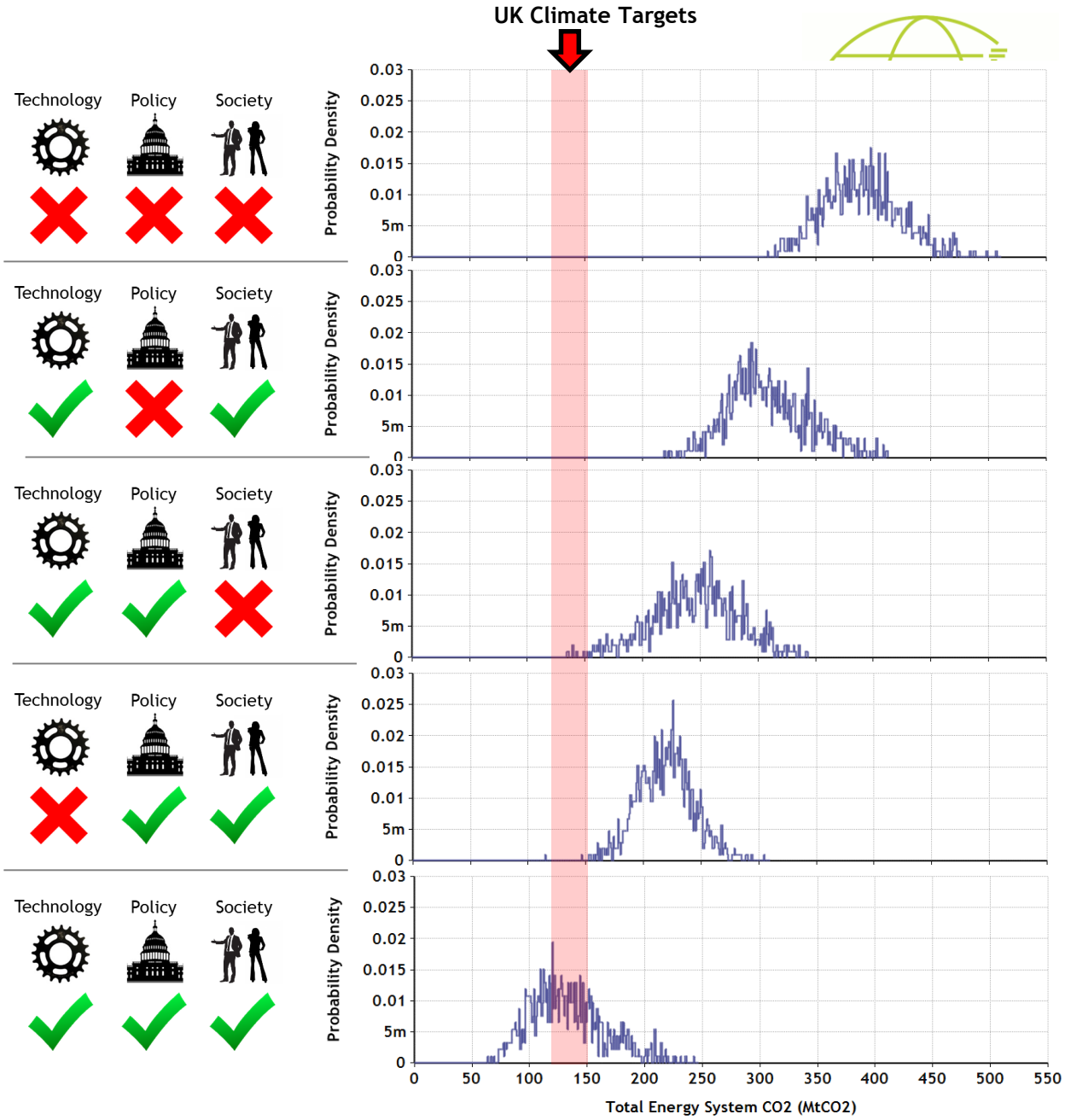
- Stylized probabilistic energy simulation model
- Lowest cost solution
- But with iterative government drivers, and new niche social practices
- Actors make independent reactive investment decisions with highly limited knowledge of the future



Detailed model information: Li F. and Strachan N. (2016), *Modelling energy transitions for climate targets under landscape and actor inertia*, Environmental Innovation and Societal Transitions, http://dx.doi.org/10.1016/j.eist.2016.08.002

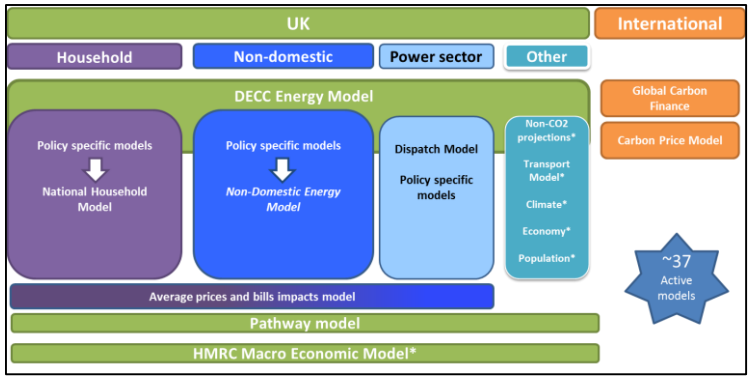
BLUE Output

- 2050 emissions visualised as a distribution vis-à-vis the UK's GHG targets (here 146-180 MtCO2)
- Incremental changes in any single dimension alone do not bring the system to achieve UK climate targets
- Breakthroughs in technology, behaviour and political action all appear critical for achieving deep decarbonisation



What is the UK Government doing?

- Dedicated BEIS effort to rationalise the energy models it uses
- Close collaboration with other model experts
  - e.g., UKTM user group
  - e.g., Review of the DECC Energy Model
- Drive towards Open source modelling
  - With exceptions (e.g. HMRC CGE model)
- Drive towards Quality Assurance of models
  - Difficult to do with complex/large tools



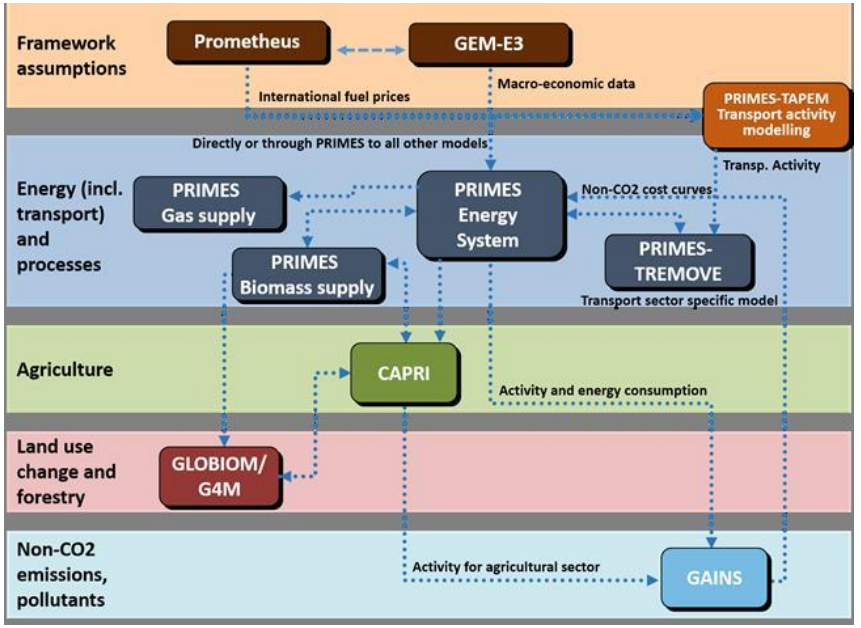
- Significant RCUK (UK R&I) whole systems portfolio concluding models
  - UKERC, EUED, wholeSEM, CESI, SuperGen etc

What is the US government doing?

- US EIA
  - **NEMS model**: https://www.eia.gov/outlooks/aeo/nems/documentation
  - Nested multiple market sector simulation model with integration model of supply/demand
  - Available but…
    - >100 staff at the US DOE to run
    - Requires multiple programming languages and software environments
    - Many obtain the model simply to use the data in its input files
- PNL National Laboratory
  - **GCAM model**: http://www.globalchange.umd.edu/gcam/
  - Dynamic-recursive model with technology-rich representations of the economy, energy sector, land use and water linked to a climate model
  - One of the big 4 (or 6) Integrated Assessment Models
  - Open source (download using GitHub)
  - Annual training working and documentation
  - But, after 20 years of development no-one knows the full model

What is the EU government doing?

- Historical reliance on PRIMES
  - Nested multiple market sector simulation model with integration model of supply/demand
  - Very opaque…



- New EU models of energy system (POTENCIA) and power/gas (METIS)
  - Open documentation, open source (ish), but certainly not free!
  - https://ec.europa.eu/jrc/en/potencia
  - https://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis

What are international modellers doing?
(academics and consultants)

- Incumbent model teams sharing insights via model comparison exercises
  - EMF: https://emf.stanford.edu/
  - EMP-E: http://www.reeem.org/index.php/emp-e-main/
- Collaborative modelling teams sharing code, software and data to reduce model maintenance and development
  - TIMES: http://iea-etsap.org/
- Overall drive for smaller, more nimble, (and free!), open-source models
  - Note, not necessarily new model types
  - http://www.energyplan.eu/
  - http://openmod-initiative.org/
  - http://www.optimus.community/
  - http://www.osemosys.org/
- Consultants are pursuing alternate strategies for stable income
  - https://www.auroraer.com/about/our-models/
  - https://energyexemplar.com/software/plexos-desktop-edition/
  - Most difficult for these players to undertake open source, Q/A, peer review, model collaboration etc.

Recap: Future modelling directions

- **From techno-economic to socio-political**
  - Capture the non-equilibrium, non-optimality, non-rationality elements
  - Of the path-dependent, agent-dependent and scale-dependent energy system
- Address data bottle-necks
  - e.g., via smart meters?
- Open source and collaborative
  - Raise the bar on model QA and replicability
  - Pursue novel methods of model communication