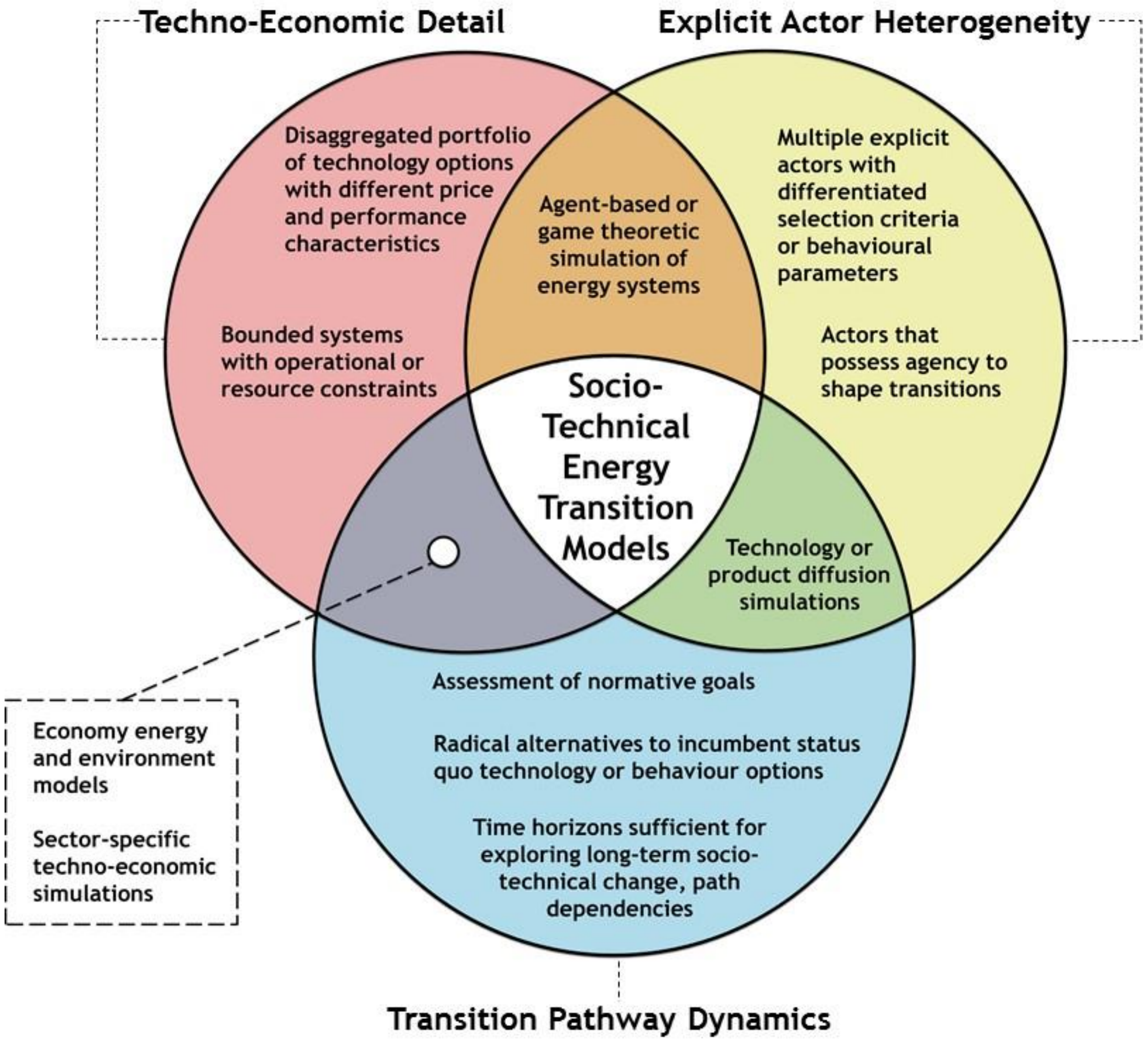
Modelling human behaviours in energy transition – a socio-technical energy transition (STET) perspective

ETSAP Workshop series

15/9/2022

Rachel Freeman, UCL Energy Institute

A taxonomy for socio-technical energy transition models (Li and Strachan, 2017)



The TEMPEST model: socio-politically driven energy transition

- System dynamics simulation model of UK energy transition, 1980 to 2080, calibrated to historical data 1980 to 2019
- Model "fuel" is UK political capital for energy transition
- "Public willingness to participate" indicates likelihood of measures being deployed
- "Influence of affluence" (disposable income)
  - increases energy services demand (ESD)
  - increases the adoption of low carbon technologies in the mass consumer demand sectors
- Behavioural measures cause reductions in ESD across demand sectors
- Behavioural changes in the adoption of low-carbon demand equipment (e.g. EVs) increased through policies and feeds the measure diffusion process (S-curve)
- Societal pushback against policies can reduce mitigation

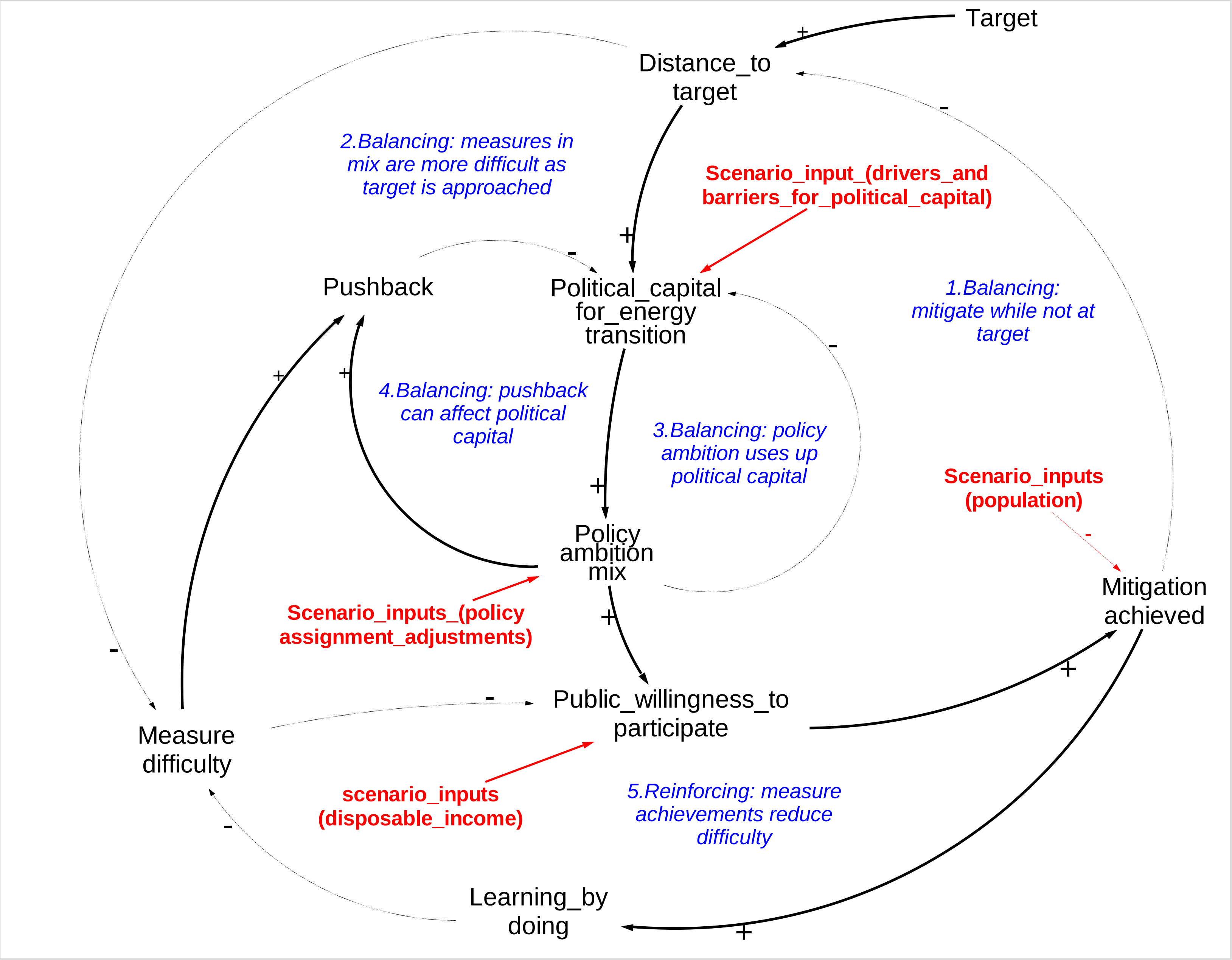
Freeman R, 2021, "Modelling the socio-political feasibility of energy transition to net-zero with system dynamics", *Environ. Innov. Soc. Transitions* **40** 486–500

Energy behaviours and GHG emissions - demand side

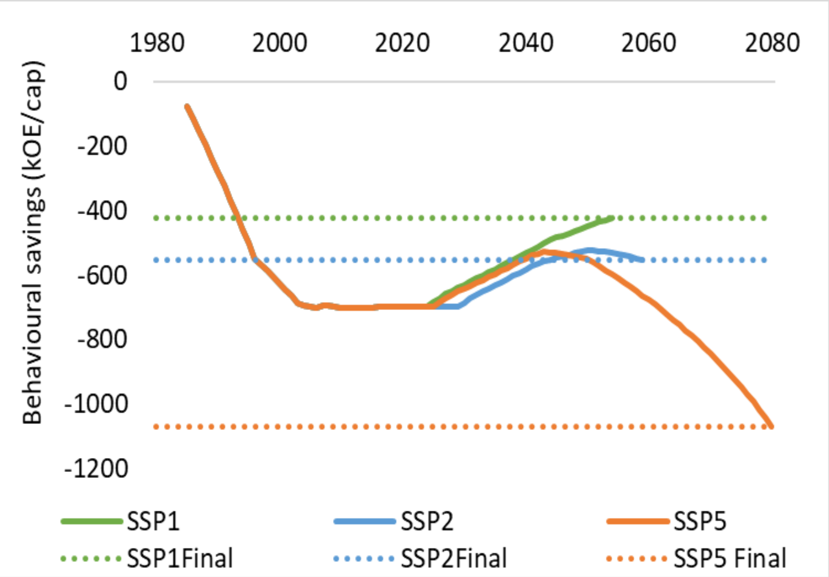
$$\text{GHG emissions} = \textit{energy service demand} * \frac{energy}{service\ demand} * \frac{GHG}{energy}$$

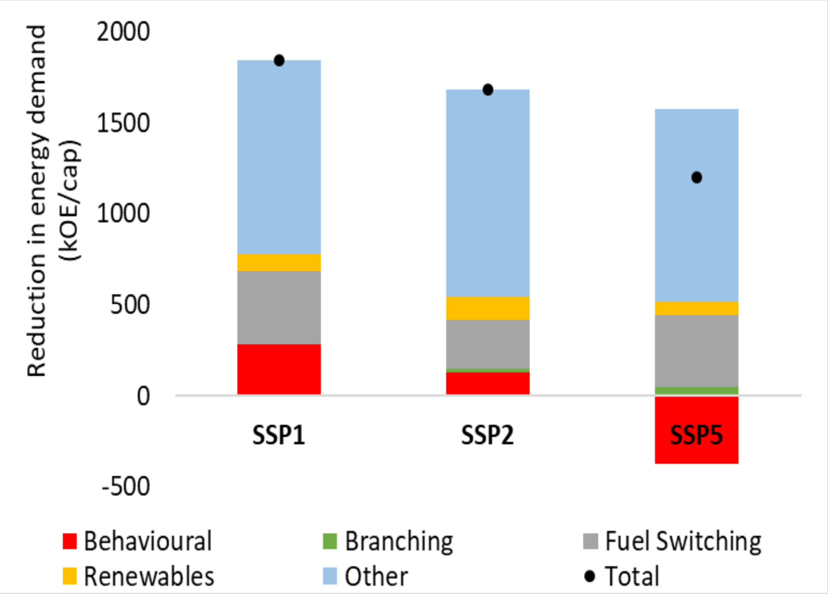
Term	Explanation/ Examples	Behavioural changes
Energy service demand (ESD)	passenger-km travelled per year, average indoor temperature in winter, capacity of refrigeration per capita, average tons of goods consumed per year	Reduce or shift consumption (e.g. private driving to public transport)
Energy intensity of ESD	Amount of energy used to produce, run and “end-of-life” goods and services	Energy efficient equipment, reduce energy wastage
GHG intensity of energy	GHG emissions per unit of energy used to supply energy services	Distributed renewable energy, fuel switching (e.g. to electricity from natural gas)

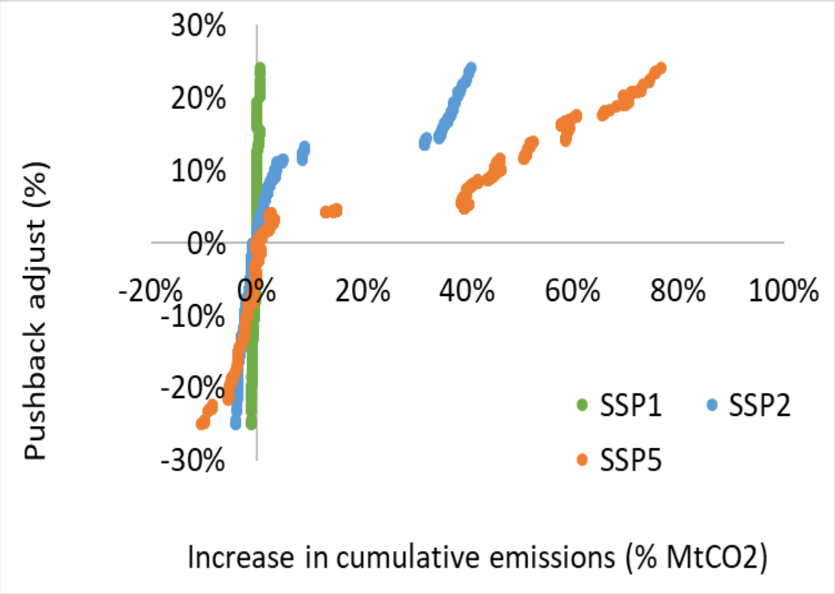
Feedbacks in TEMPEST



TEMPEST results related to behaviours

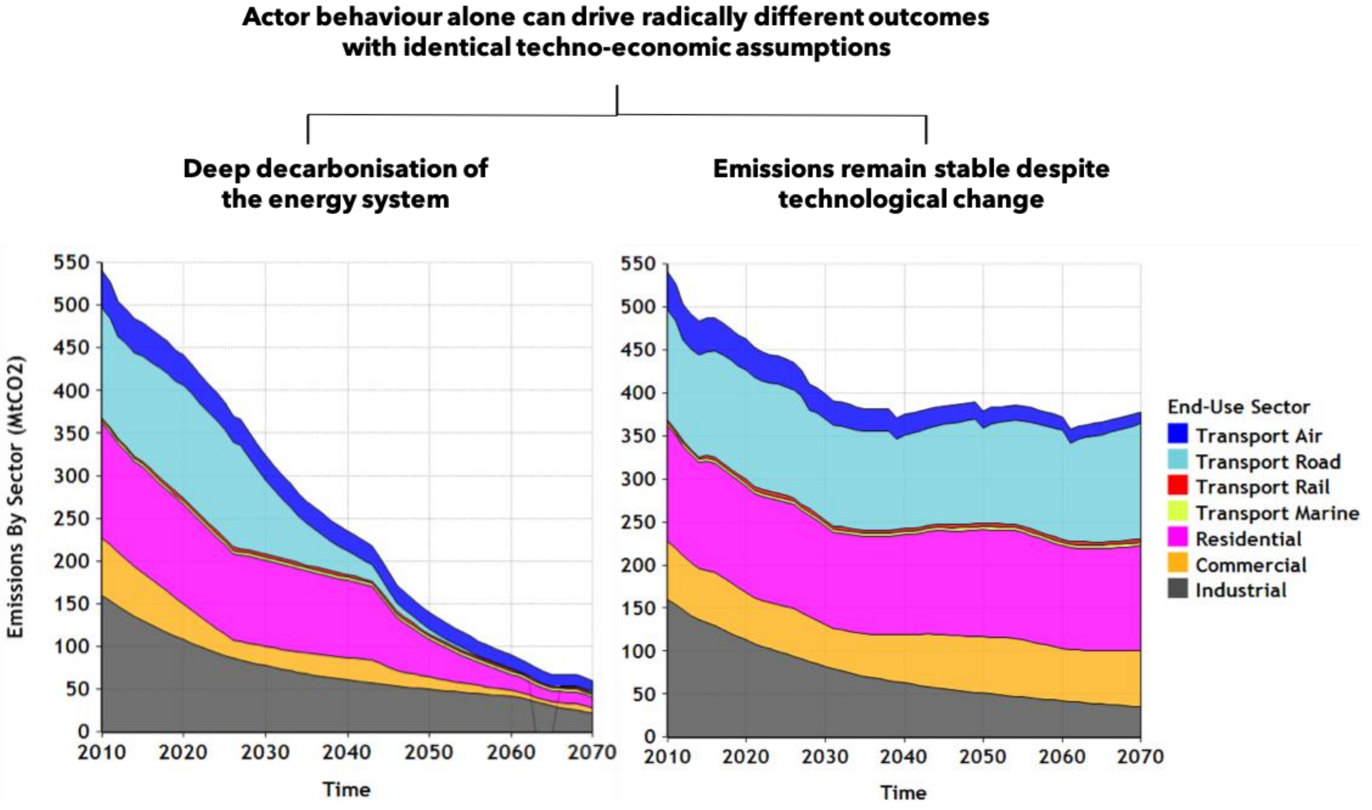


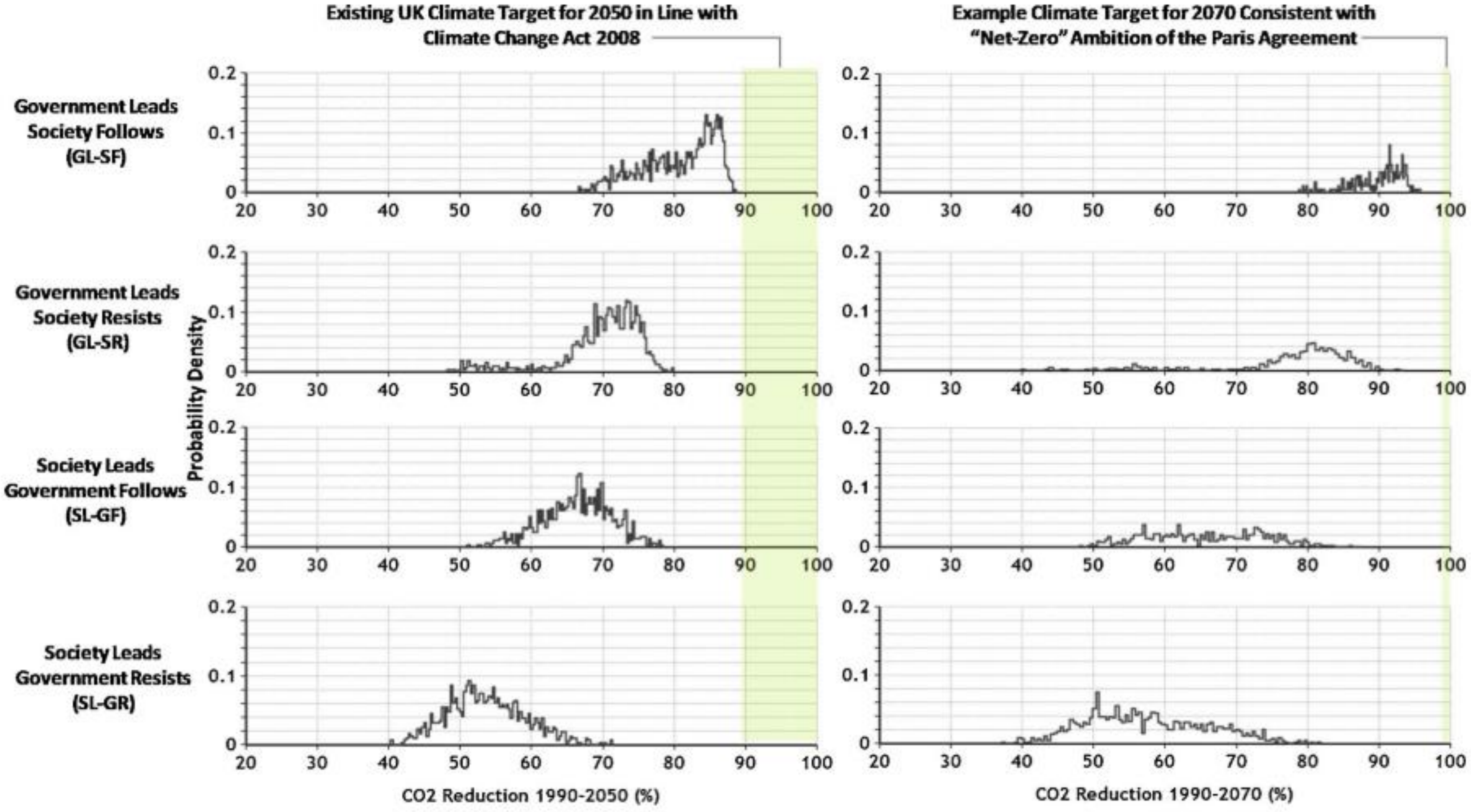




Behaviour lifestyles and uncertainty energy model (BLUE)

- Technologically and behaviourally detailed
- Employs multiple representative agents
- Suitable for policy (quantitative, captures whole energy system)
- Explore questions about behaviour and energy governance
- Uncertainties due to sector- and actor-specific behavioural elements:
    - market heterogeneity
    - intangible costs and benefits
    - hurdle rates
    - replacement rates
    - refurbishment rates
    - demand elasticity



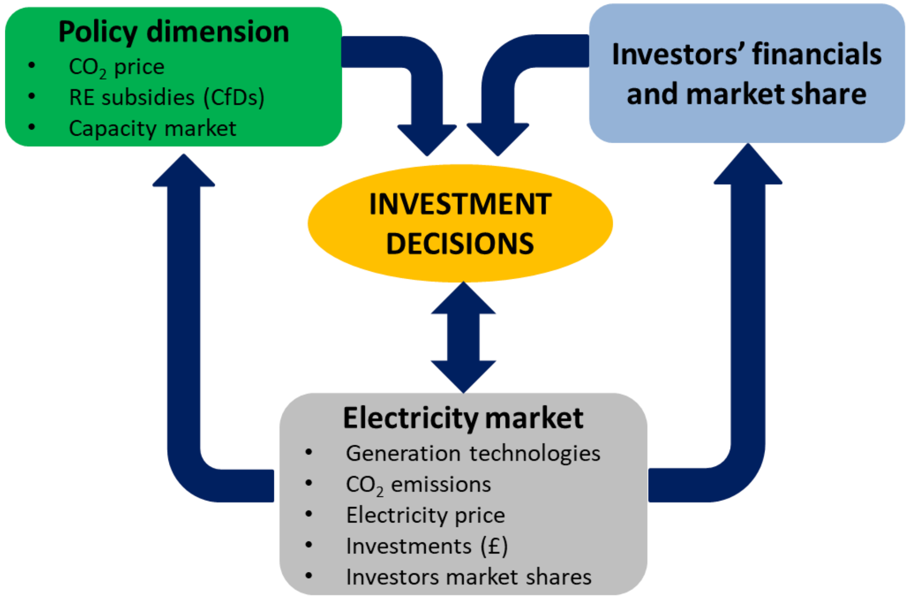


3. Emissions reductions against climate targets for the year 2050 and for the year 2070 in different transition scenarios (n = 500 simulations

Li, F. G. N. and Strachan, N. (2019) 'Take me to your leader: Using socio-technical energy transitions (STET) modelling to explore the role of actors in decarbonisation pathways', *Energy Research and Social Science*.

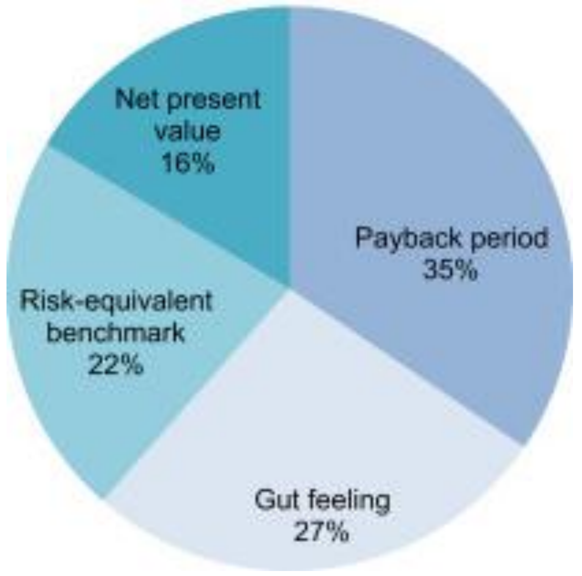
BRAIN-Energy (Bounded Rationality Agents Investment model) Elsa Barazza

- BRAIN-Energy is an agent-based model of electricity generation and investment and focuses on UK power sector.
- Demand and supply balanced to give investment costs, security, and emissions pathways up to 2050.
- National and local investor agents and policy agents
- Investors and policy agents have bounded-rationality resulting in non-optimal decision-making process. Investors are heterogeneous based on their characteristics and strategies
- Major market schemes (capacity market, Contracts for Difference, CO_2 price) interact with investors' investments



Energy behaviours – supply side

- Investors in the energy system are a diverse group:
  - Private actors: incumbent utilities, institutional investors, project developers, regional utilities, households
  - Public sector actors: state-owned enterprises, governments, development banks
- Motivations for investors in renewable energy vary:
  - Different risk/return considerations
  - Economic motivations
  - Social and environmental considerations



Investment motivations of retail investors

(Salm et al. (2016) “What are retail investors' risk-return preferences towards renewable energy projects? A choice experiment in Germany”, Energy Policy

BRAIN-Energy’s outcomes

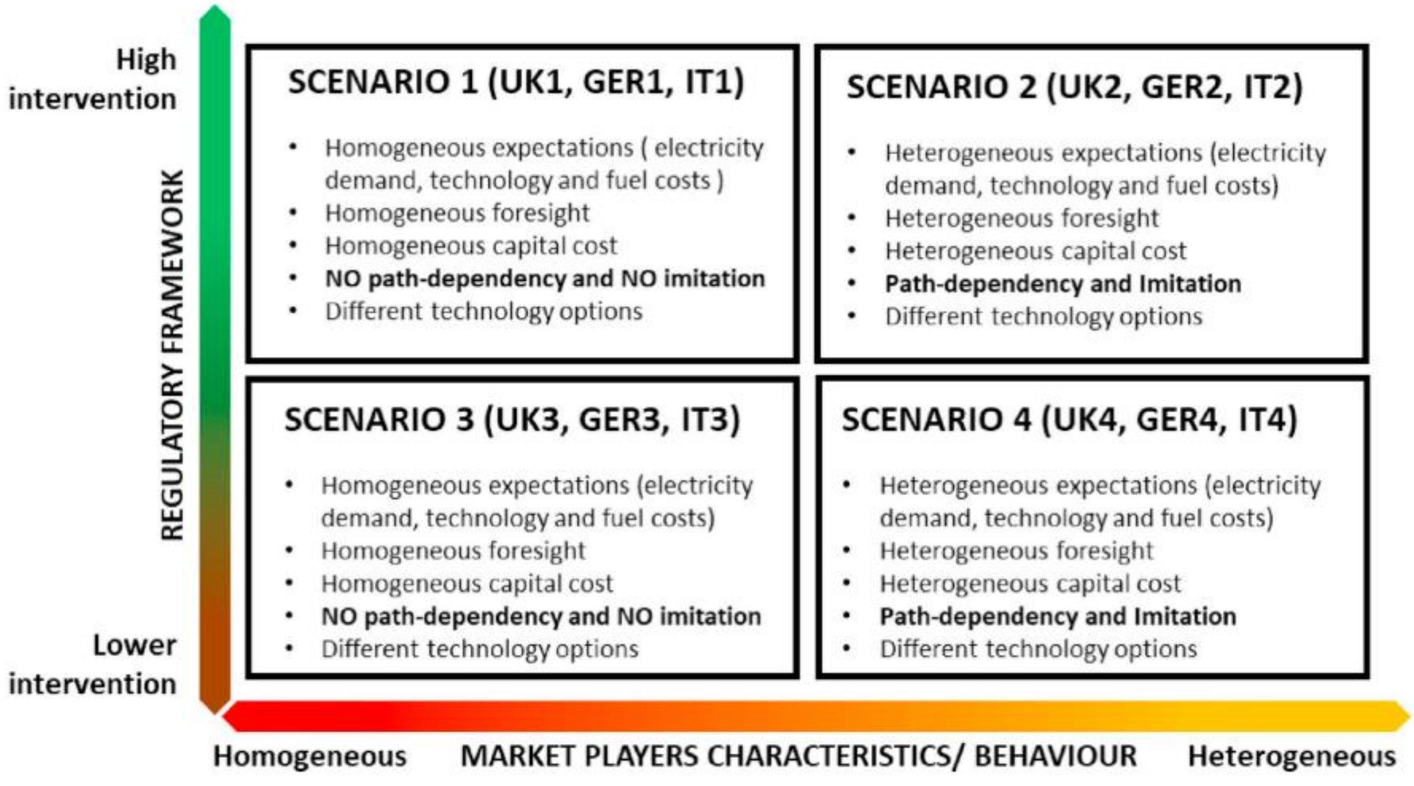
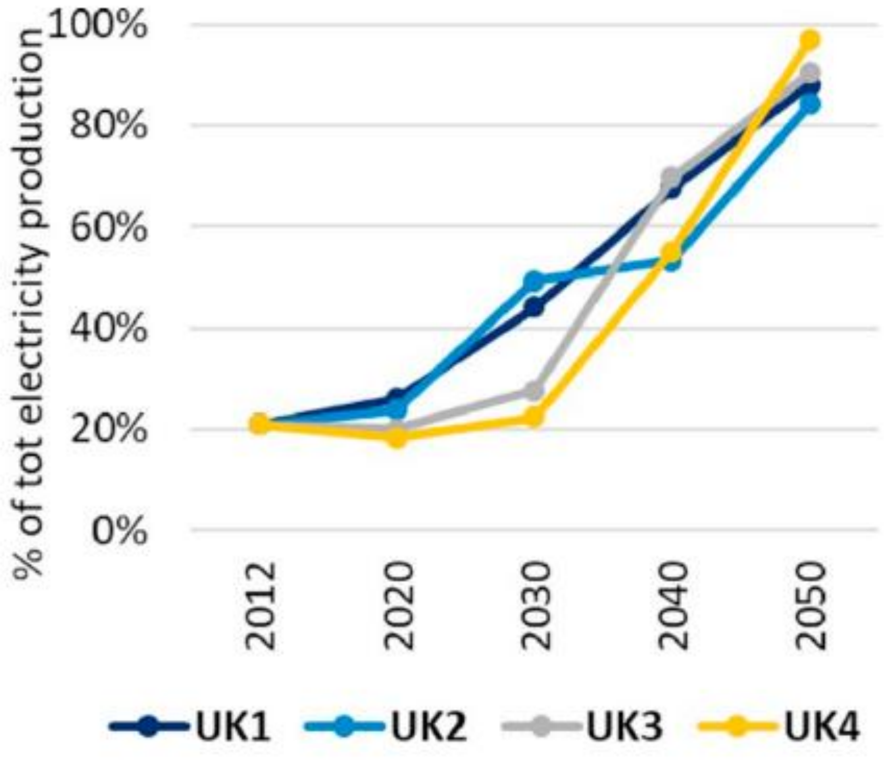


Fig. 4. Overview of scenarios.

Share of power as renewables



Barazza E and Strachan N 2020 “The impact of heterogeneous market players with bounded-rationality on the electricity sector low-carbon transition” *Energy Policy* **138** 111274

Agent-based models (ABMs)

- ABMs are **bottom-up simulation models**
- In ABMs the main unit of analysis are **agents** and their **interactions**
- Agents are **autonomous and heterogeneous**. They have their **own set of attributes and rules** which define their behaviour.
- The actions and interactions of the agents in an environment give rise to the environment's **emergent properties**