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

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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

Energy behaviours and GHG emissions - demand side

GHG emissions = \( \text{energy service demand} \times \frac{\text{energy}}{\text{service demand}} \times \frac{\text{GHG}}{\text{energy}} \)

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

1. Balancing: mitigate while not at target

2. Balancing: measures in mix are more difficult as target is approached

3. Balancing: policy ambition uses up political capital

4. Balancing: pushback can affect political capital

5. Reinforcing: measure achievements reduce difficulty

Target

Scenario_inputs (population)

Mitigation achieved

Distance to target

Policy ambition mix

Political capital for energy transition

Learning by doing

Public willingness to participate

Measure difficulty

Scenario_inputs (policy assignment adjustments)

scenario_inputs (disposable_income)
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
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, CO₂ 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*

BRAIN-Energy’s outcomes

**SCENARIO 1 (UK1, GER1, IT1)**
- Homogeneous expectations (electricity demand, technology and fuel costs)
- Homogeneous foresight
- Homogeneous capital cost
- NO path-dependency and NO imitation
- Different technology options

**SCENARIO 2 (UK2, GER2, IT2)**
- Heterogeneous expectations (electricity demand, technology and fuel costs)
- Heterogeneous foresight
- Heterogeneous capital cost
- Path-dependency and Imitation
- Different technology options

**SCENARIO 3 (UK3, GER3, IT3)**
- Homogeneous expectations (electricity demand, technology and fuel costs)
- Homogeneous foresight
- Homogeneous capital cost
- NO path-dependency and NO imitation
- Different technology options

**SCENARIO 4 (UK4, GER4, IT4)**
- Heterogeneous expectations (electricity demand, technology and fuel costs)
- Heterogeneous foresight
- Heterogeneous capital cost
- Path-dependency and Imitation
- Different technology options

Fig. 4. Overview of scenarios.

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**