Current modelling practices: Human behaviour in IFE-TIMES-Norway
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Impact of behaviour on the energy system

• Energy system development depend on **behaviour** of private households, e.g.
  • New technology
  • Technology preferences
  • Flexibility availability
  • Energy efficiency implementation
  • Modal shift in transport
  • Settlement patterns

• Energy system development depends on **public acceptance** of capacity expansion and new infrastructure
Example of energy behaviour assumptions related to demand projections

- Behavior dependent drivers for demand projections in buildings
  - Number of people living per building type
  - Area of new buildings
  - Type of buildings, apartments or single houses
  - Location of new buildings, decentralization versus centralization
  - Demolition rate
  - Implementation of energy efficiency

Source: KPN FlexBuild 2020
Example of energy behaviour assumptions related to energy efficiency measures

A og B represents different scenarios in 2050

Investments in energy efficiency (EE) reduces demands for energy services
- A: 24 TWh
- B: 18 TWh

EE reduced final energy demand
- A: 6 TWh bio + 17TWh el.
- B: 4 TWh bio og 21 TWh el.
NTRANS transition pathways
Behavioral assumptions – Narrative, assumptions and results
Four types of pathways

- **Modular substitution pathway**
  - Incumbents are challenged
  - Existing rules (‘fit-and-conform’) are updated
  - Subsystem knowledge becomes obsolete
  - Architectural knowledge remains intact

- **Radical transformative pathway**
  - Incumbents are severely challenged
  - New rules (‘stretch-and-transform’) are introduced
  - Subsystem knowledge becomes obsolete
  - Architectural knowledge remains intact

- **Incremental innovation pathway**
  - Incumbents are not challenged
  - Existing rules remain unaltered
  - Subsystem knowledge remains intact
  - Architectural knowledge remains intact

- **Architectural change pathway**
  - Incumbents are very challenged
  - New rules are introduced
  - Subsystem knowledge remains intact
  - Architectural knowledge becomes obsolete

**Technology change**

**Minor**

**System architecture change**

**Major**

**socio-institutional, behavioral & cultural change**
<table>
<thead>
<tr>
<th>Modular substitution pathway</th>
<th>Radical transformative pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lead firms</strong></td>
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</tr>
<tr>
<td>Some incumbents reorient to EV but some fail, limited new entrants</td>
<td>Dominated by new entrants while some incumbents may preserve</td>
</tr>
<tr>
<td><strong>Users practice</strong></td>
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</tr>
<tr>
<td>End-user practices are largely unchanged; charging at home in addition</td>
<td>Shift from personal cars to shared zero-emission vehicles and mobility. New high-tech assisted ways to replace mobility needs.</td>
</tr>
<tr>
<td><strong>Institutions</strong></td>
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<tr>
<td>Regulation: support new vehicles and charging Informal: unchanged</td>
<td>Regulations: major change; shared mobility; digitalization Informal: New sustainable values, novel ways to meet human needs.</td>
</tr>
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<td><strong>Technology</strong></td>
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<td>Electric/H2 vehicles</td>
<td>Autonomous and shared zero-emission vehicles. New technologies to circumvent the need to travel, e.g. virtual reality</td>
</tr>
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<td><strong>Consumption</strong></td>
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<td>Level unchanged</td>
<td>Reduced demand level and new structure</td>
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<td>Incumbent firms stay in place with minor adaptations to technologies and business models</td>
<td>Dominated by new entrants while some incumbents may preserve. Focus on ICT.</td>
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<td><strong>Users practice</strong></td>
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<td>End-user practices are unchanged</td>
<td>Shifts to shared mobility (radical change) and new modalities (public transport, biking, walking)</td>
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<td>Formal and informal institutions are largely unchanged</td>
<td>Institutional and cultural change towards less unnecessary travelling, change of values towards sustainable mobility.</td>
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<td>Biofuels strategy (100%) with existing engines and fuelling infrastructure</td>
<td>Smart apps for multi-model mobility, mobility-as-a-service</td>
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Assumptions

Modular
- High activity/demand
- High wind onshore
- Unlimited transmission
- 10 % rate
- Municipal waste as today

Radical
- Low activity/demand
- Low wind onshore
- No new transmission
- 4 % rate
- No waste

Wind offshore
- High potential, lower cost
- Expensive
- High learning rate
- Yes
- Yes

Biofuel & bio coal
- Expensive
- No

Hydrogen technologies
- Unlimited
- Yes (?)

Blue hydrogen
- No

CCS
- No

Incremental
- High activity/demand
- High wind onshore
- Unlimited transmission
- 10 % rate
- Municipal waste as today

Architectural
- Low activity/demand
- Low wind onshore
- No new transmission
- 4 % rate
- No waste

Wind offshore
- High cost
- Unlimited
- Low learning rate
- No
- Yes (?)

Biofuel & bio coal
- Unlimited
- No

Hydrogen technologies
- Low learning rate
- No

Blue hydrogen
- No

CCS
- No

Socio-institutionnel, cultural change

Minor ← Subsystem change ←→ Major
Example of results

CO2-emissions

- District heat
- Other
- Air
- Sea
- Rail
- Bus
- Truck
- Van
- Car
- Industry

Power generation

New power generation

TWh/year

- CHP
- PV
- Wind offshore
- Wind onshore
- Hydro
Linkage with ABM to represent behaviour in energy systems

• We will evaluate and test different methods for a bi-directional connecting agent-based model with the energy system model in ongoing project.

Three case studies:
• Building mass upgrade
• Building applied PV
• Flexible demand in buildings

maximize \( c^T x \)
subject to \( Ax + s = b, \)
\( s \geq 0, \)
\( x \geq 0, \)
and \( x \in \mathbb{Z}^n, \)
**Interdisciplinary approach**

**WP1: Psychology (NTNU-PSY)**
- Psychology, Consumer decision strategies (Christian A. Klöckner, NTNU-PSY)
  - Developing and using a decision-making model which is sensitive to the societal, technical, and political context

**WP2: Society (NTNU-KULT)**
- Society, Socio-technical constraints and enablers (Tomas Moe Skjølsvold, NTNU-KULT)
  - Organizational, institutional, technological and practical conditions and processes that enable or disable the successful implementation of energy efficiency
  - Responsible for facilitating work across the scholarly disciplines and methods involved in the project

**WP3: Panel Survey (NTNU-PSY)**
- Panel survey (NTNU-PSY)
  - Bundling empirical work related to data collection

**WP4: Agents (SINTEF)**
- Agent-based modelling (Lars Hellemo, SINTEF)
  - Providing insights on the behavior of collective consumers in and with details of individuals' consumer decision processes in a societal context
  - Bridge the qualitative research in WP1-WP3 to quantitative input on consumer decisions in WP5

**WP5: Energy system (IFE)**
- Energy system modeling (Pernille Seljom, IFE)
  - Energy system analysis considering consumer-dependent decisions in private household towards 2050
  - Investigate different methodologies to couple agent-based model with energy system model

**WP6: Project Management, user involvement, dissemination (Pernille Seljom, IFE)**
Agent-Based Models (ABM) for Energy Behavior

- **Agent-based models (ABMs)** may yield more realistic predictions than equation-based models.

- **Top-down modeling** approach focused on individuals and their interaction within an environment.
Framework design - Interaction ABM & ESM

Energy System model (ESM)

Energy efficiency measures
Electricity prices
Capacities
Demand profiles

Energy standards
Energy consumption
Retrofits performed over time
Potential realized vs predicted

Agent-Based Model (ABM)

Initialization
Simulation
Pre decision-making events
Household parameterization
Household energy standard
Household friendfinder
Neighborhood parameterization
Consider new energy standard
Recover investment potential
Choice of changing owners
Chance of changing owners

Can afford retrofit?
No
Perform retrofit
Improve energy standard

Agent-Based Model (ABM)

Energy System model (ESM)
Questions?