DEVELOPING COLLABORATION AND INFORMATION-EXCHANGE MODULES TO IMPROVE MEASURES FOR A SMART AND RESILIENT ENERGY TRANSITION

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NTA11

SESSION III.B: TECHNOLOGY ADOPTION

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Energy system modelling - Socio-technical ABM

Categorisation of Agent-based methods	2019	2020	2021
Multi-agent system - Energy system management			
Building *(electricity, heat, cooling)*	-	-	6
District *(distributed energy generation, energy conversion, energy storage)*	3	5	7
Region *(multiple district systems / microgrid clusters)*	1	4	5
Agent-based modelling			
Energy consumer behaviour (*appliance useage, technology adoption*)	1	3	1
Policy making (*regulation, price-development, technology push*)	-	4	-

Some observations

- *´Increased interest´* in developing agent-based methods, but *´share´* remains limited
- *Socio-technical aspects* – various aspects still limited considered, including various knowledge exchange mechanisms

Source: Yao, R., Hu, Y. and Varga, L. (2023) 'Applications of Agent-Based Methods in Multi-Energy Systems — A Systematic Literature Review', Energies, 16, 36 pp.

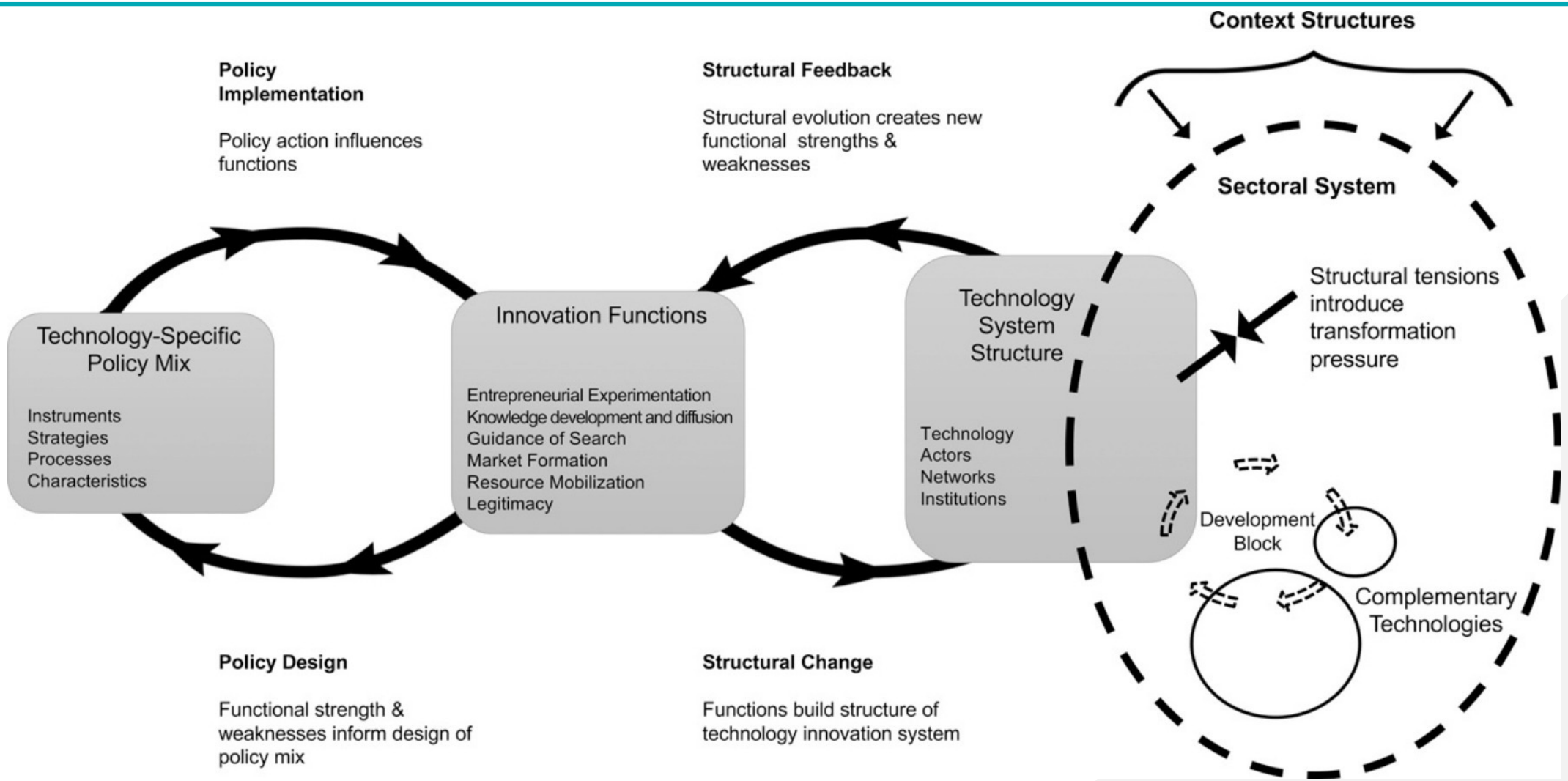
Energy systems & resilience

- Increased attention **towards resilient systems** (Gasser *et al.*, 2021; Jasiūnas, Lund and Mikkola, 2021)
  - *Sustainability* & energy transition
  - *Shifts in supply-demand* renewable energy technology dynamic
  - *Climate change* & extreme weather events
- Developing resilience **increases system complexity** -> Need for reassessment (Fiksel, 2006; Bie *et al.*, 2017):
  - Technology *diffusion*
  - Sub-systemic integration & *sector-coupling*
  - Systemic flexibility & *adaptability*

Technology assessment & challenges

- **Technology assessment challenges** - The need to go beyond traditional (objective) approaches creates potential for conceptual diffuseness (Grunwald, 2018; Büscher, 2018):
  - *Widened spectrum of addressed actors* (e.g. bottom-up socio-technical dynamic)
  - Increased *social and epistemic complexity* (e.g. intensified supply- & value-chains)
  - Stronger embedding of (evolving) *normative perspectives*
- **Technology assessment revisions** - could be addressed through:
  - *Complexity reduction* and increased *practice-based orientation*
  - *Modularisation* of technological innovation systems (Hekkert *et al.*, 2007; Bergek *et al.*, 2015)

Technological innovation systems

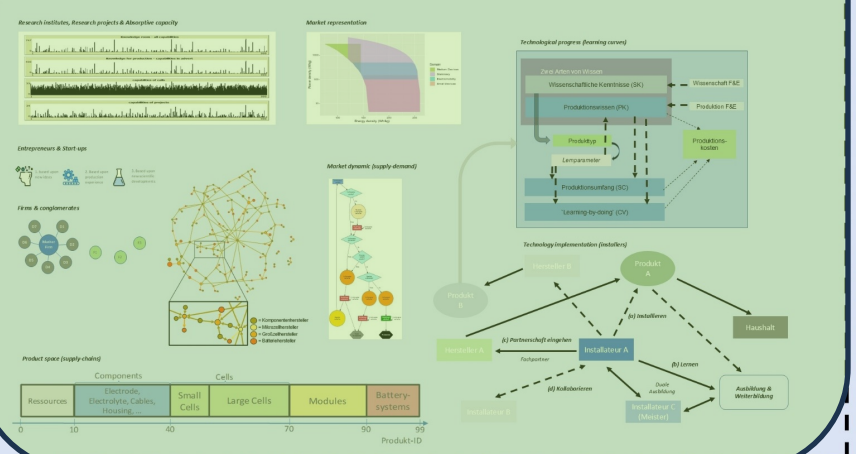


Source: Haley, B. (2018) 'Integrating structural tensions into technological innovation systems analysis: Application to the case of transmission interconnections and renewable electricity in Nova Scotia, Canada', Research Policy, 47(6), pp. 1147–1160.

Multi-level innovation systems modules

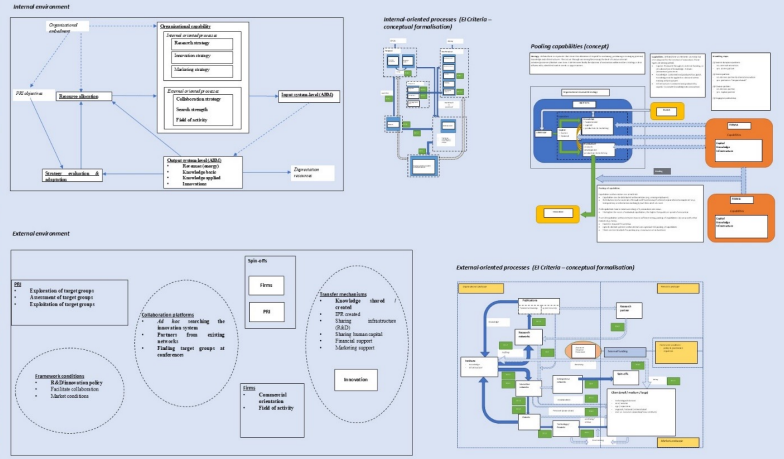
System level

Firms, research institutes, start-ups/entrepreneurs, installers; technological progress, network-based knowledge exchange, supply-demand dynamic



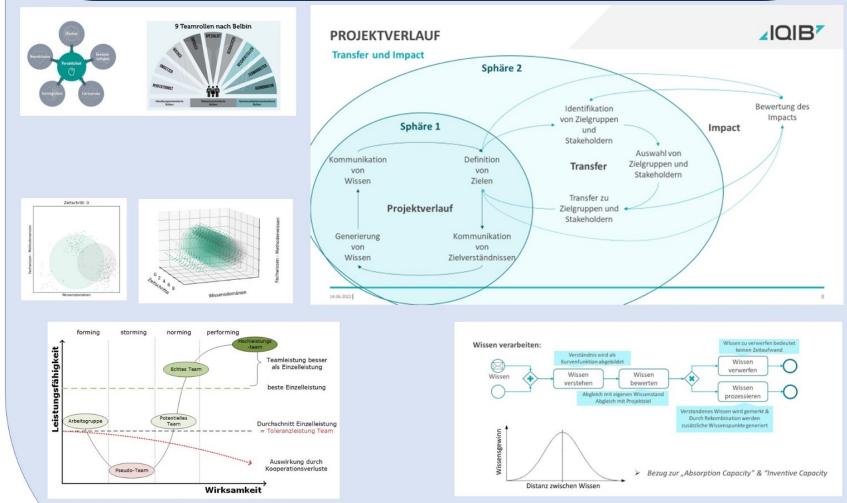
Sub-system level

Public research institutes; organisational capacity building; R&D collaboration strategies; target-group knowledge; exploration-exploitation processes



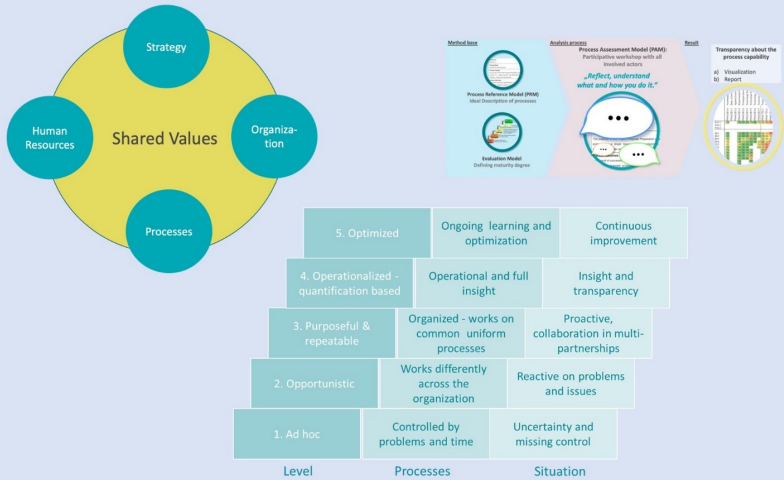
Project level

Project execution, team-effectiveness, employee motivation

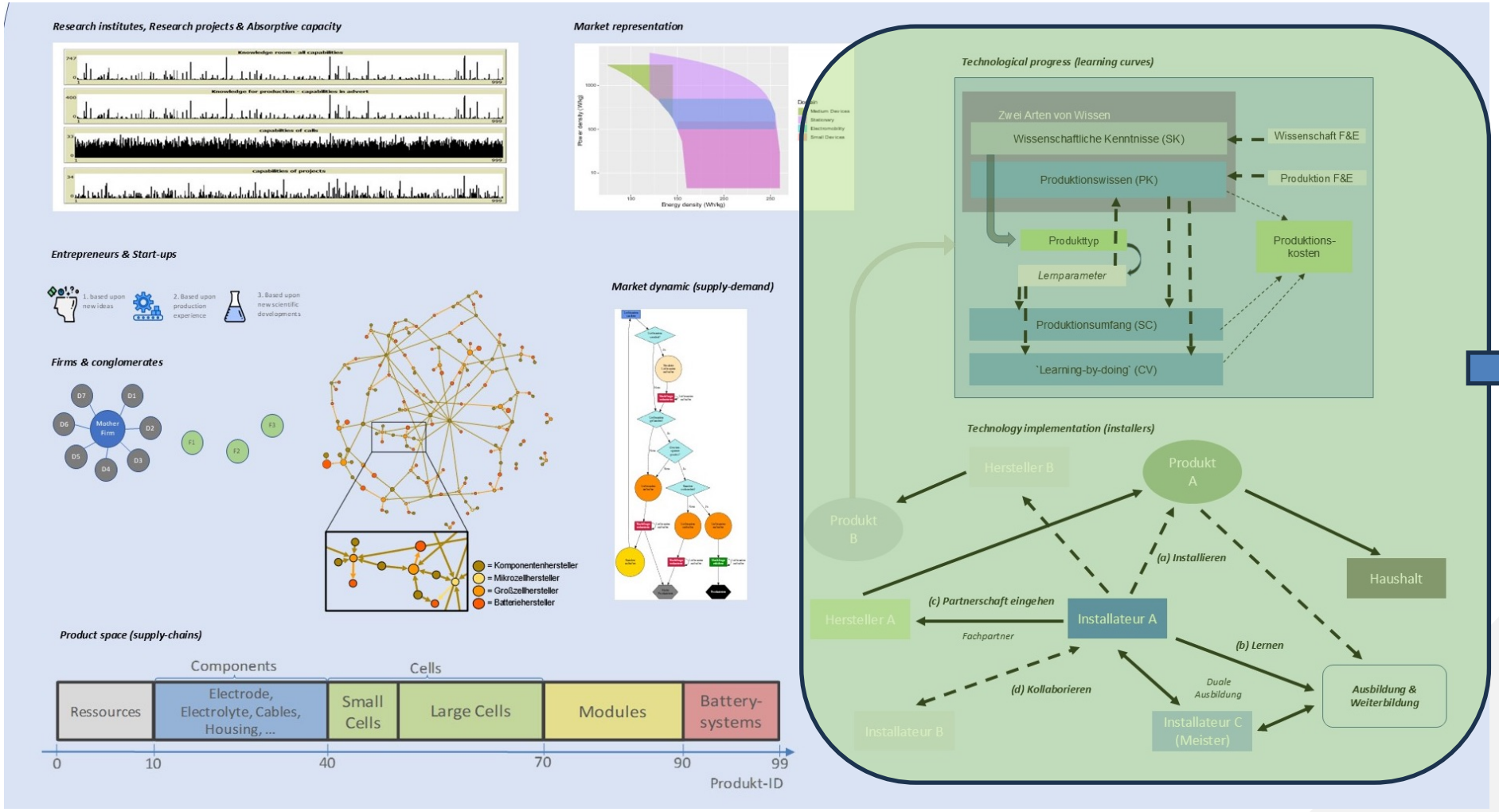


Organisational level

Organisational processes, process assessment



Modelling technological innovation systems



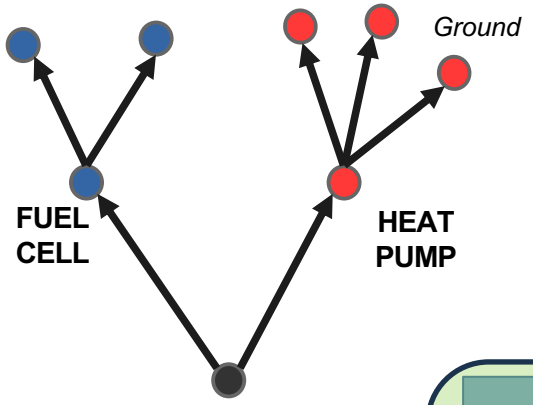
- **Funding mechanisms** (consortia-building & absorptive capacity)
- **Product-space** (characterisation, complementarity)
- **Supply-chains** (market-dynamic, collaboration)
- **Organisational development** (entrepreneurship, conglomeration)
- **Learning** (organisational strategy, knowledge trees)
- **Socio-technical dynamic** (learning curricula, product diffusion,

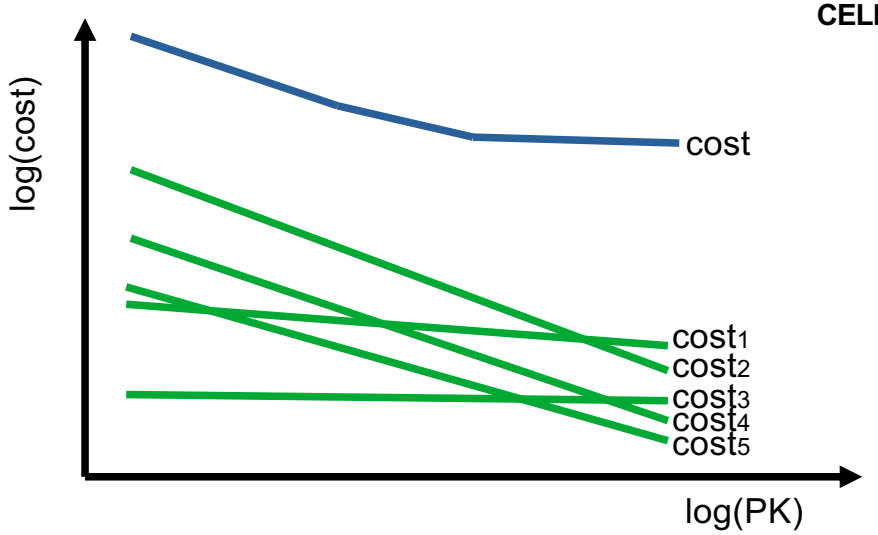
Project Manifold

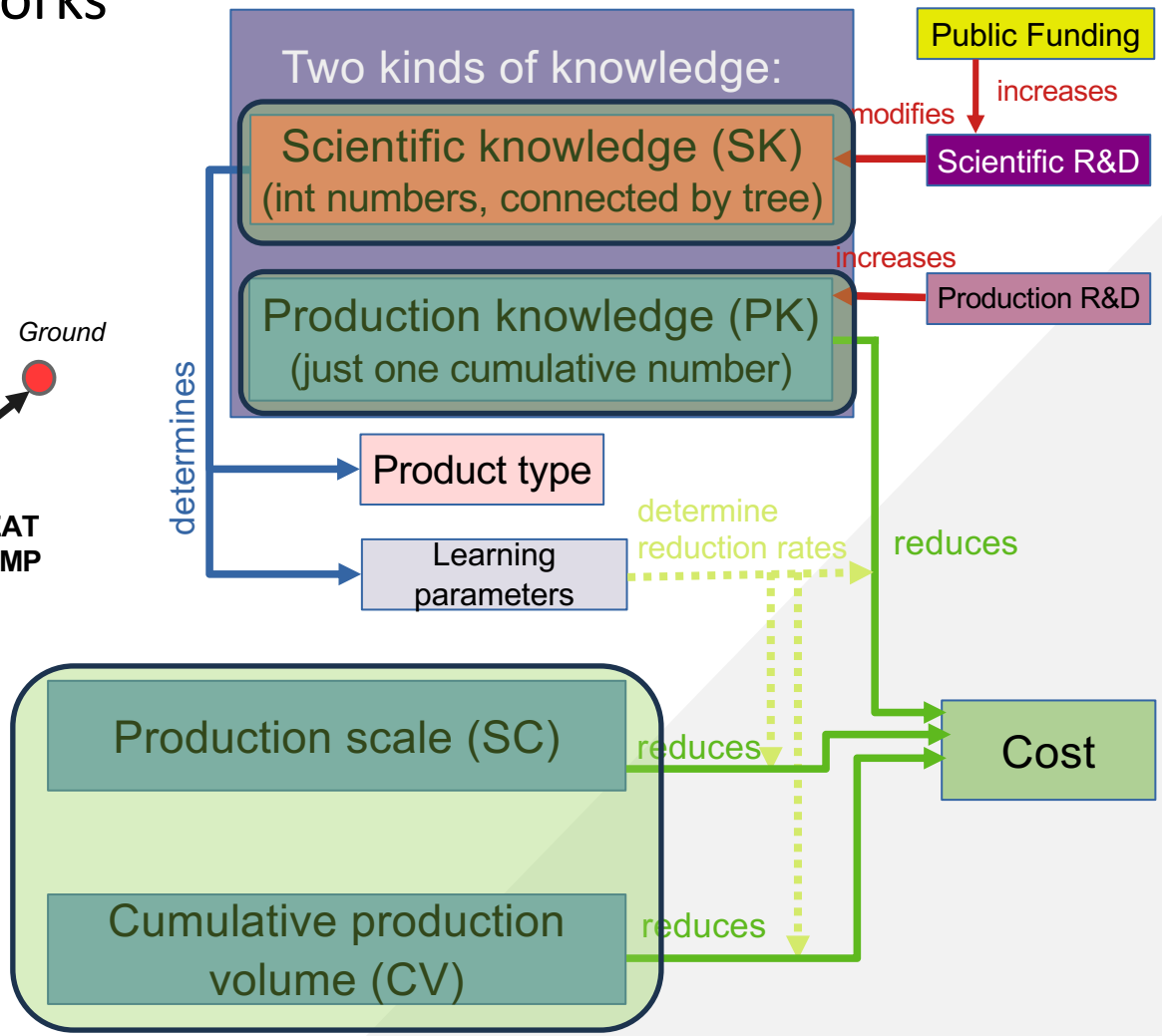
- *Aim*: Understanding the **evolution and diffusion** of heating **technologies**
- *Approach*: **Interdisciplinary development** of an ABM
  - Simulating socio-technical knowledge creation-exchange mechanisms within innovation systems
  - Main agent-types: (1) Technology producers, (2) Installers
  - Central processes:
    - **Production**: Technological evolution, through modelling learning curves
    - **Installation**: Diffusion of end-products
- *Simulation*: Different policy scenarios (Germany focus)
  - *Reference scenario:* Keeping the status quo
  - *Policy scenario 1*: Focus on gas-based solutions
  - *Policy scenario 2*: Strong stimulation of heat pump-technology
  - *Policy scenario 3*: Open market; stimulation of sustainable technologies

Technology production - Learning curves

- To model learning effects in innovation networks of firms/institutes -> **3 types of learning**:
  - learning by **research** (PK)
  - learning by **doing** (CV)
  - economies of **scale** (SC)



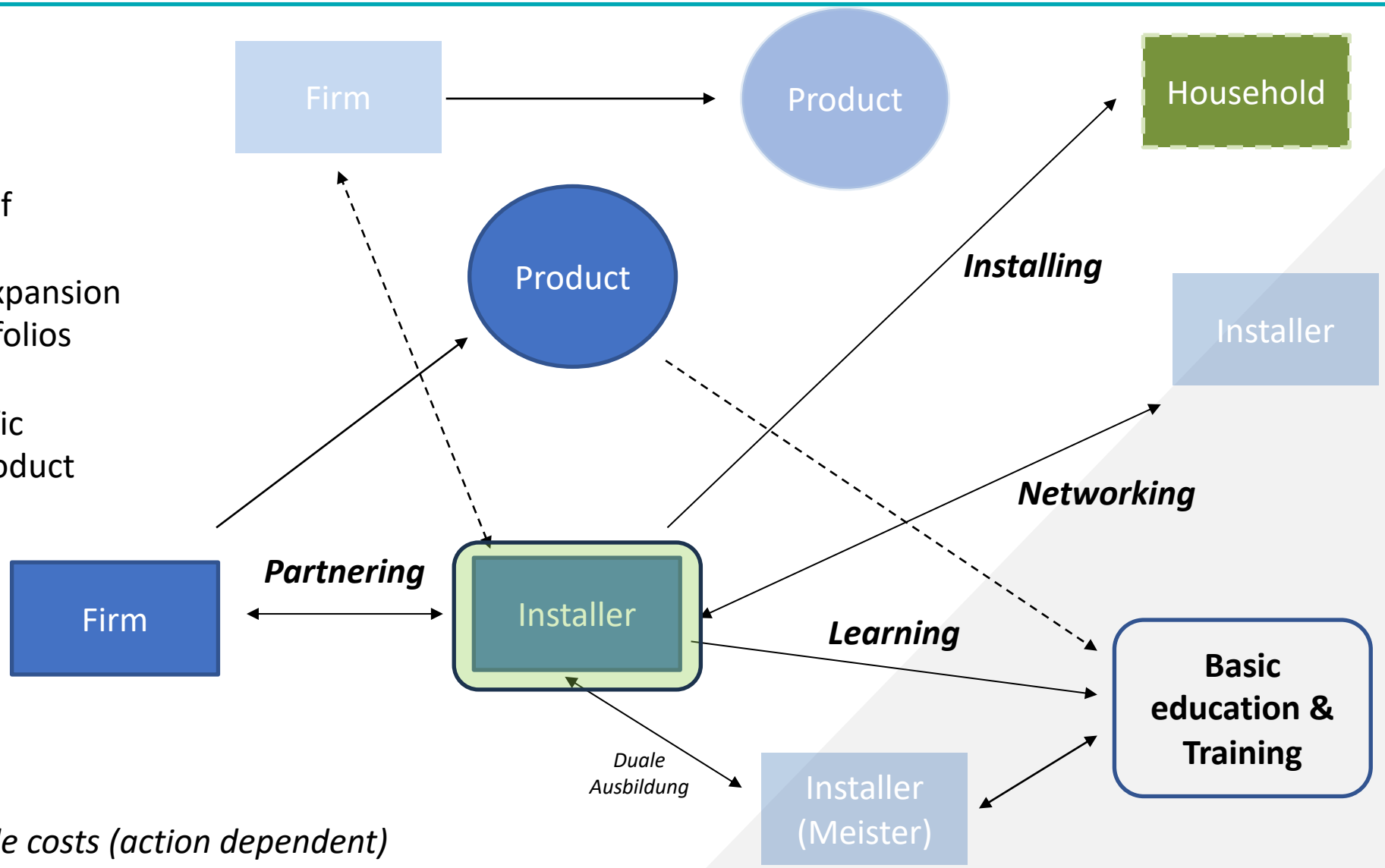




Technology diffusion – End-product installation

Policy dimension

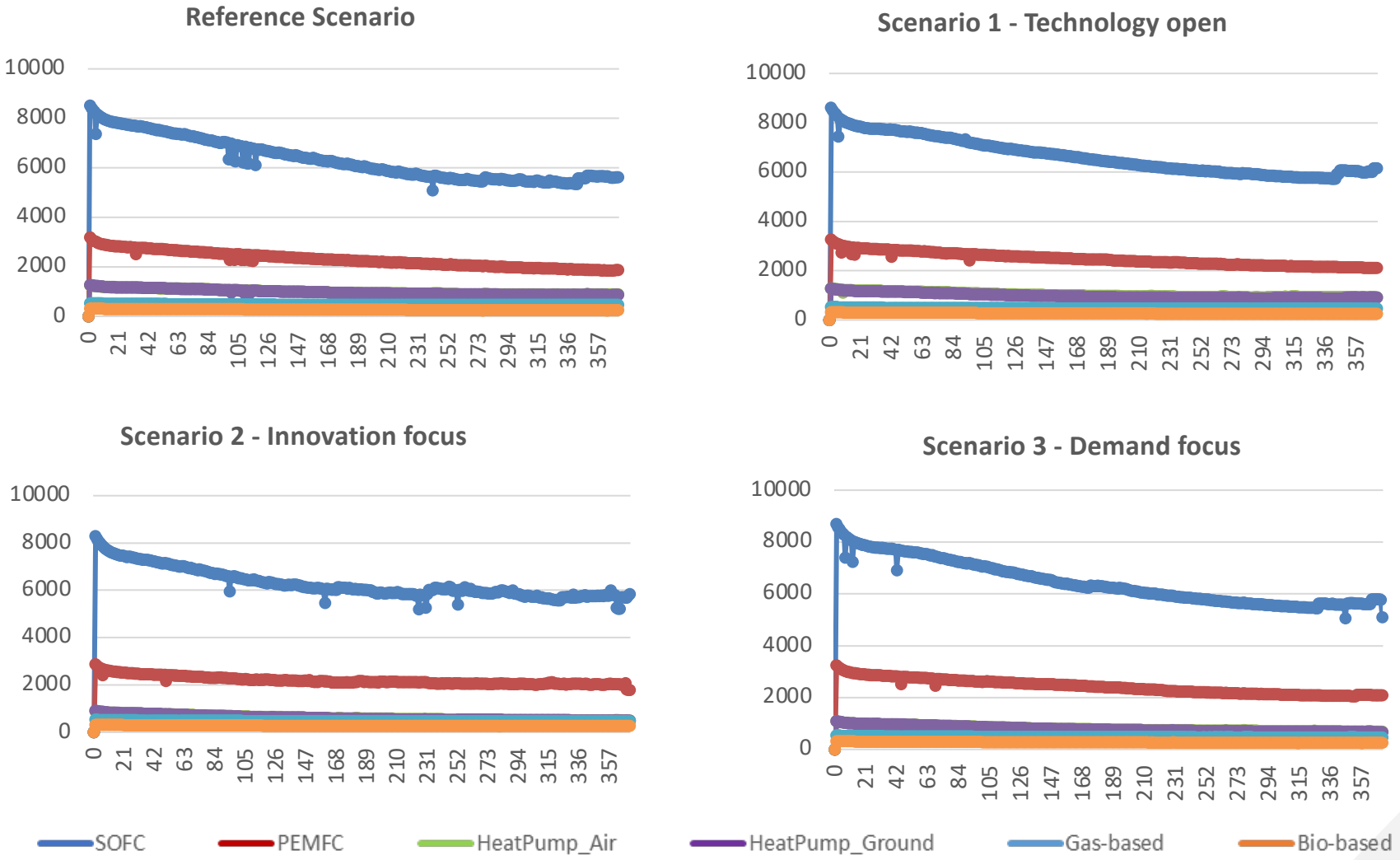
- *Supply of installers*
  - **Education**: Generation, capabilities & expertise of installers
  - **Training**: Influence the expansion of installer product-portfolios
- *Demand of installers:*
  - **Price regulation** of specific products –> influence product demand & capabilities & expertise of installers



Main resources installers

- *Time: Perform actions*
- *Capital: Fixed costs & variable costs (action dependent)*

Simulation output – Learning curves



X-axis: time-steps (months); Y-axis: Total average cost of the final product (€)

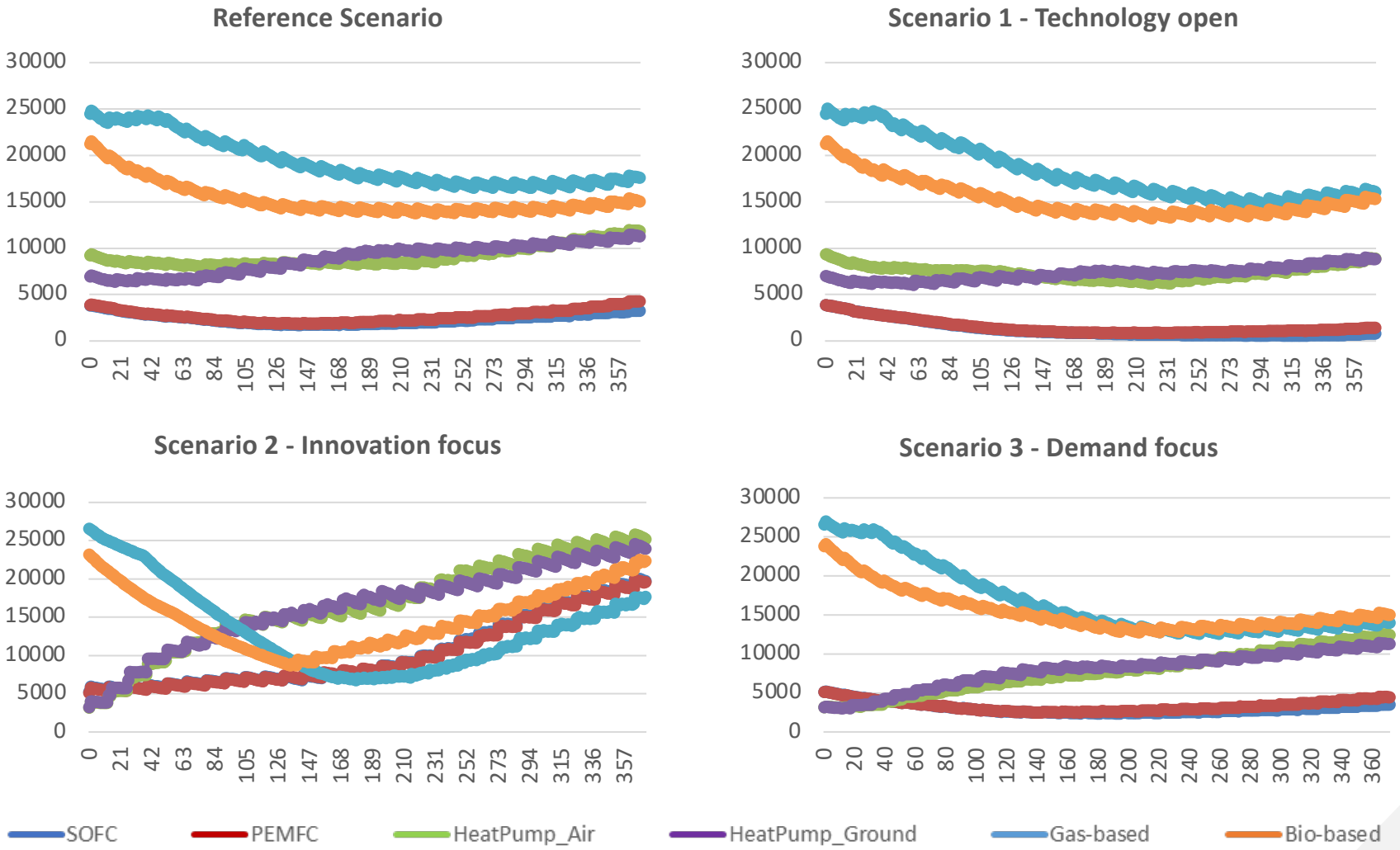
Technology push: Does not necessarily improve the **innovation system performance** of (stimulated) technologies, through:

- dedicated R&D programs
- technology-specific incentive- and subsidy-schemes

Main effects:

- **stabilise potential disruptions** in the supply chain
- **resist imbalances** in the overall supply-demand dynamics

Simulation output – Installation capacity



X-axis: time-steps (months); Y-axis: total capacity

Investments in installer education and training: have an impact on the availability and growth of installation capacity

- However, do **not immediately bridge the gap** between technology demand and installation capacity.
- Mainly due to:
  - the **time intensity** of learning and training programs
  - the generally **long product-life** of heating technologies (influencing **innovation momentum**)

Conclusion

Based on conceptualised modules we argue how modularised agent-based models can be used to provide tailer-made but analytically simplified multi-level solutions, which can overall lead to improved advisory practice within different organisational and socio-political contexts.

Main insights:

- Improved understanding of potential **inter-actor effects** and associated knowledge-exchange mechanisms
- Analysis shows a predominant **stabilising function** of system-investments (from technology-producer & -installer perspective) **-> Resilience**

Challenges:

- **Calibration and validation** (e.g. company internal R&D processes, exchange of information between partners)
- Full integration with **other models** (including *policy models*, *energy-system* models, *consumer* models – difficult harmonisation of ´timing´)

Next steps

- Development of **additional scenarios** (e.g. disrupted supply chains, “hydrogen-economy“)
- **Sustainability performance** of different scenarios (used materials, CO2-balance)
- Add geographical dimension; i.e. **regionality** of innovation processes (RIS)
- Further assessment and redevelopment of the **generalisability** of modules

THANKS FOR YOUR ATTENTION

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ABM4Energy - Context

ABM4Energy: "Agent-Based Modelling for Energy Economics and Energy Policy"

- ´Energy policy´ -> Need to integrate **multiple perspectives**
- ´Modelling´ -> Need to address alternative **technology development and diffusion scenarios**

Theme session: "Technology adoption"

- ´Technology adaption´ -> Need to assess **existing and new energy technology options**

This presentation: Developing socio-technical agent-based models

- **Reflection existing ABM approaches** - assessing energy systems
- **Technology assessment challenges -** Multi-level modularised modelling
- **Example modelling socio-technical processes** – knowledge development & diffusion