ISES

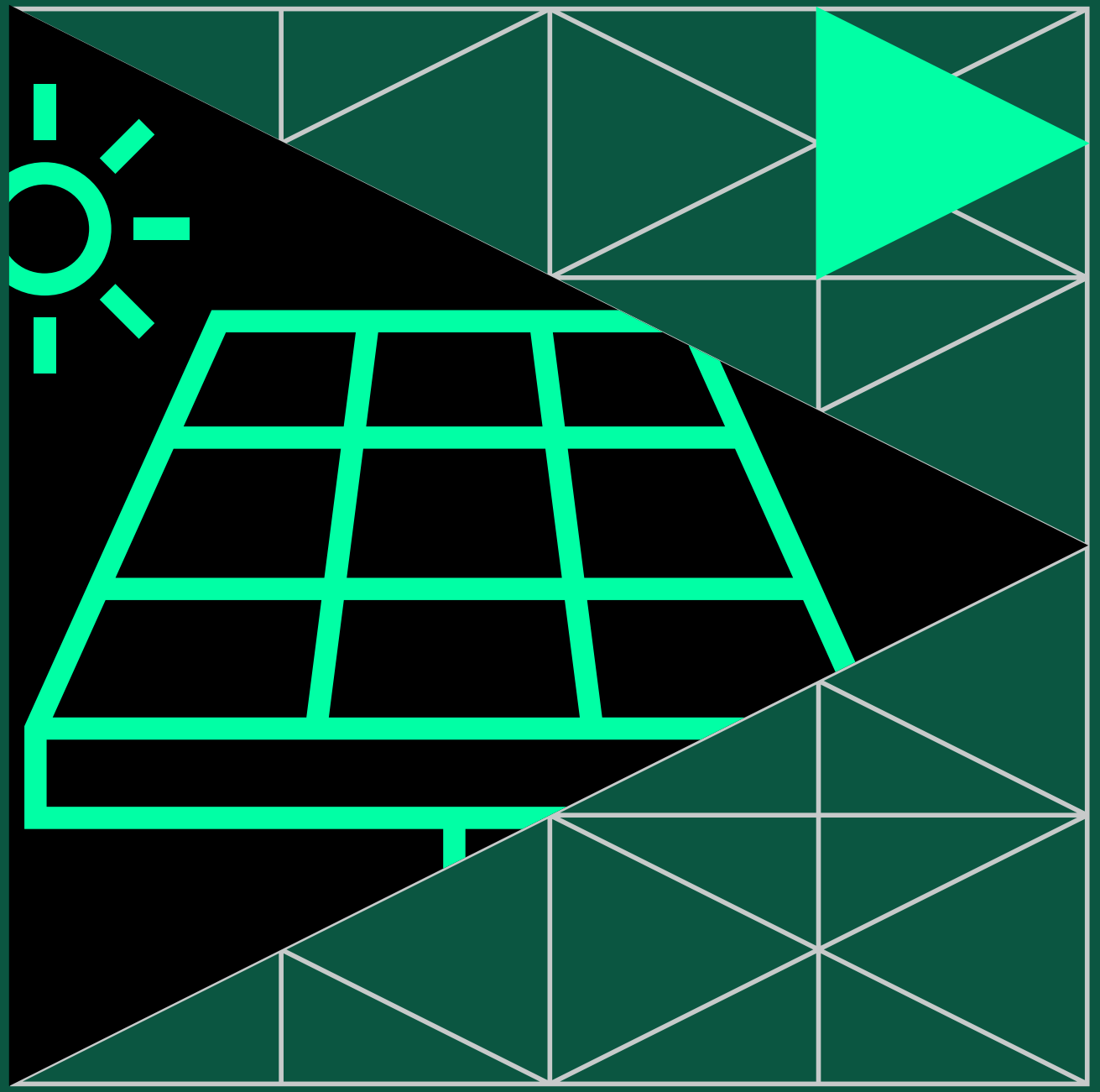
Institute for Sustainable Energy Systems

Integrating Behavior in Energy Technology Diffusion Models:

A Feedback Perspective on the SSBC Model

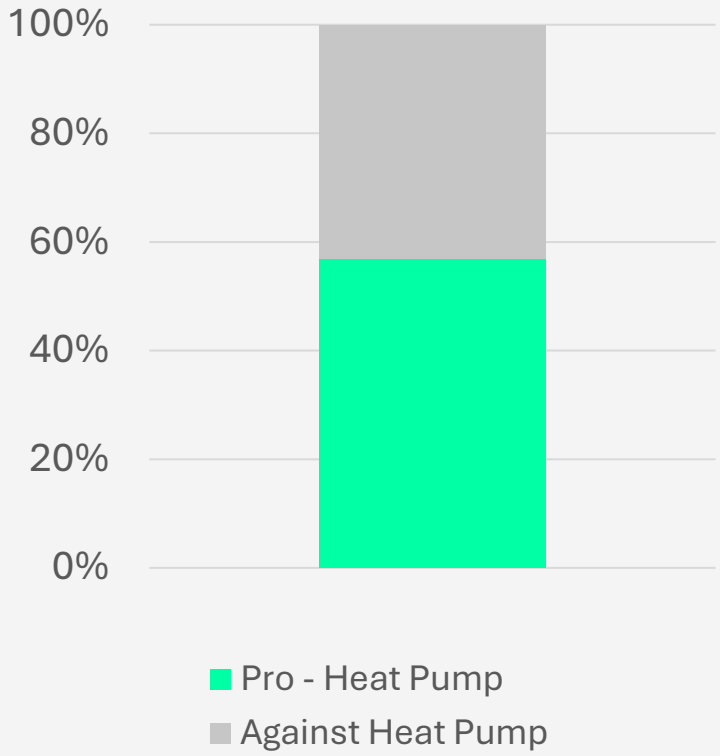
05.08.2025 / Theresa Liegl and Merla Kubli

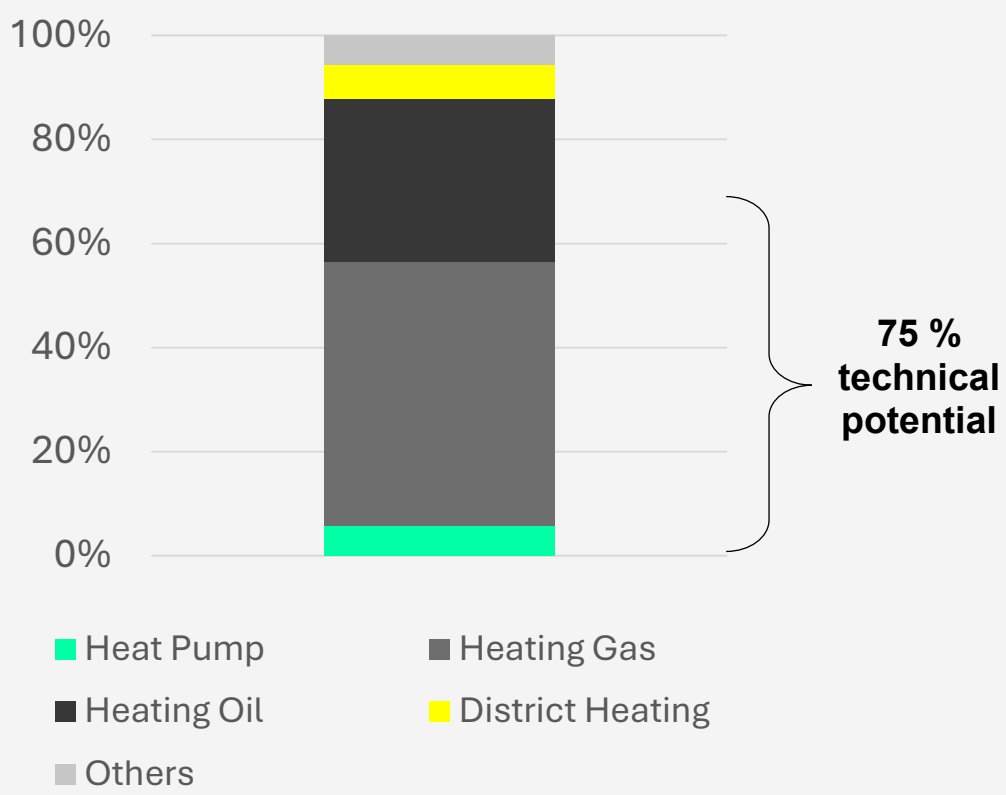
HM TU Delft



Problem Statement

Implementation Gap for Heat Pumps in Germany...





Problem Statement

Models for the energy transition

- Technical energy system models (ESM) are used for the design of more sustainable energy systems (e.g. districts or larger cities)

- ESM consider the decision-making of individuals either not at all or only in a very simplified way without reflecting relevant systemic influences

- There are already many studies and theories about sustainable behavior and behavioral change in social sciences

→ Modeling the decision for decentralized renewable energies in private households

Research Objectives
Overview

i. **Synthesis** of key findings from studies investigating behavior change, decision making and decision factors related to renewable energy

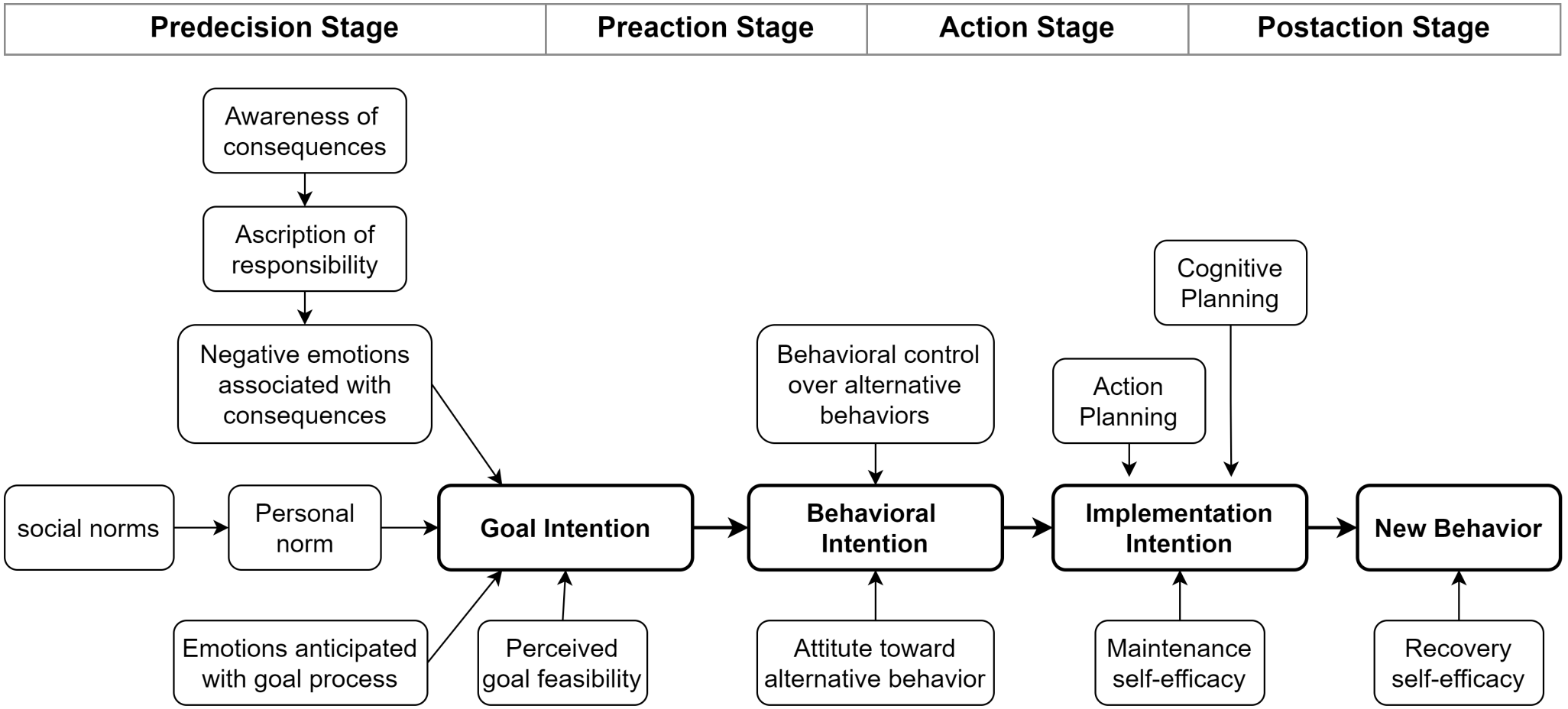
ii. **Development** of a generic modeling framework to capture the feedback perspective on behavior change in the context of renewable energy investments

iii. **Testing** of the generic model and identification of relevant factors for renewable energy technology diffusion

→ Theory-based Approach towards a System Dynamic Model

Basis Theory Model

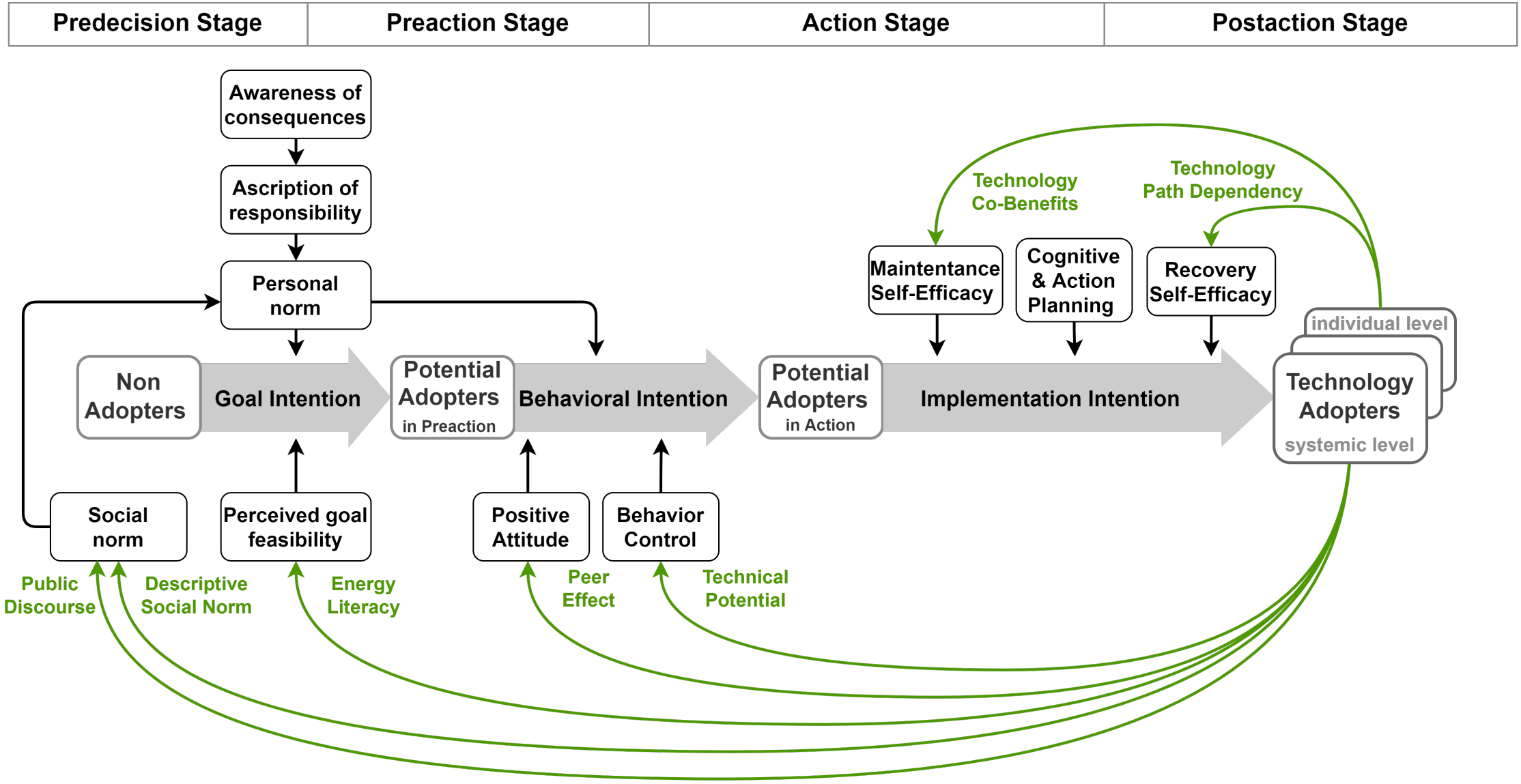
Stage model of Self-regulated Behavioral Change (SSBC)



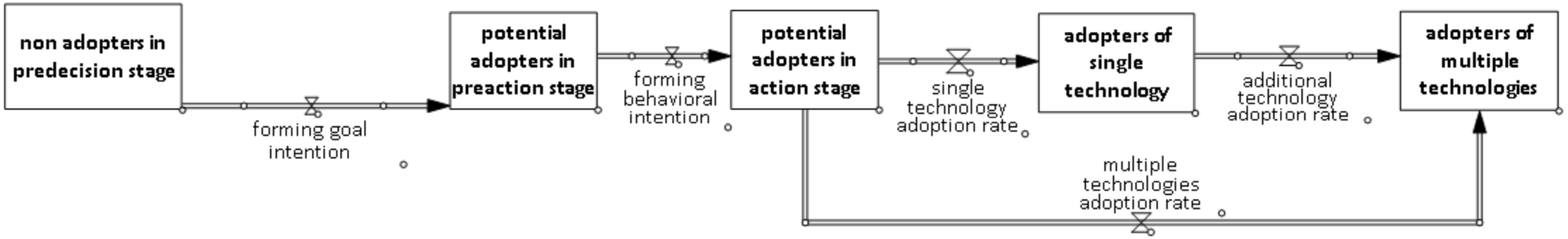
based on [4]

Conceptual Model

Synthesis

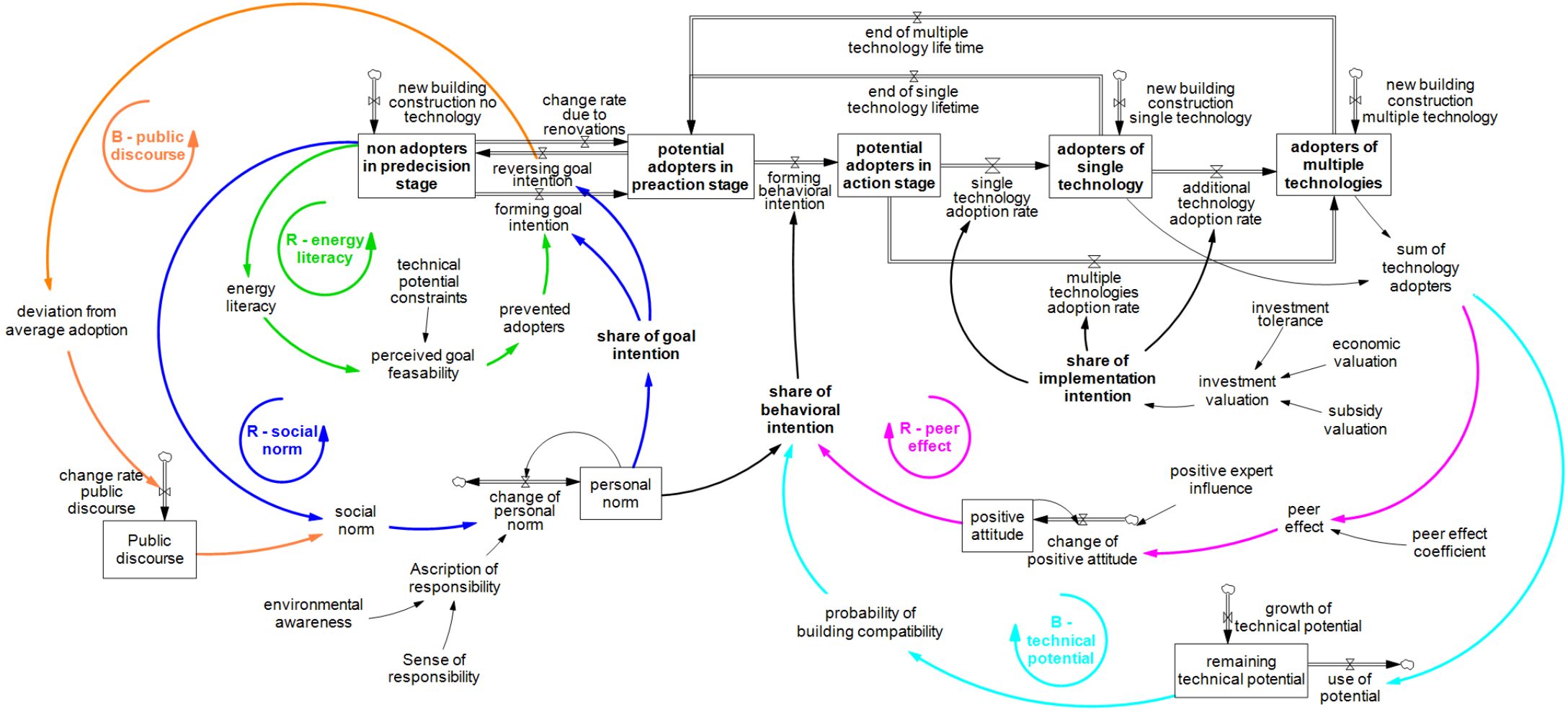


System Dynamic Model
Basic Structure



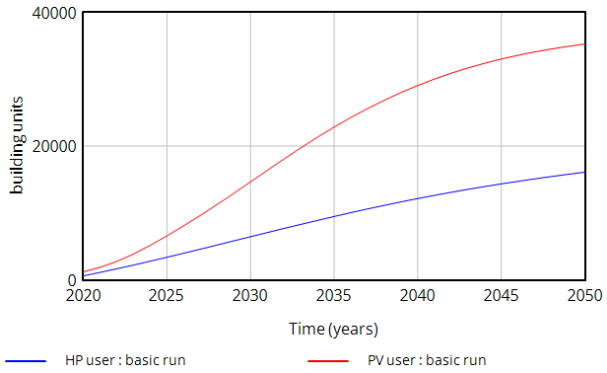
System Dynamic Model

Main Feedback-Loops



Results
Experimental Design

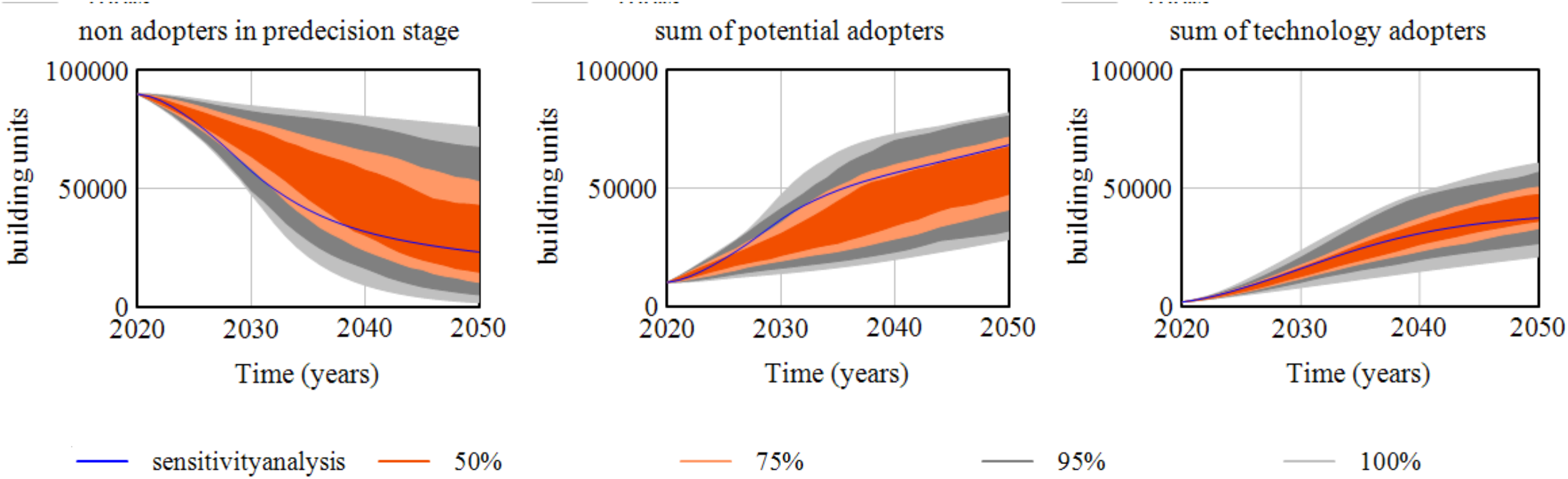
- Hypothetical region with different technologies:
  - Residential Photovoltaics (PV)
  - Heat pump (HP)
  - Technology combinations: PV+HP, HP+PV and PV+Battery (path dependency!)
- Simulation period of 30 years (2020 - 2050) capturing long-term system dynamics
- Initial: 100,000 building units in total, 90,000 non-adopters



Literature-based parameter variation:

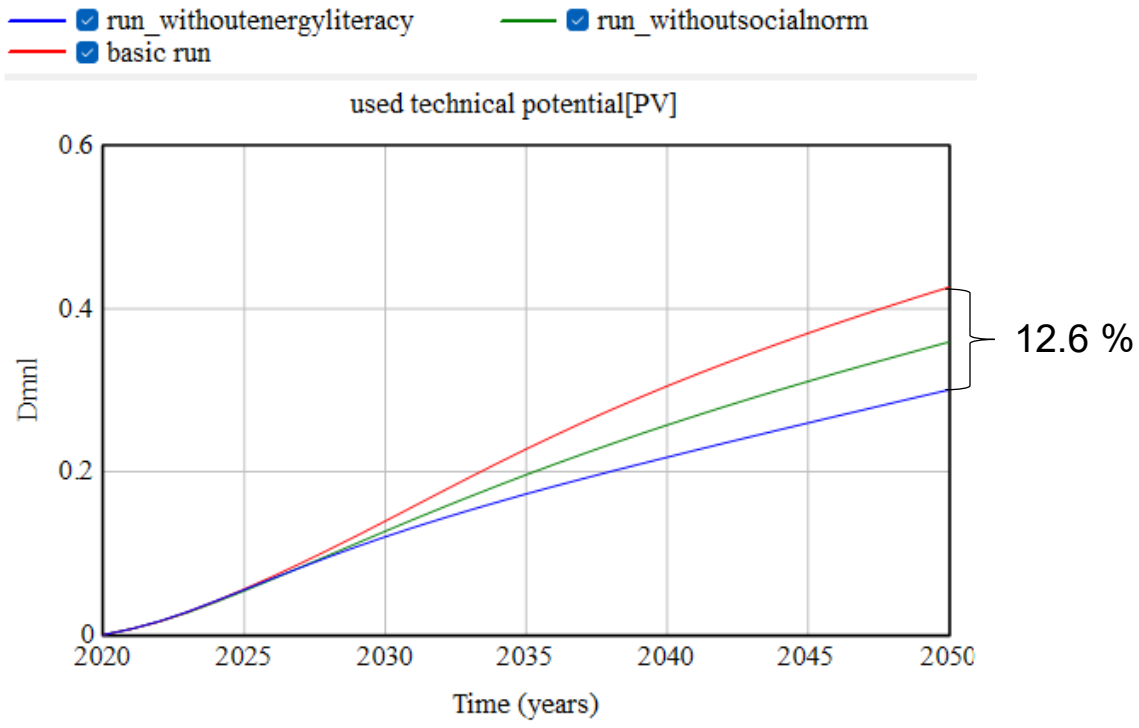
	min	basic	max	Ref
initial positive attitude[PV]	0.56	0.7	0.84	[1]
initial positive attitude[HP]	0.456	0.57	0.684	[1]
environmental awareness	0.6	0.8	0.98	[5], [6]
positive expert influence	0.110	0.138	0.166	[7]
Sense of responsibility	0.17	0.7127	0.63	[8], [9]
construction rate	0.0055	0.0079	0.0102	[10]
renovation rate	0.002	0.0088	0.03	[11],[12]
waiting time (policy risk)	0	0.8	2.0	[13]
intial share of technical potential[HP]	0.5511	0.6889	0.8267	[3]
...				

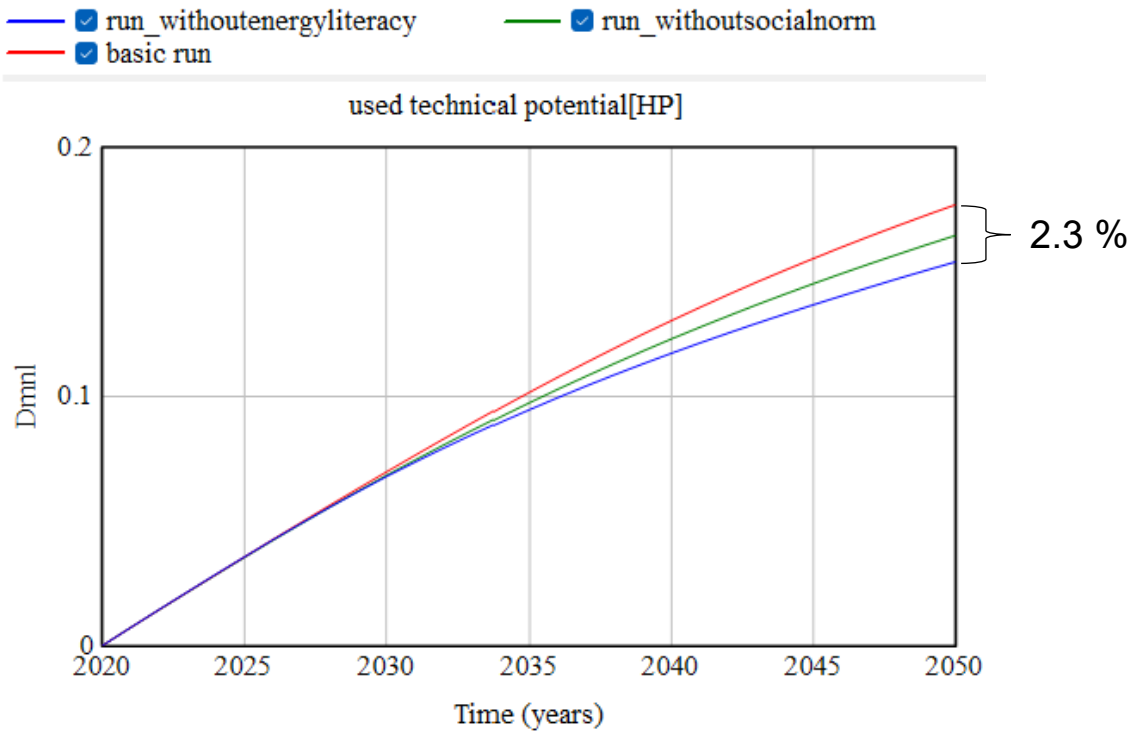
Results
Sensitivity analysis



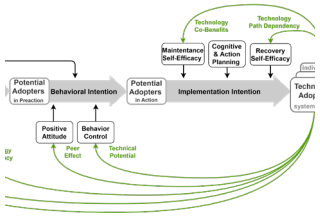
Results

Used technical potential

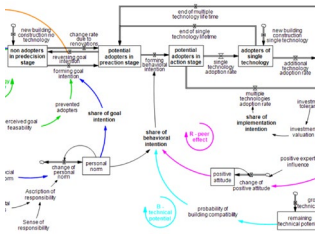




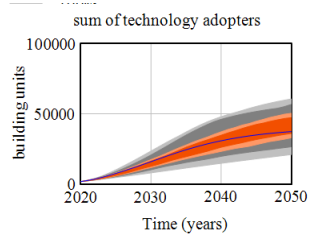
Conclusion



i. **Synthesize**: SSBC framework applied with additional feedback loops for modeling the collected individual and systemic determinants of behavioral change in the context of renewable energies



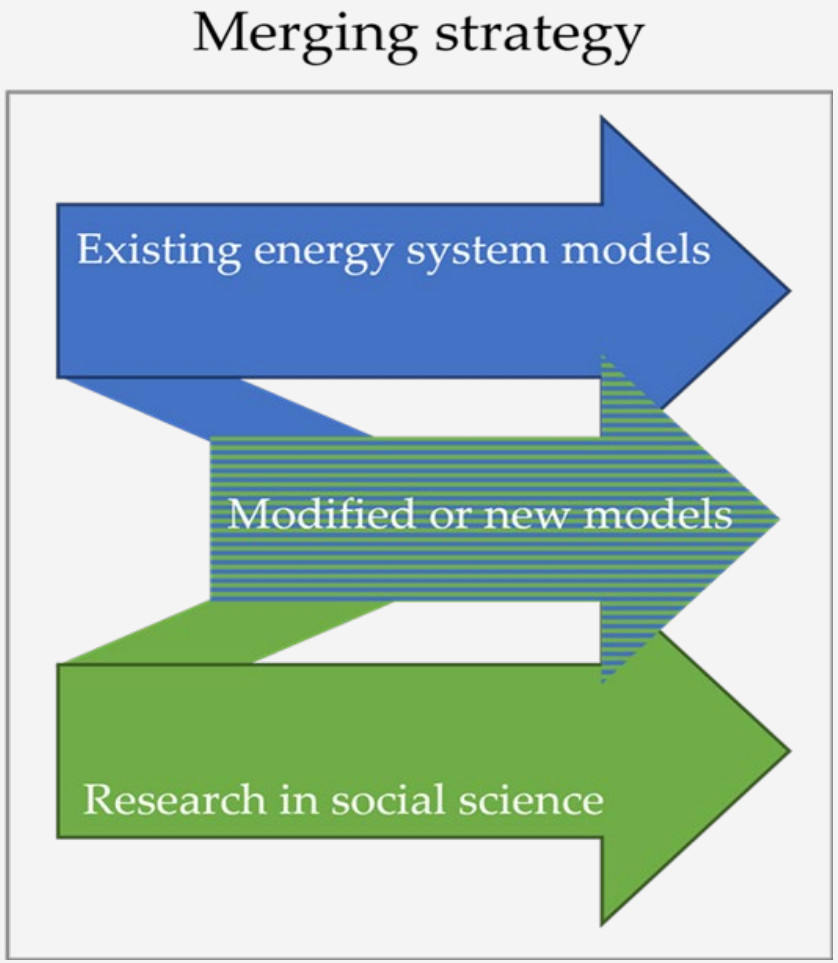
ii. **Develop:** A System Dynamics model enables the aggregated representation of heterogeneous behaviors and their dynamic influence on technology adoption.



iii. **Test:** Simulated system behavior highlighting the discrepancy between technical potential, intention, and actual adoption of different technologies

Further Steps

- Applying the model to the case of photovoltaic and heat pumps for a region in South-Germany
- Linking system dynamic model with technical energy system model (urbs)



Linking strategies based on *[14]*

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Back-up