Models in Models –
On Agent-Based Modelling and Simulation in Energy Systems Analysis

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On Computer Simulation Methods
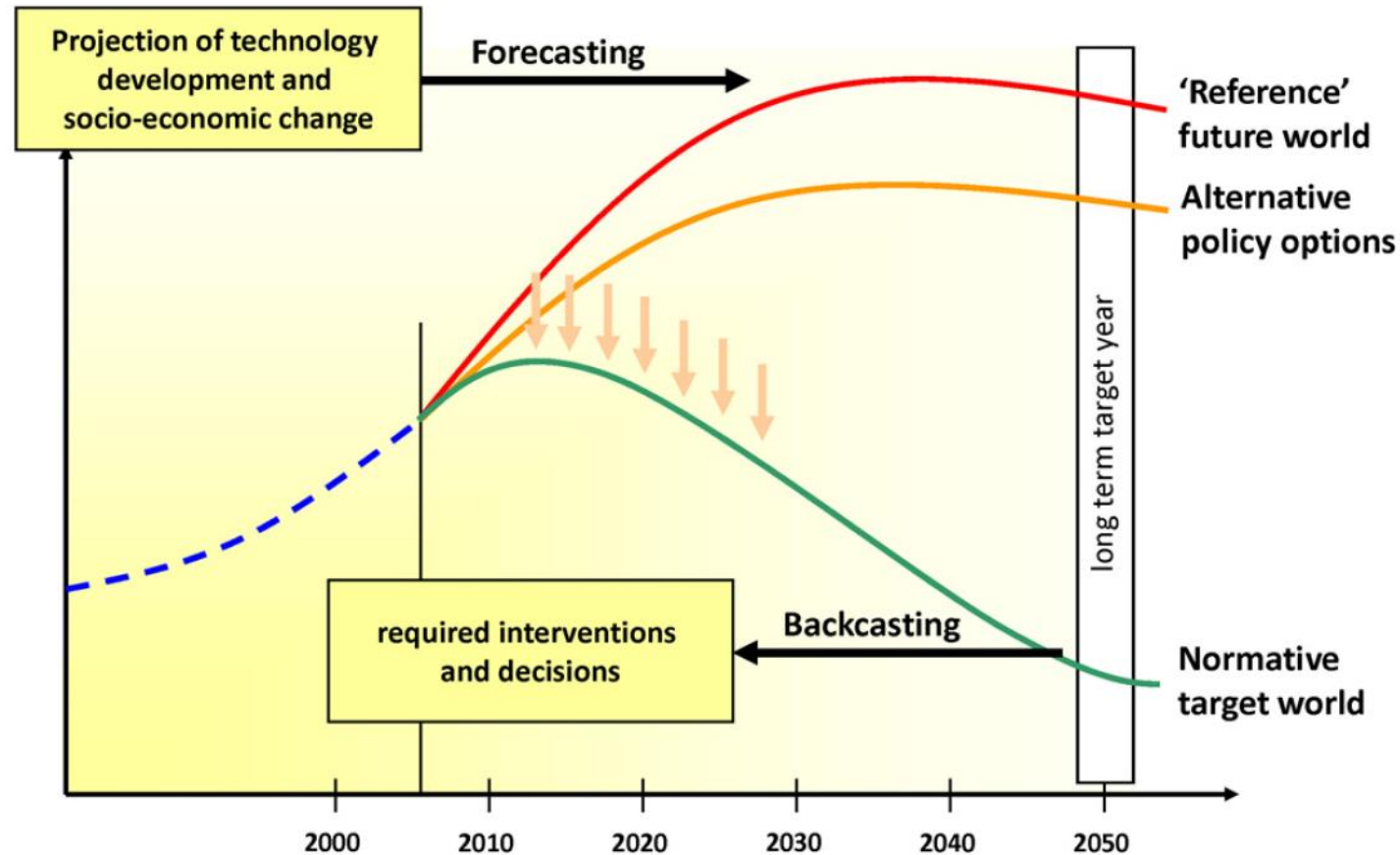
Stuttgart, 28th September 2017

Knowledge for Tomorrow

Agenda

1. Research Case: Energy Systems Analysis

2. Early examples of Agent-Based Modelling and Simulation (ABMS)

3. What is an agent, and how to classify models?

4. What is ABMS for?

5. ABMS in Energy Systems Analysis

Two Modes of Reasoning in Energy Systems Analysis

Grunwald (2011). Energy futures: Diversity and the need for assessment. *Futures*, *43*(8), 820–830. doi:10.1016/j.futures.2011.05.024

Cellular Automata: *Conway's Game of Life*

- Any live cell with fewer than two live neighbours dies, as if caused by underpopulation.

- Any live cell with two or three live neighbours lives on to the next generation.

- Any live cell with more than three live neighbours dies, as if by overpopulation.

- Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction.

- Demo: http://arr.gr/playground/life/
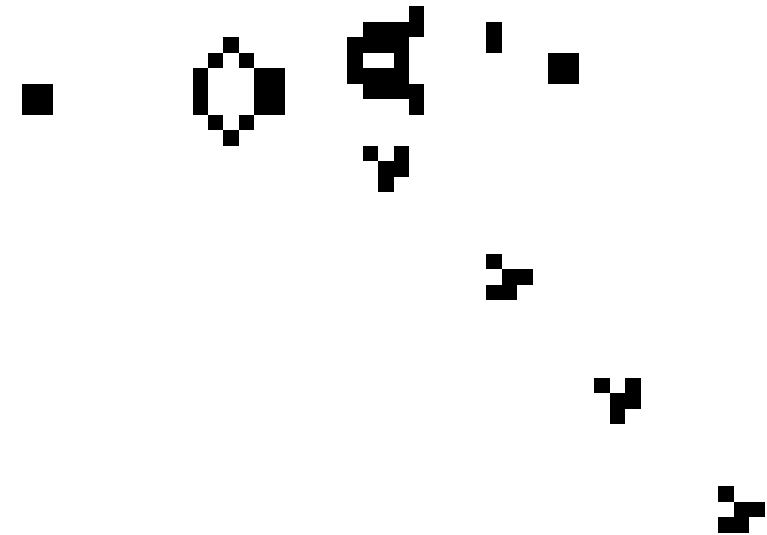
https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life
Gardner 1970 - "Mathematical Games: The fantastic combinations of John Conway's new solitaire game "Life"". *Scientific American.* **223**: 120–123.

Autonomous ABM: *Schelling's Segregation Model*

- Suppose there are two types of agents: Red and Blue.

- A satisfied agent is one that is surrounded by at least t percent of agents that are like itself. Note that the higher the threshold, the higher the likelihood the agents will not be satisfied with their current location.

- Demo: http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/
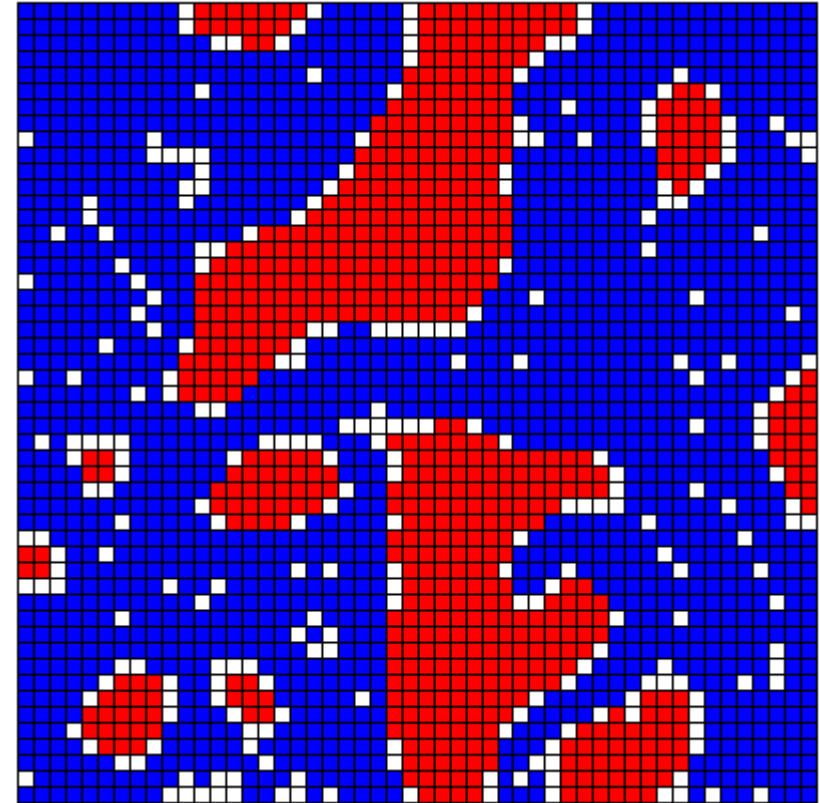
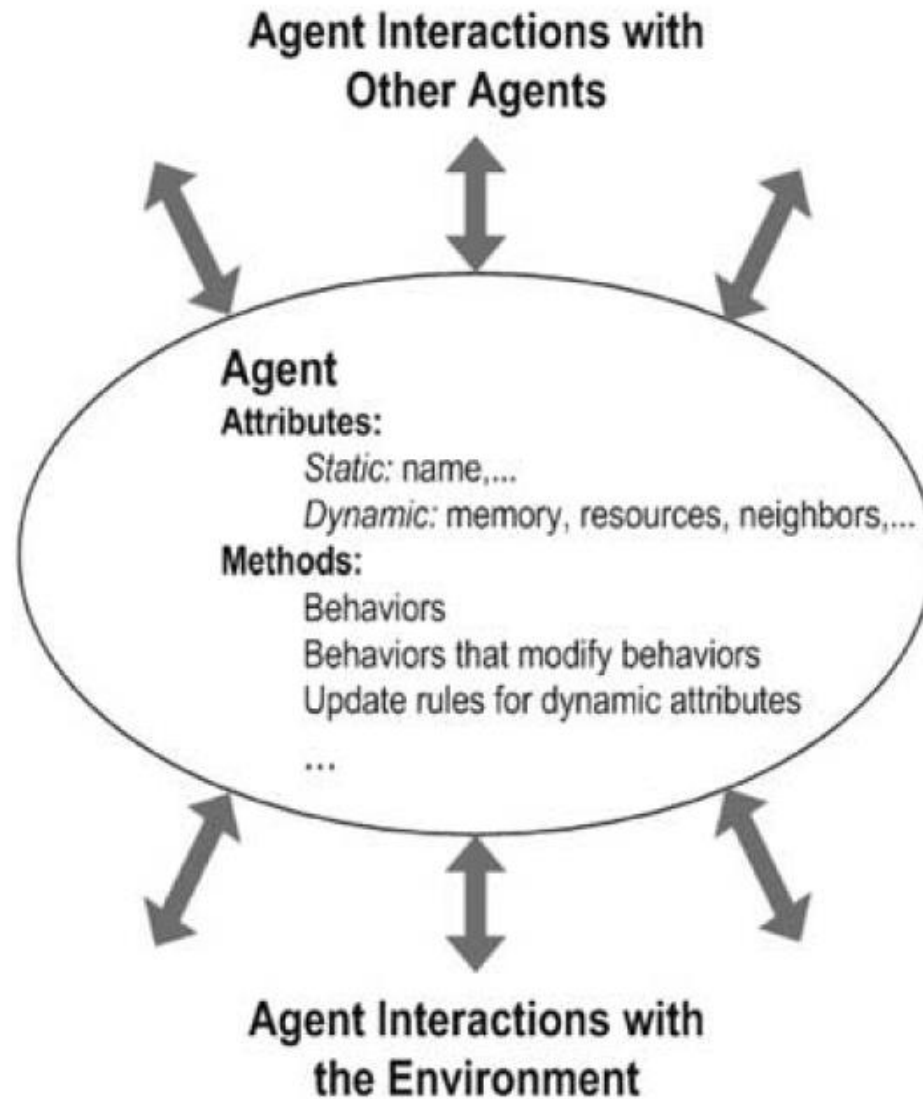Schelling 1978 - Micromotives and Macrobehavior, New York: Norton.

What is an agent?

Agents:

Attributes + Methods (+ Interfaces)

Central: Behaviors / Decision rules

Environment:

Lattice, Network, GIS, „Soup", …

Macal & North 2010 - Tutorial on agent-based modelling and simulation, *Journal of Simulation, 4*, 151 - 162

Classification

Definition	Individuality – agents have diverse set of characteristics	Endogenous, Autonomous Behaviours based on the current agent state	Direct Interactions between other agents and the environment	Adaptability - Agents change behaviours / learn during the simulation // Agent population changes over time
Individual ABMS	🟩	🟥	🟥	🟥
Autonomous ABMS	🟩	🟩	🟥	🟥
Interactive ABMS	🟩	🟩	🟩	🟥
Adaptive ABMS	🟩	🟩	🟩	🟩

Macal, 2016 - Everything you need to know about agent-based modelling and simulation Journal of Simulation, 10, 144 - 156

What is Agent-Based Modelling and Simulation for?

Agent perspective allows us to direct our attention to otherwise understudied phenomena, to incorporate decisions and other behavioural aspects into otherwise „cold" models, and to explore unknown adaptations and emergence.

ABMS is …

- a multi-paradigm method,
- a bridge between different scientific fields,
- a bridge between induction and deduction,
- a way to study disequilibria,
- evolutionary in nature.

https://de.wikipedia.org/wiki/Bewusstsein#/media/File:RobertFuddBewusstsein17Jh.png
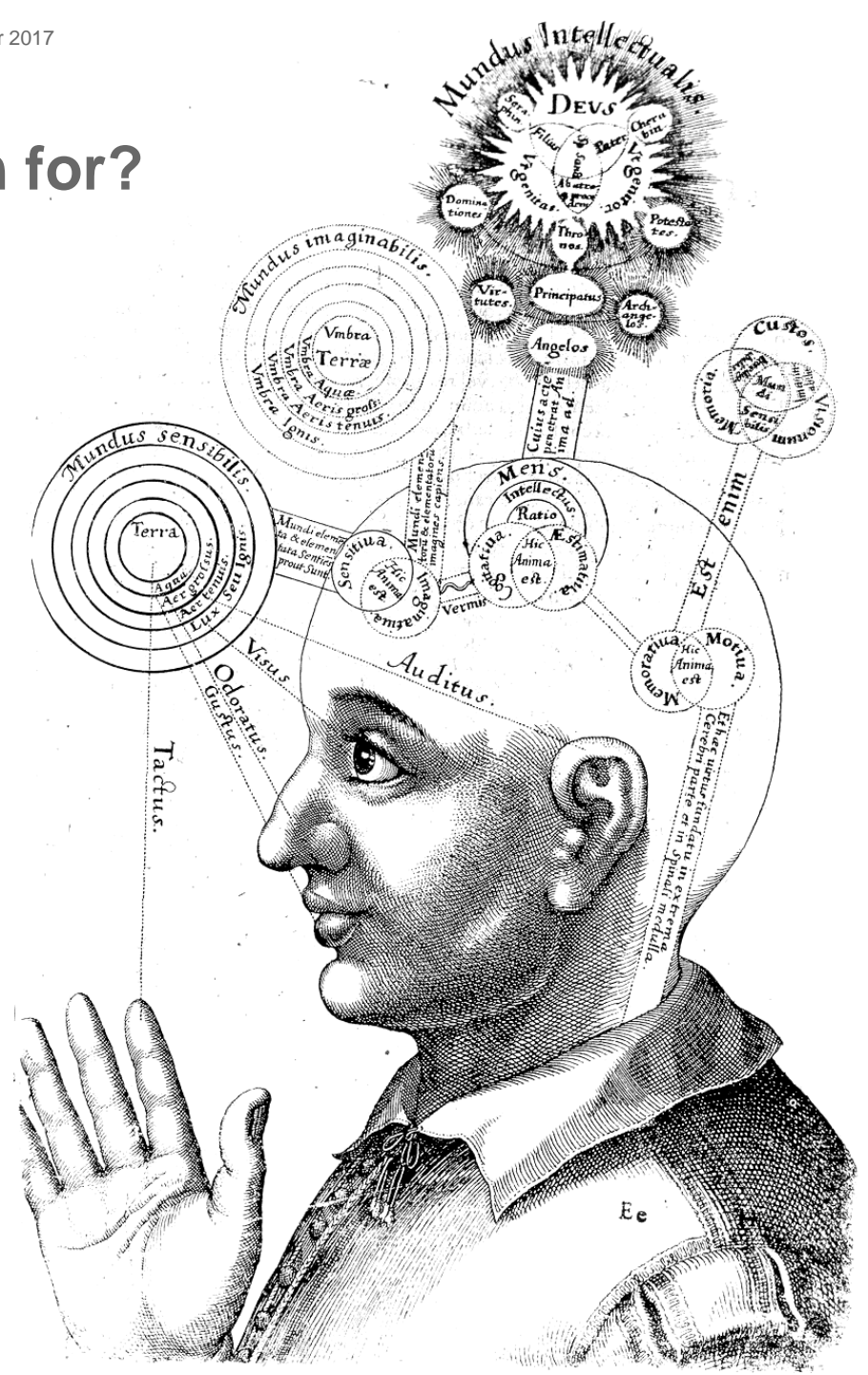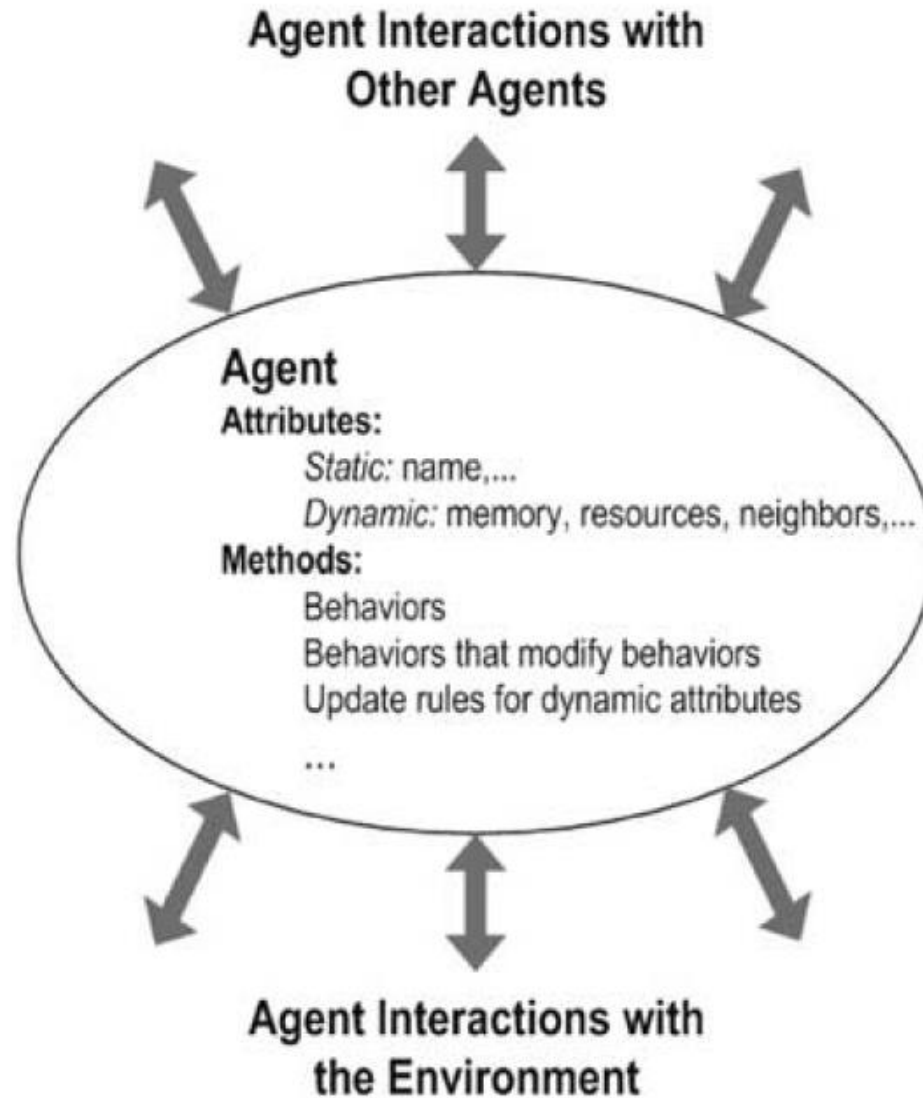
What is an agent?

Agents:

Attributes + Methods (+ Interfaces)

Central: Behaviors / Decision rules

Decision rules can be based on **_any_** model

- Logic (if… , then…; else…)
- Machine Learning Algorithm
- System dynamics model
- Dispatch model
- …

Macal & North 2010 - Tutorial on agent-based modelling and simulation, *Journal of Simulation, 4*, 151 - 162

Agent Interactions with Other Agents

Agent
Attributes:
  Static: name,...
  Dynamic: memory, resources, neighbors,...
Methods:
  Behaviors
  Behaviors that modify behaviors
  Update rules for dynamic attributes
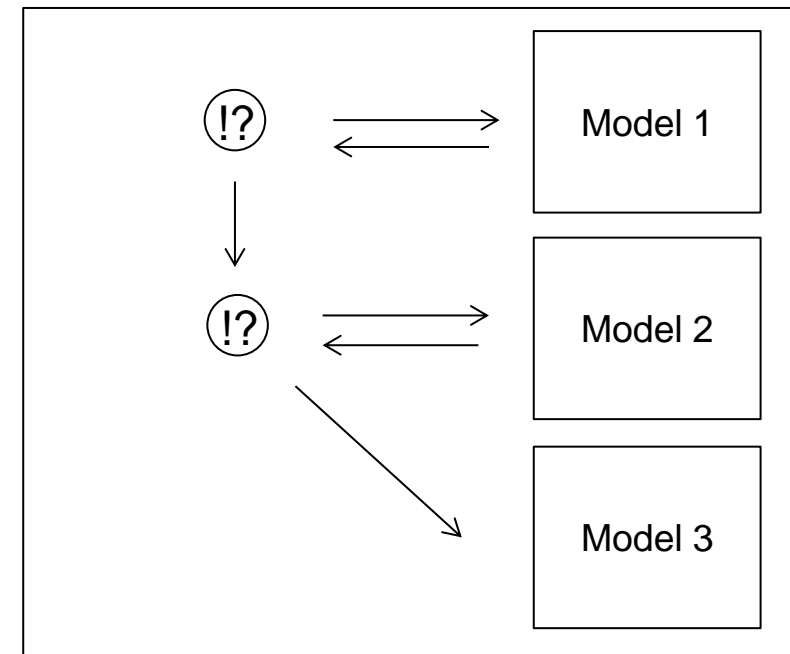 ...

Agent Interactions with the Environment

Models in Models – ABMS as multi-paradigm simulation

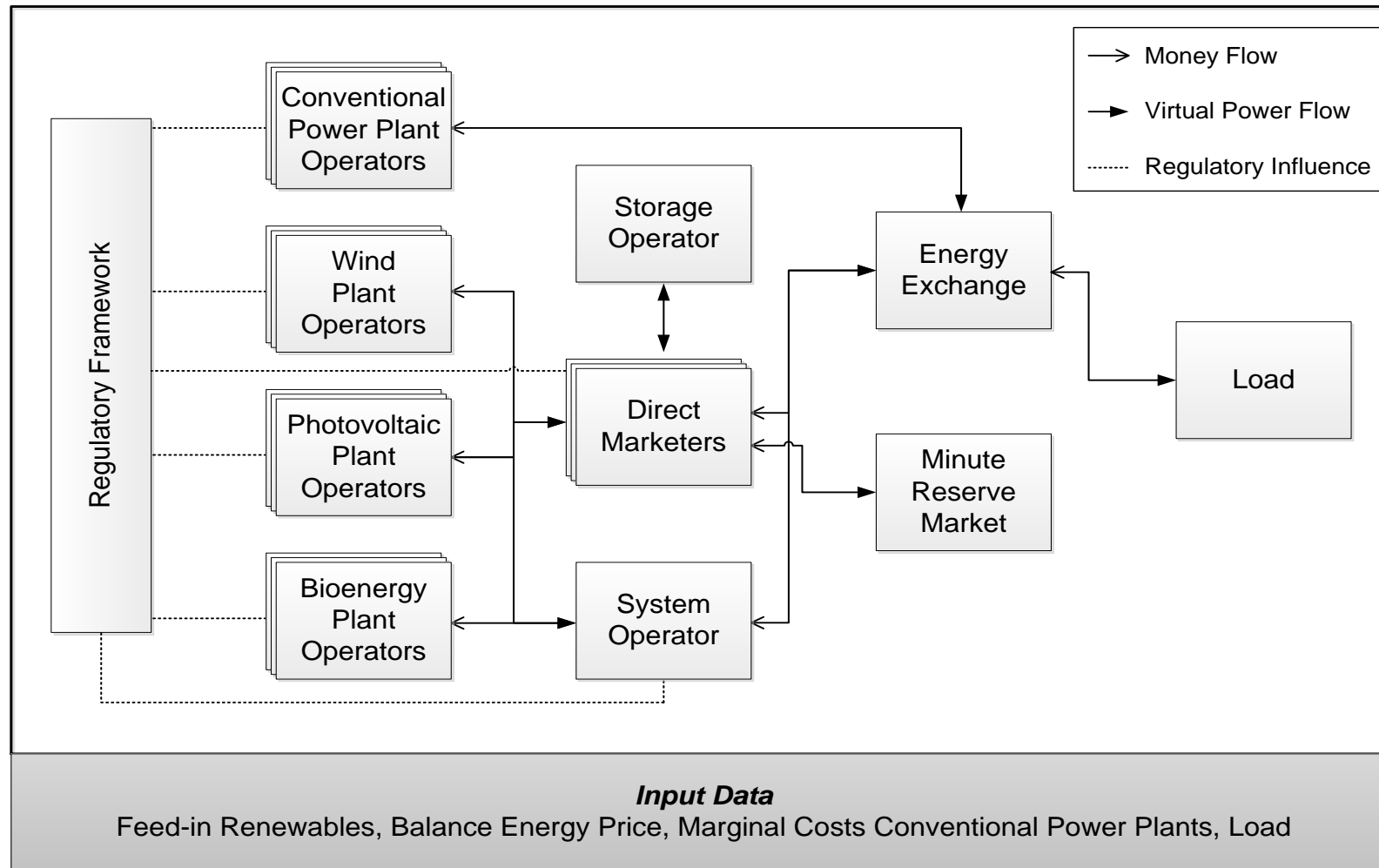- Proposition: Model coupling can always be depicted as an (abstract) ABMS
- Example:
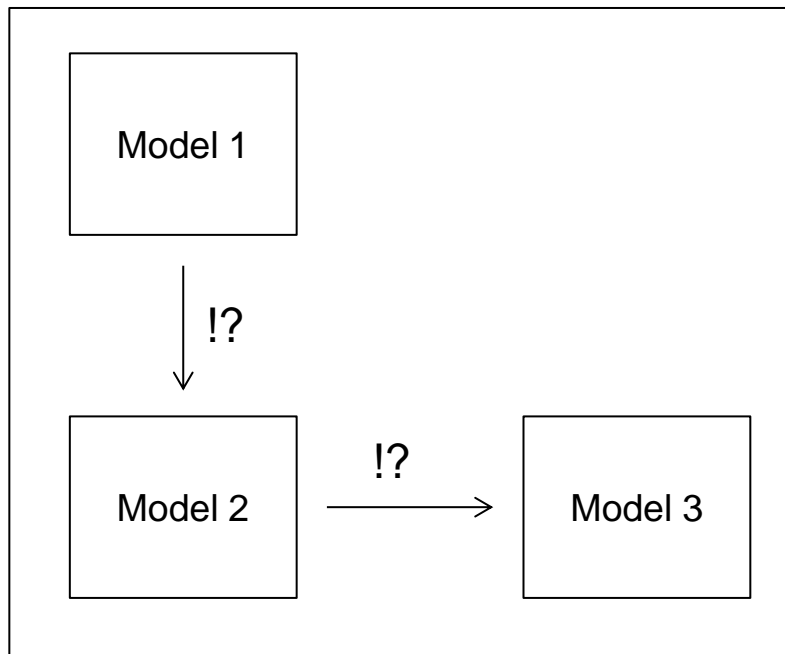
„Manual" model coupling
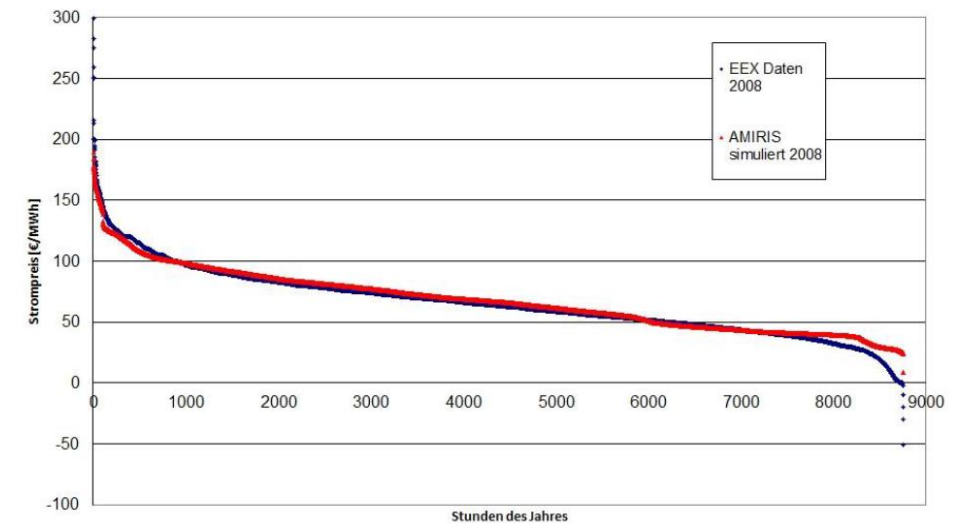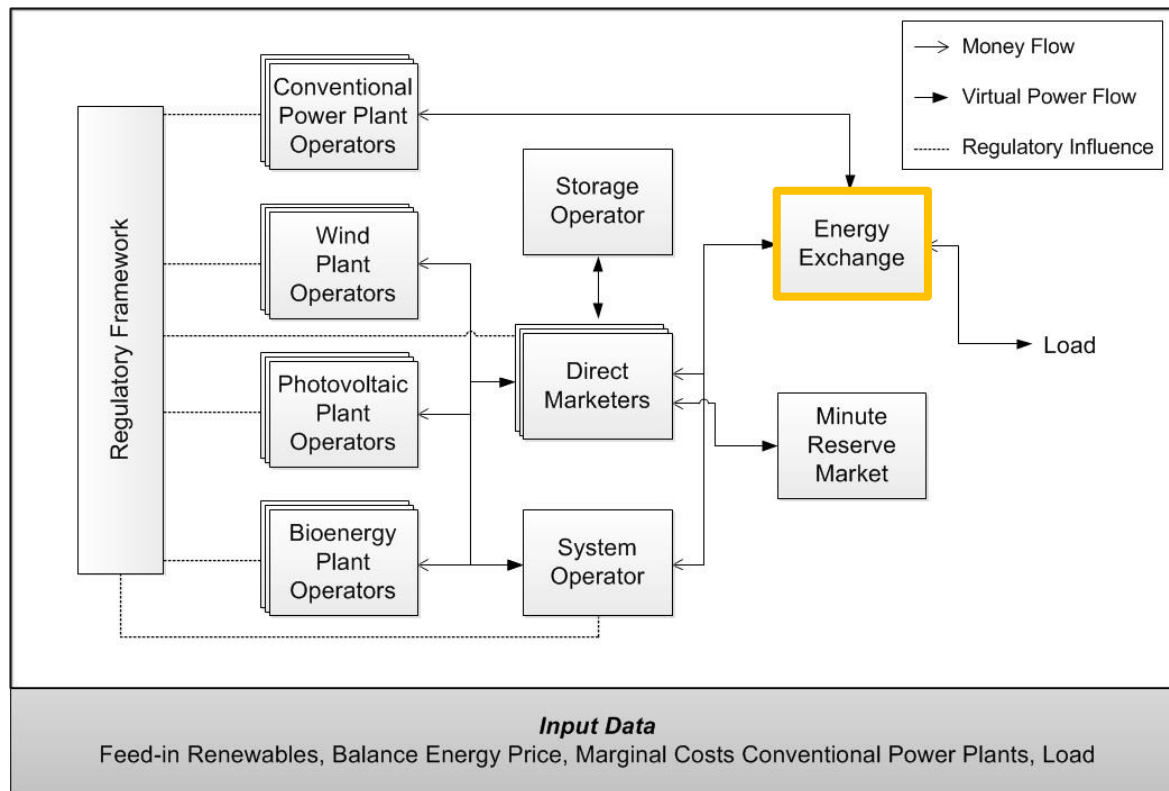
Explicit ABMS model coupling via mediating agents !?

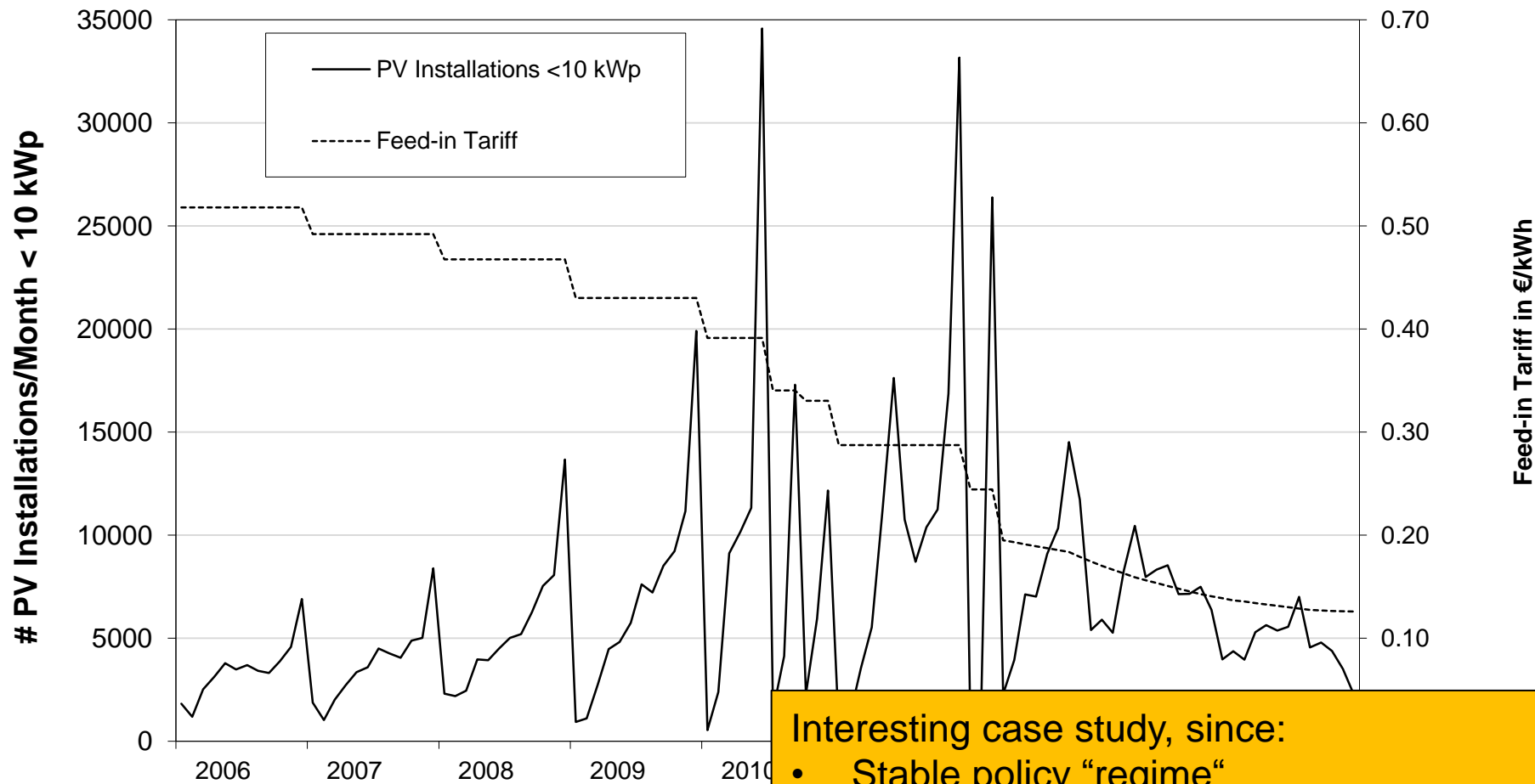# AMIRIS

ABMS as a container framework

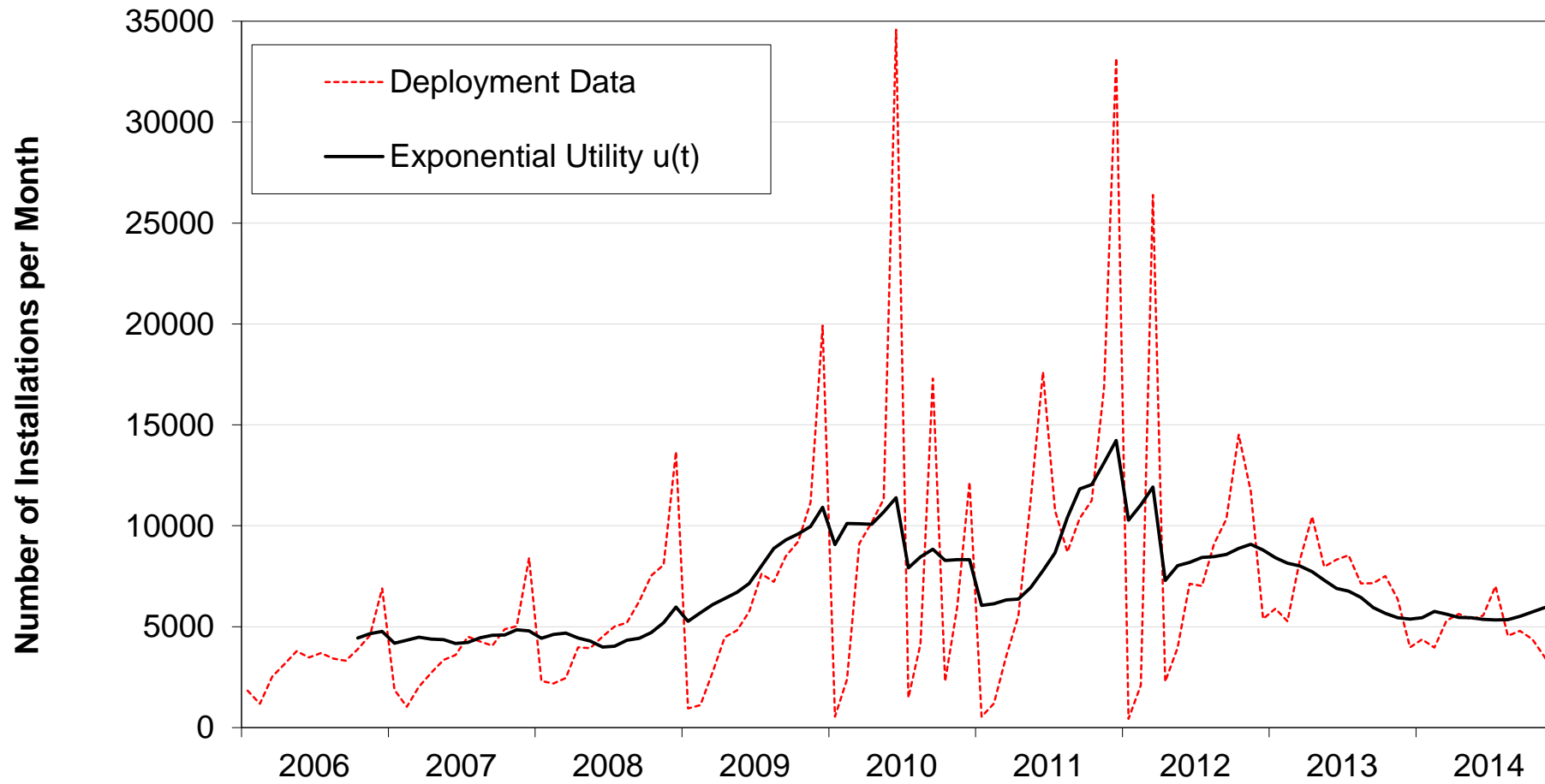AMIRIS: example of explicit internal model coupling

= internal model

Other Example: Investment Decisions in Solar Photovoltaics

Interesting case study, since:
- Stable policy "regime"
- Relatively understudied,
- Magnitude of the effect: ca. 750.000 installations
- → Possibility to study investment in RES

Retrospective Analysis of Profitability

Application in Behavioral Economics

- Value not only determined in absolute terms, but also in changes relative to the status quo (i.e. in gains and losses)
- **Value function of Prospect Theory**:
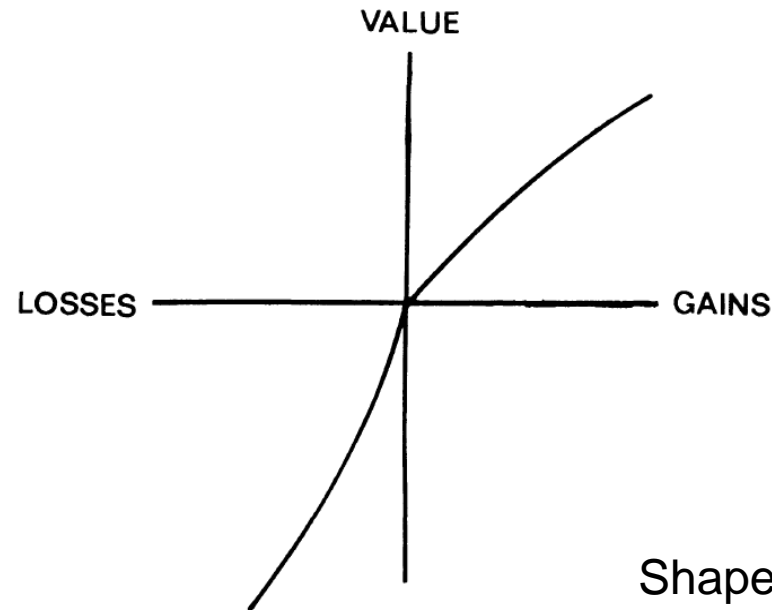
Shape parameters determined in choice experiments

Kahneman, D. & Tversky, A.; Prospect Theory: An Analysis of Decision under Risk; *Econometrica,* **1979***, 47*, 263-291
Tversky, A. & Kahneman, D.; Advances in prospect theory: Cumulative representation of uncertainty; *Journal of Risk and Uncertainty,* **1992***, 5*, 297-323

Retrospective Analysis of Profitability

Klein, M. & Deissenroth, M., 2017. When do households invest in solar photovoltaics? An application of prospect theory. *Energy Policy*, 109, pp. 270–278, DOI: 10.1016/j.enpol.2017.06.067
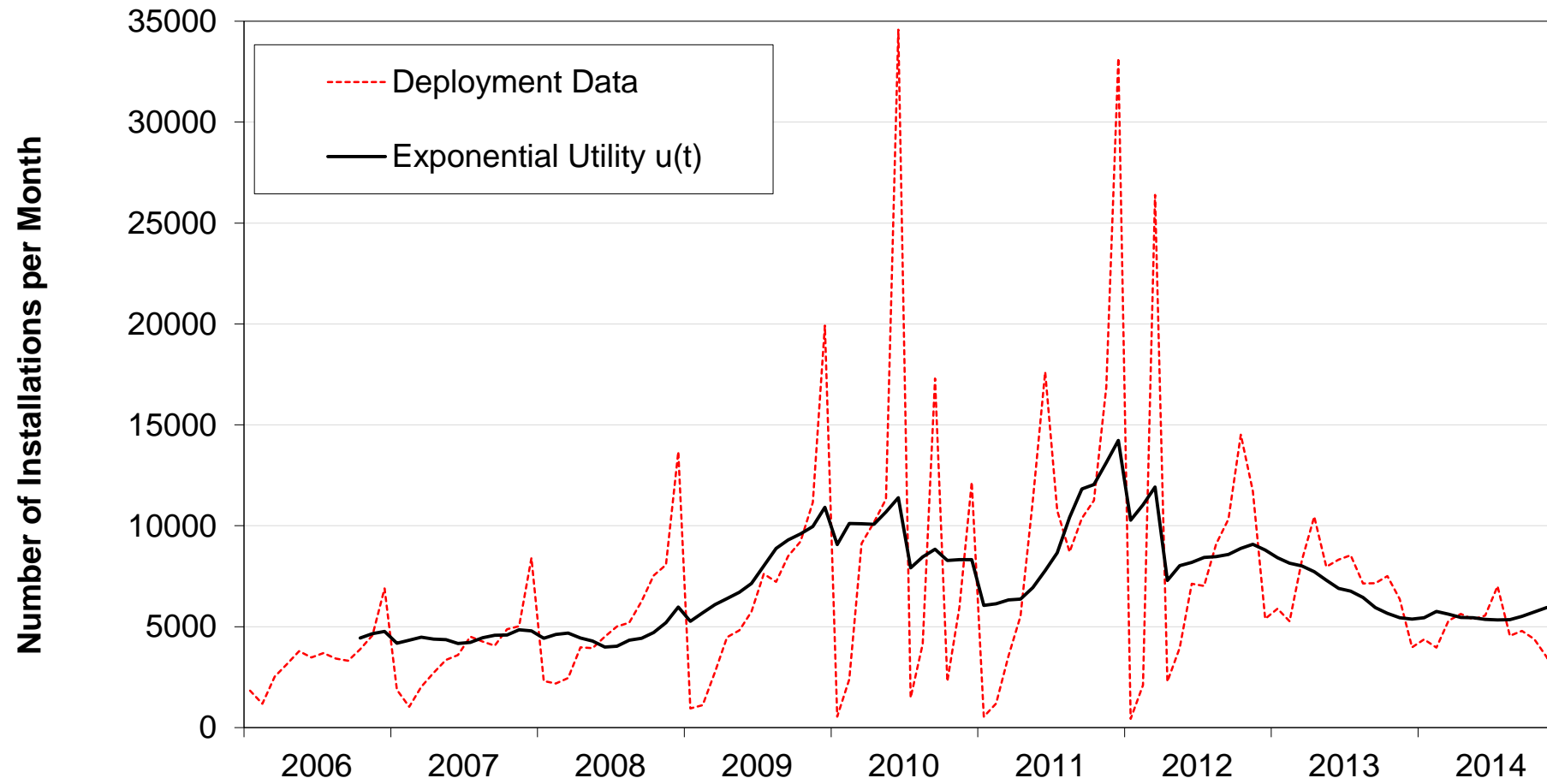
Retrospective Analysis of Profitability incorporating Prospect Theory

Klein, M. & Deissenroth, M., 2017. When do households invest in solar photovoltaics? An application of prospect theory. *Energy Policy*, 109, pp. 270–278, DOI: 10.1016/j.enpol.2017.06.067
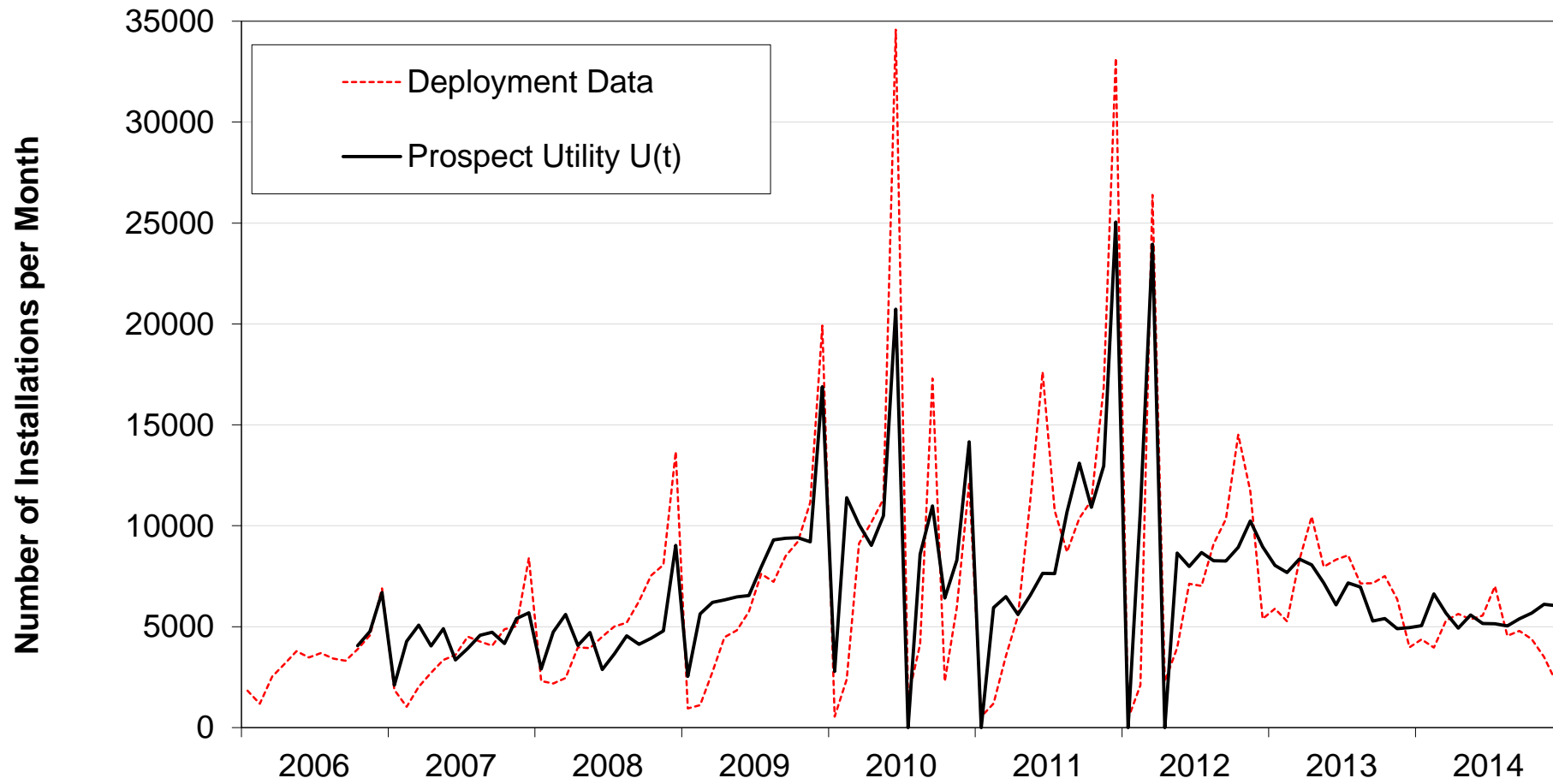
Induction and Deduction in Energy Systems Analysis

Induction

Deduction

Observation // Experiment

Generalization

Predictions

Paradigm // Theory
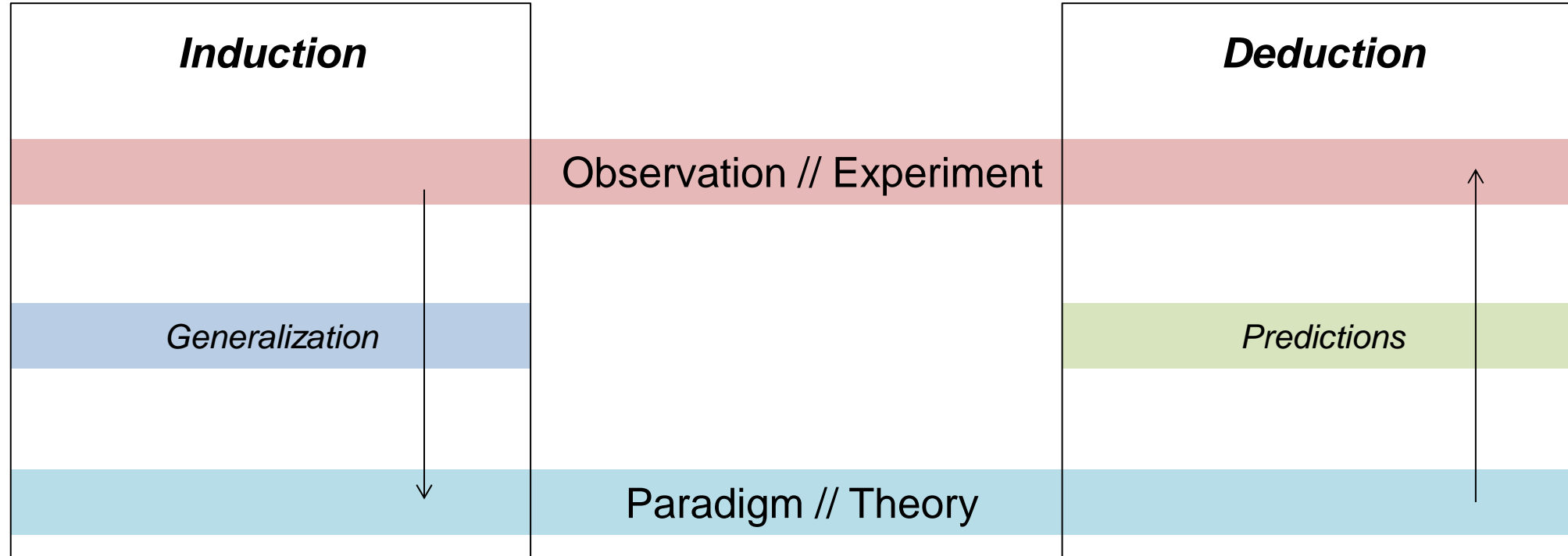
How do energy market and policy instruments work? What are drivers of demand and innovation?

Given (Σ constraints), how does an optimal energy system look like?

ABMS potentially in the middle of the two
Incorporating observation and model logic
Axelrod's „third way of doing science"

DLR

What's "wrong" with Equilibrium Theory in the first place?

- Equilibria might exist but are effectively uncomputable

- Equilibrium might not be attained by boundedly rational agents

- Equilibria might be obtained asymptotically but not realized over long periods

- Equilibria might exist but are unstable

- **Equilibrium might be less important than fluctuations and extreme events**

https://de.wikipedia.org/wiki/Gas-und-Dampf-Kombikraftwerk#/media/File:ISK_Knapsack_GuD_2007.jpg

https://data.giss.nasa.gov/gistemp/graphs/
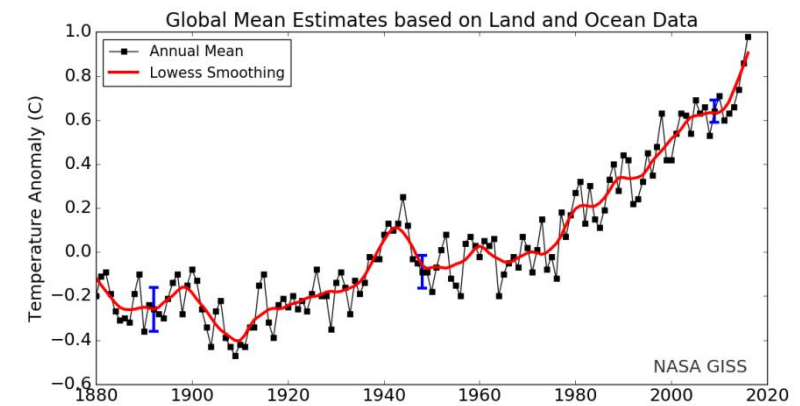
Axtell 2000 – Why Agents? On the varied motivations for agent computing in the social sciences

Inherent Difficulties of ABMS

- There is no „archetypical" ABMS

- There is 1 way to be rational, but 1000 to be boundedly rational

- Complexity impedes reporting and consulting (there are some standards though (Grimm et al. 2010))

- Complete models of human interactions do not exist, they tend to invalidate themselves
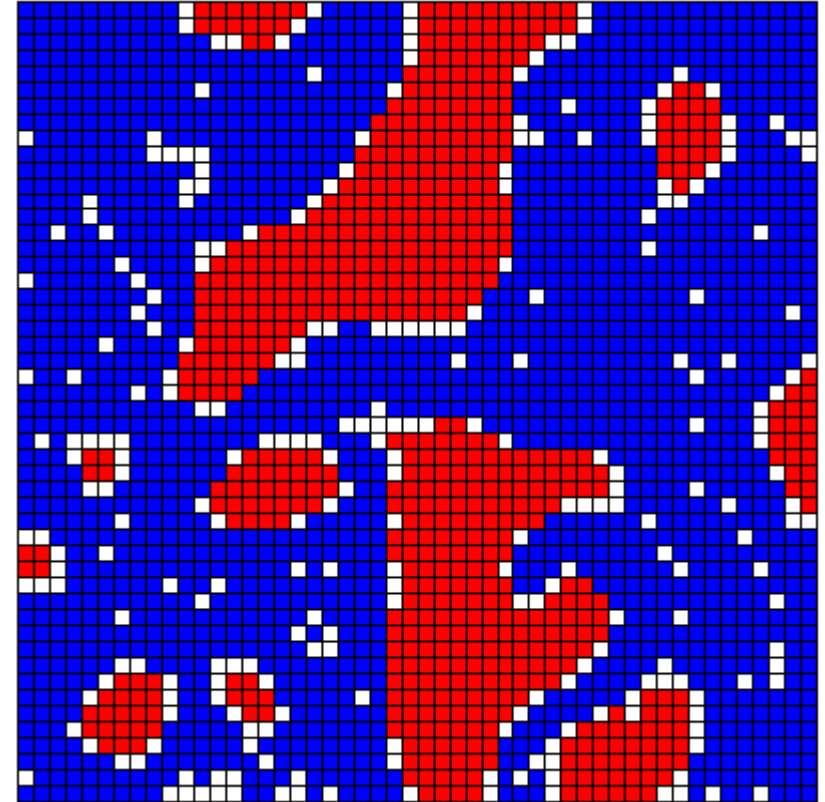
Conclusions

Agent perspective allows us to direct our attention to otherwise understudied phenomena, to incorporate decisions and other behavioural aspects into otherwise „cold" models, and to explore unknown adaptations and emergence.

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https://de.wikipedia.org/wiki/Bewusstsein#/media/File:RobertFuddBewusstsein17Jh.png
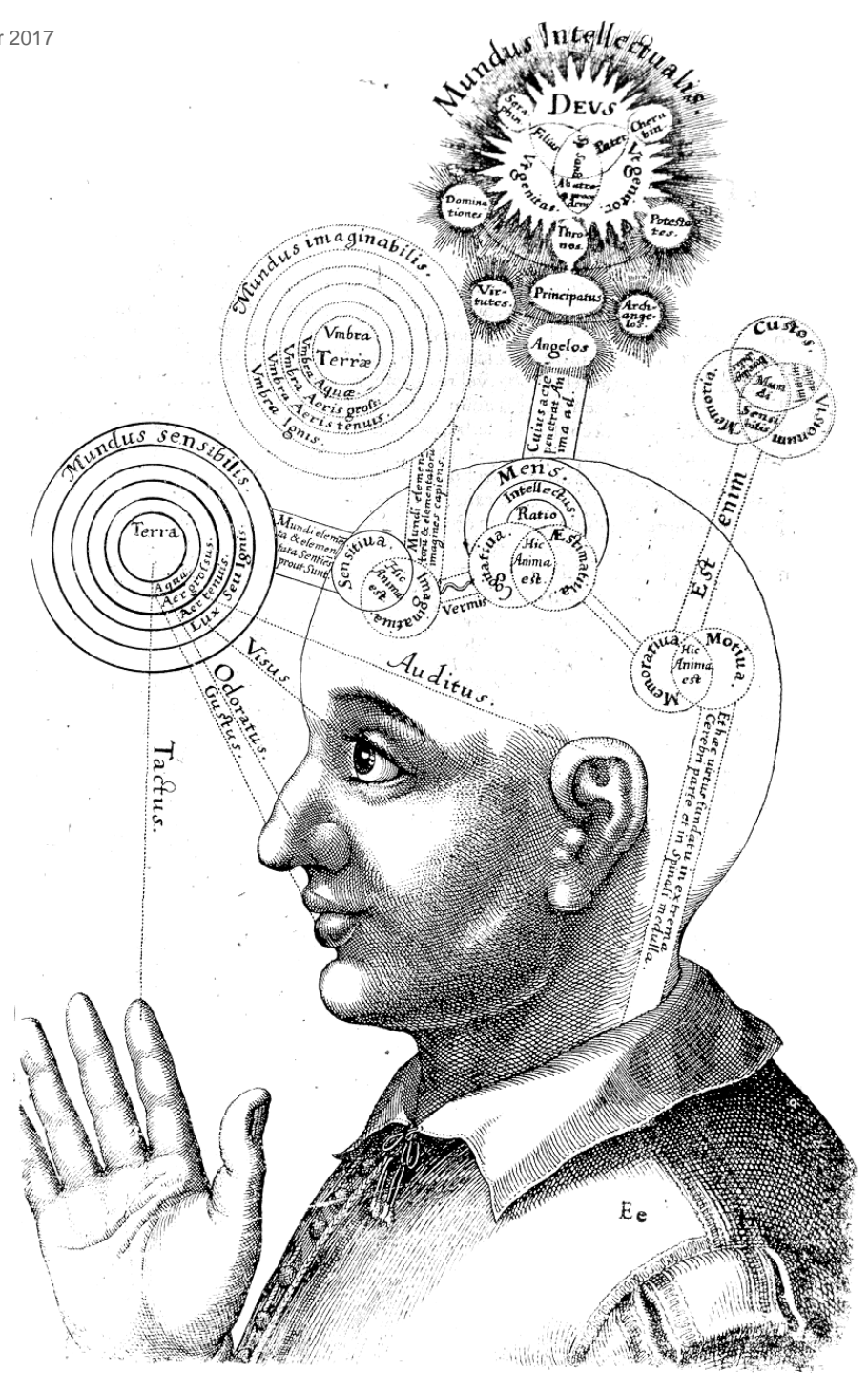
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Contact

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Contact: http://www.dlr.de/tt/desktopdefault.aspx/tabid-4074/6449_read-30526/start-k/sortby-lastname/

Knowledge for Tomorrow

ACE and Evolutionary Economics

- Compare: Black vs. White Moths during the time of industrial revolution
- ABMS is by definition evolutionary, as it studies adaptations to the environment

https://en.wikipedia.org/wiki/Peppered_moth_evolution#/media/File:Biston.betularia.7200.jpg

https://en.wikipedia.org/wiki/Peppered_moth_evolution#/media/File:Biston.betularia.f.carbonaria.7209.jpg

See also: https://www.youtube.com/watch?v=USlJm-2qT2w