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

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Stuttgart, 28th September 2017

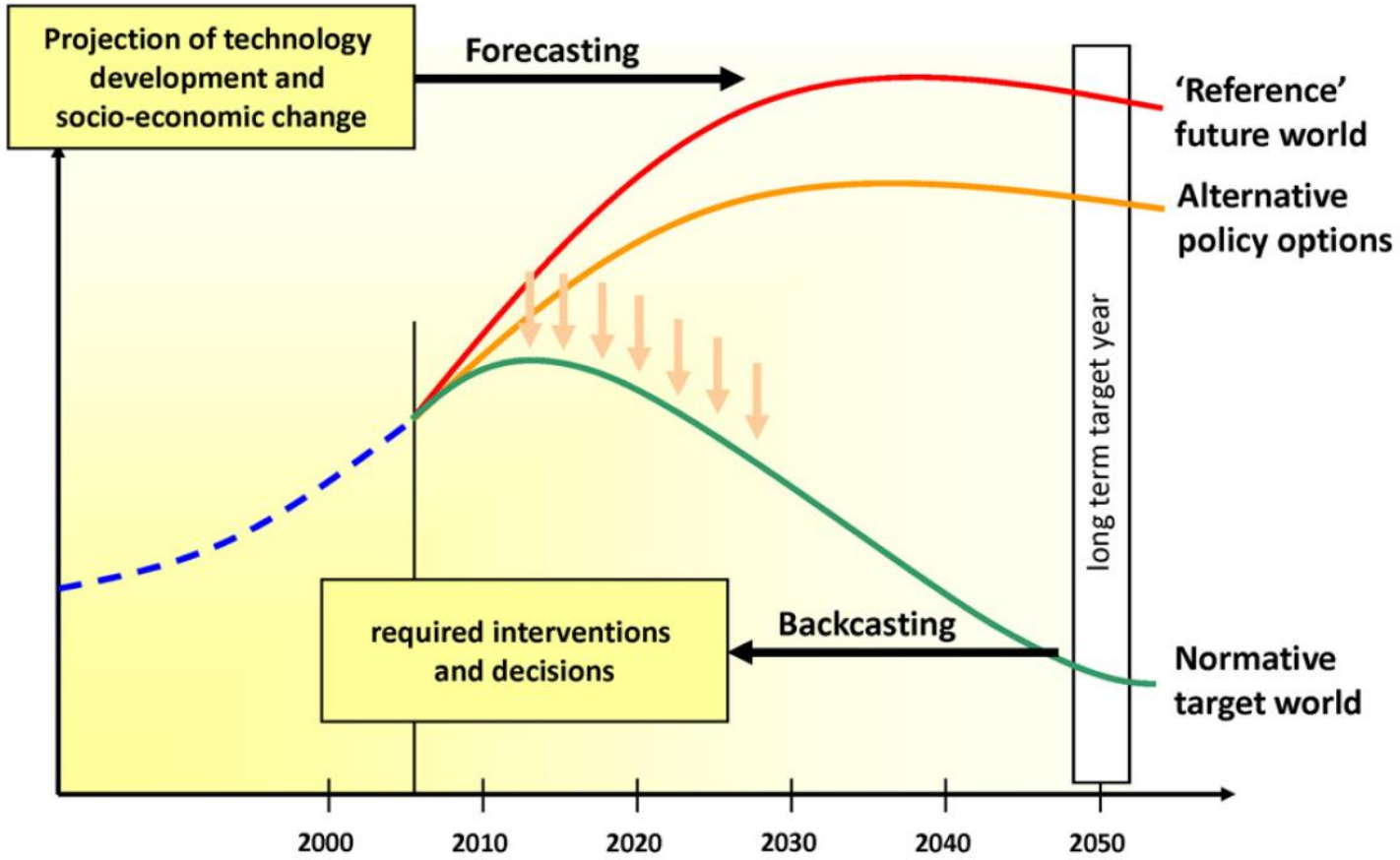

DLR

energy scenarios school

# 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

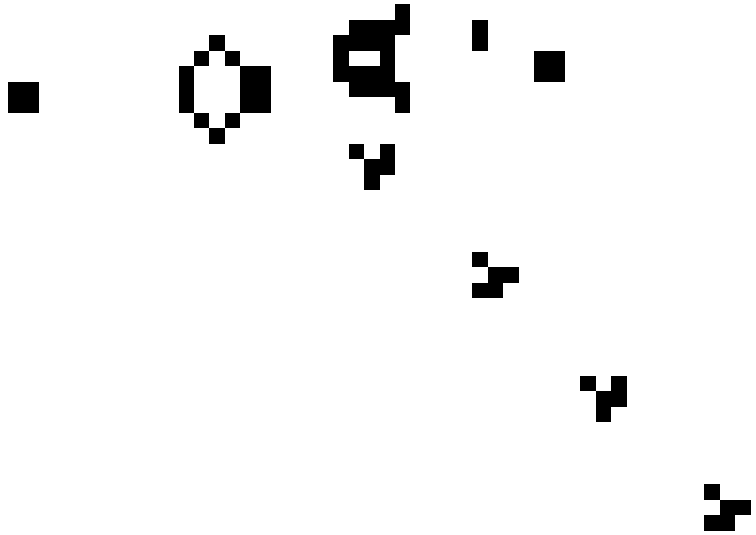
# Two Modes of Analysis Analysis in Energy Systems Analysis




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*

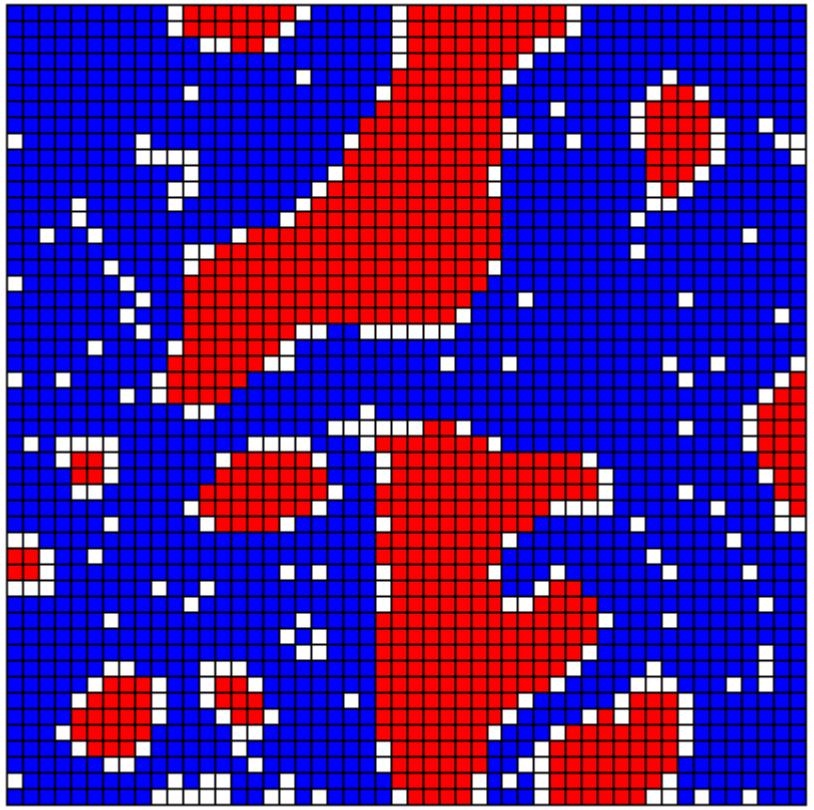
- Any live cell with fewer than two live neighbours dies, as if caused by underpopulation.
- Any live cell with two or three live neighbours lives on to the next generation.
- Any live cell with more than three live neighbours dies, as if by overpopulation.
- Any dead cell with exactly three live neighbours 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/

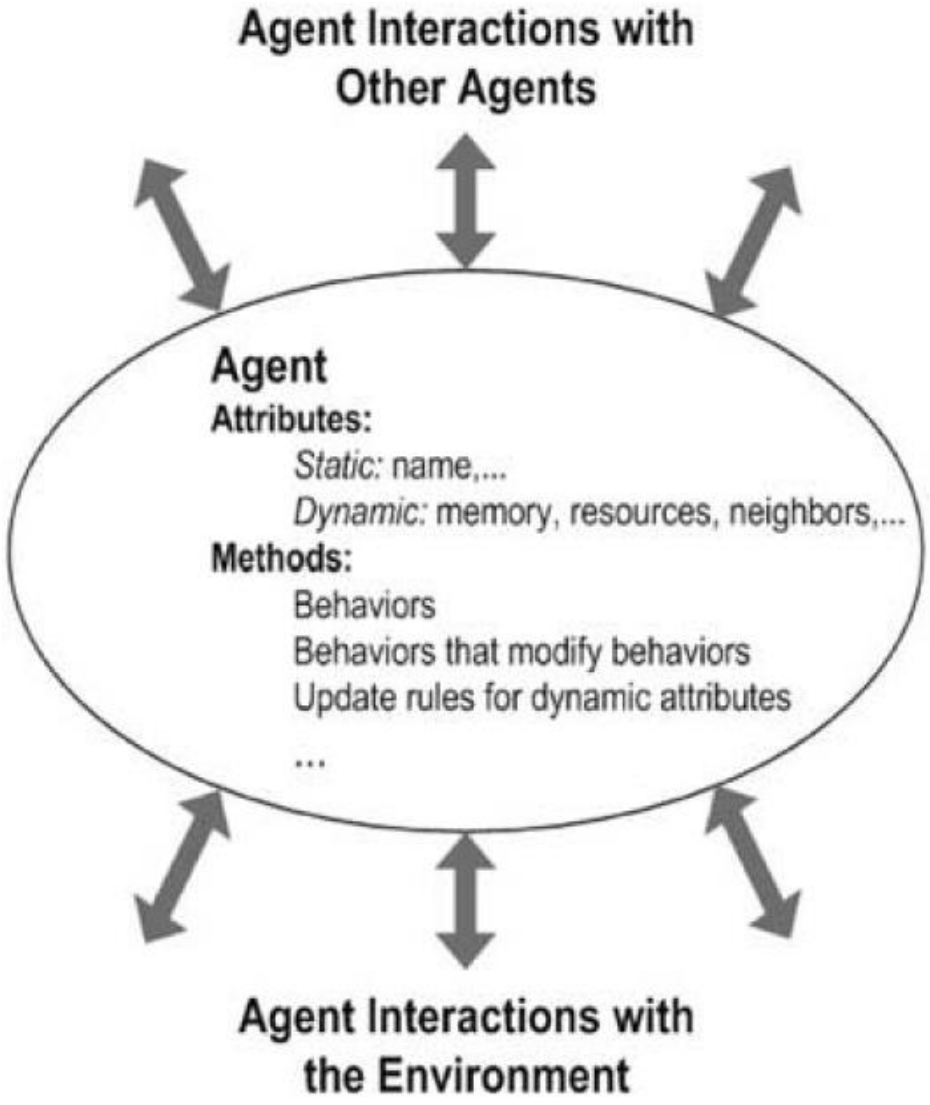


Schelling 1978 - Micromotives and Macrobehavior, New York: Norton.

# 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 | | | | |

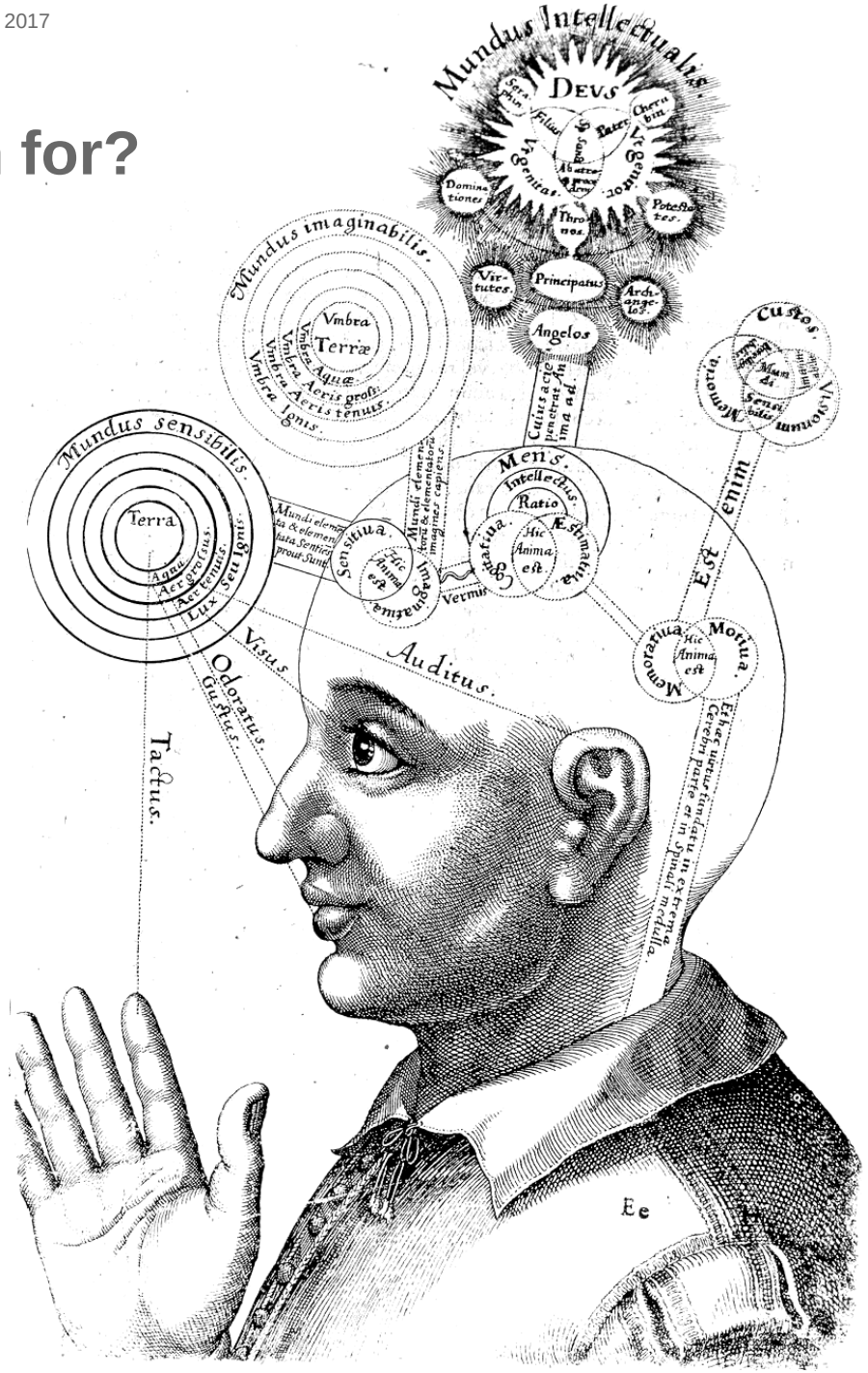
Macal, 2016 - Everything you need to know about agent-based modelling and simulation Journal of Simulation, 10, 144 - 156

# 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:*

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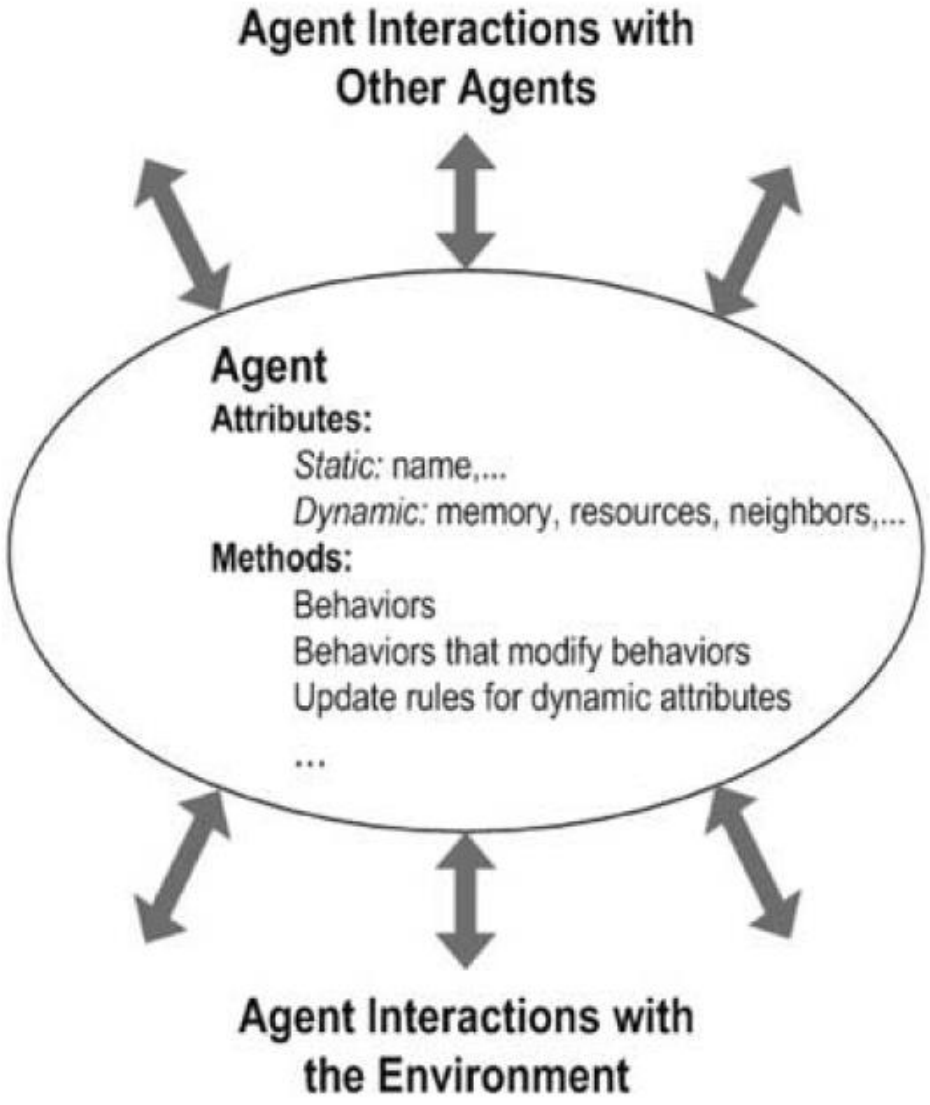
Central: Behaviors / Decision rules

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

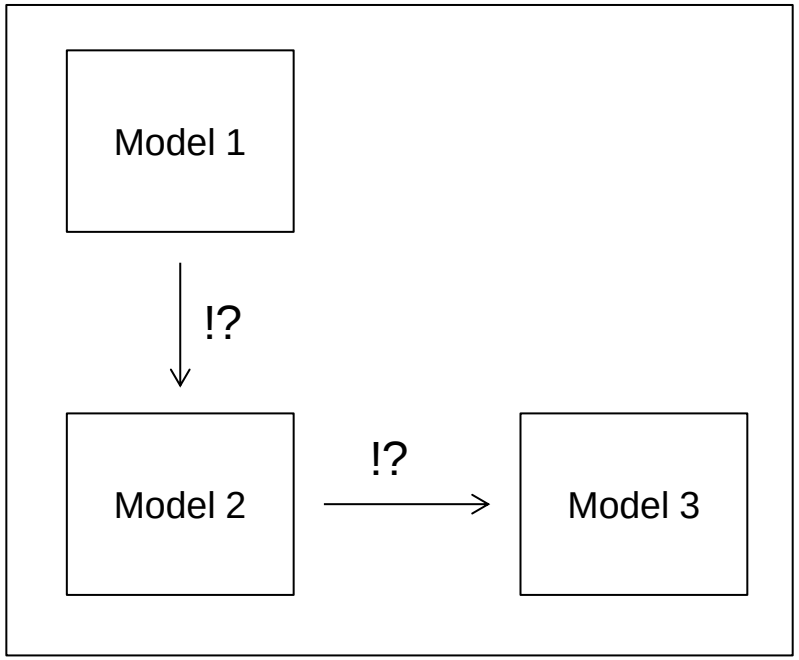
- Logic (if… , then…; else…)
- Machine Learning Algorithm
- System dynamics model
- Dispatch model
- …



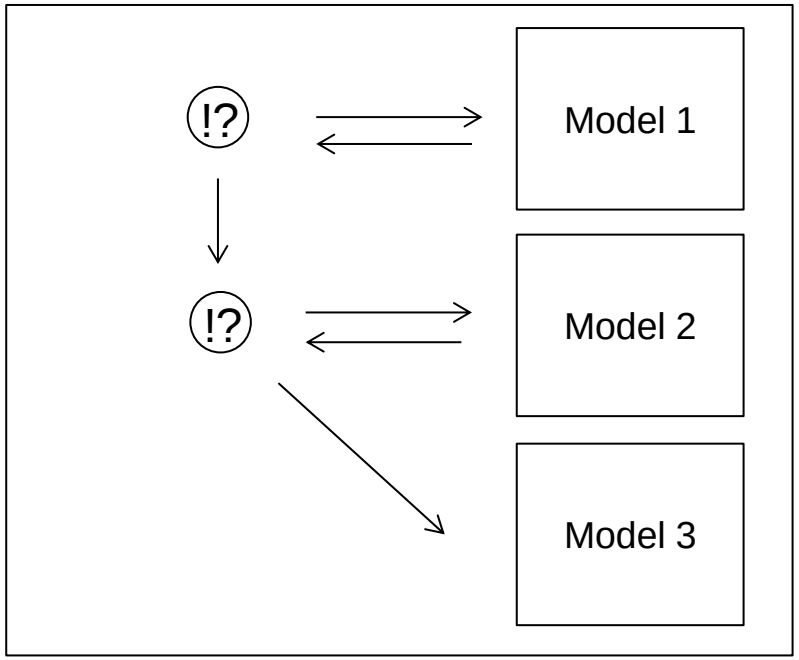

Macal & North 2010 - Tutorial on agent-based modelling and simulation, *Journal of Simulation, 4*, 151 - 162

# Models in Models – ABMS as multi-paradigm simulation

- Proposition: Model coupling can always be depicted as an (abstract) ABMS
- Example:

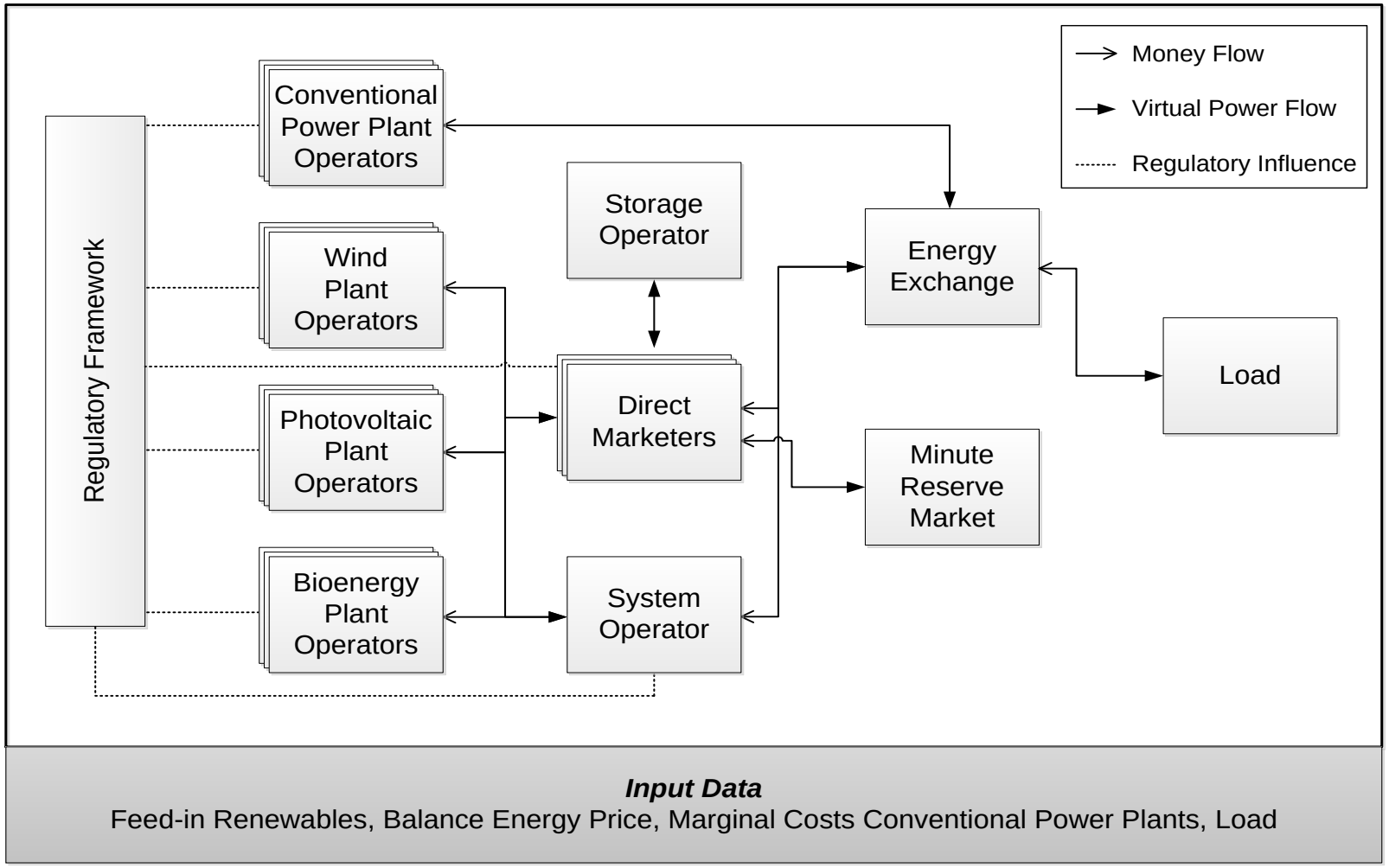



„Manual“ model coupling




Expicit ABMS model coupling via mediating agents (!?)

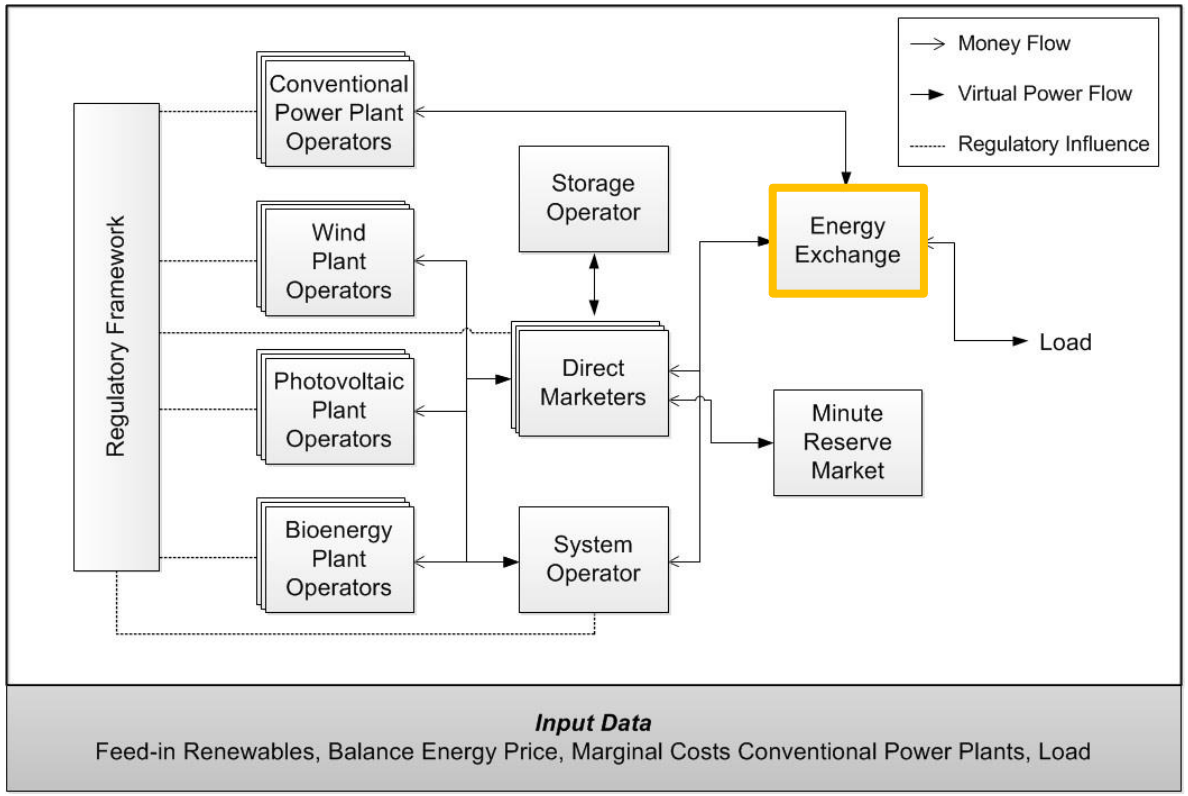
# AMIRIS

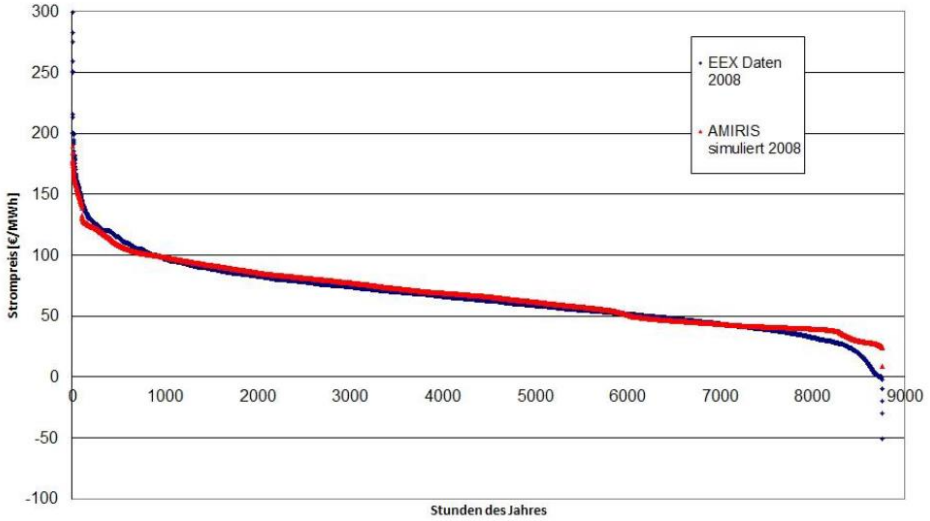



http://www.dlr.de/Portaldata/41/Resources/dokumente/institut/system/Modellbeschreibungen/DLR_AMIRIS_short_description_2016.pdf

# ABMS as a container framework

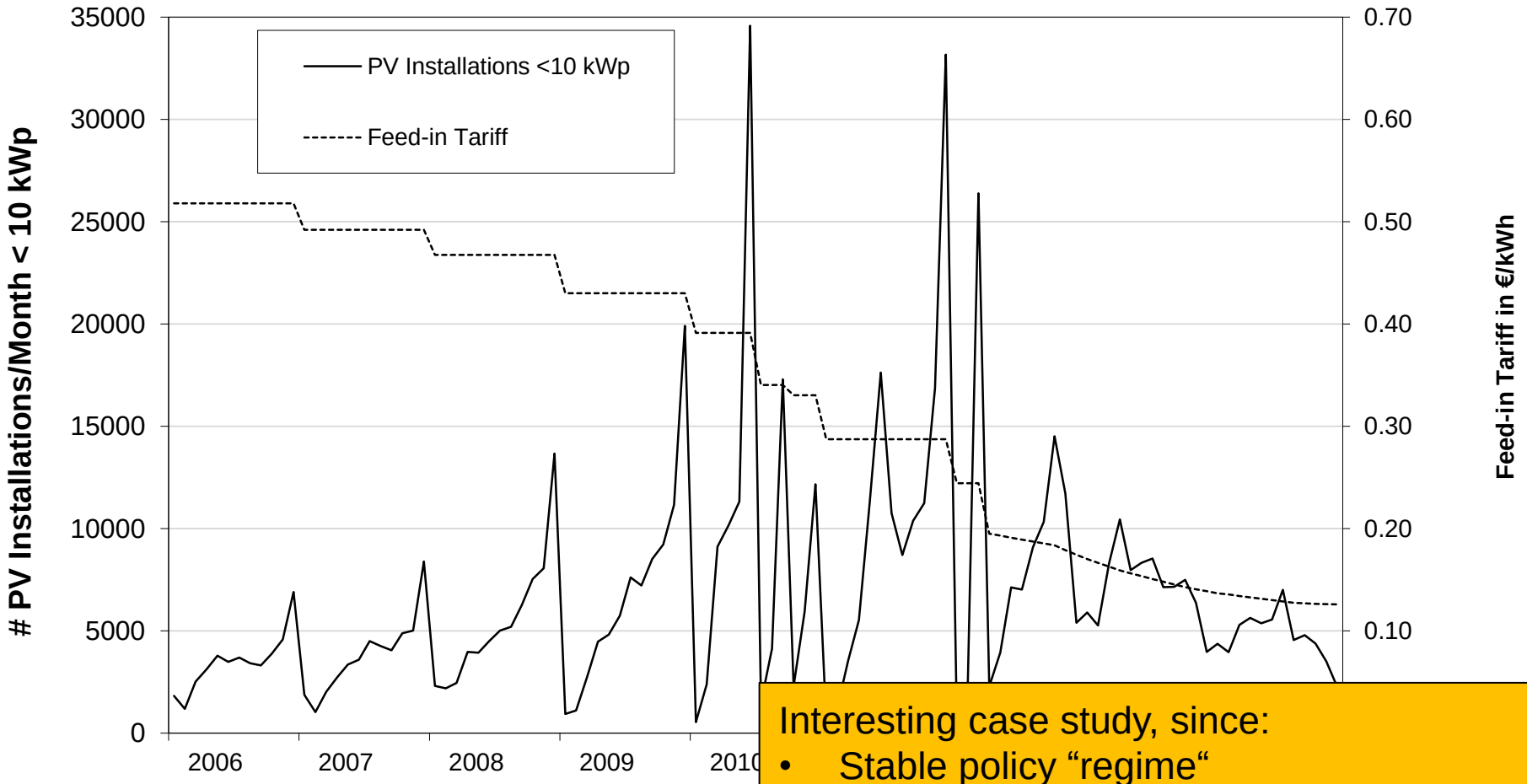
## AMIRIS: example of explicit internal model coupling




= internal model

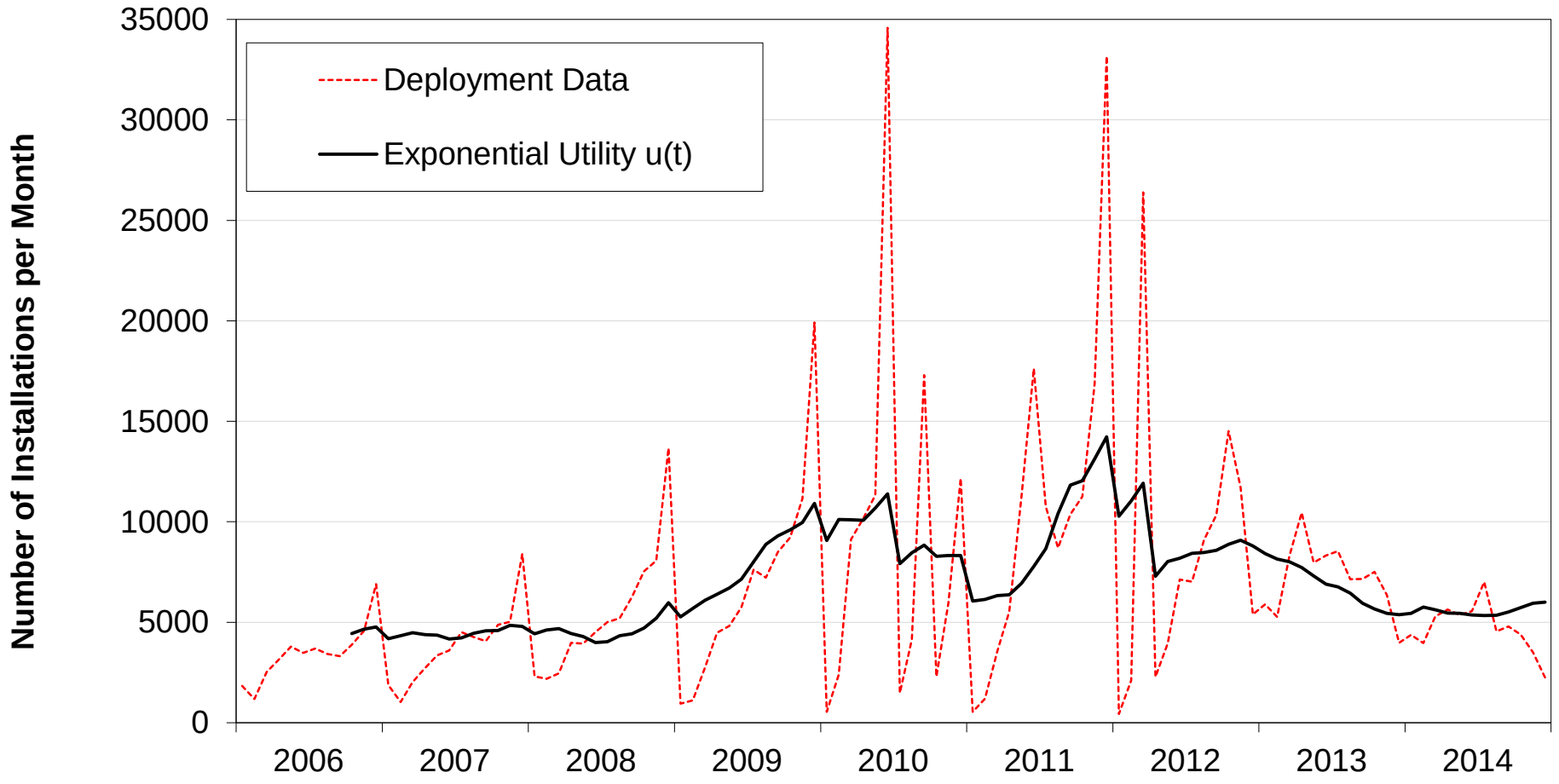
# Other Example: Investment Decisions in Solar Photovoltaics




Interesting case study, since:

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

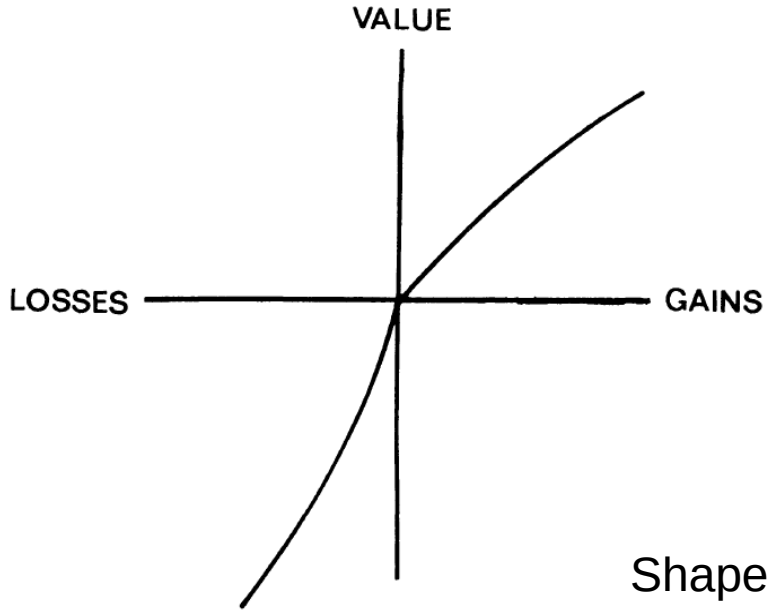
# Retrospective Analysis of Profitability




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

# 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 expermients

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

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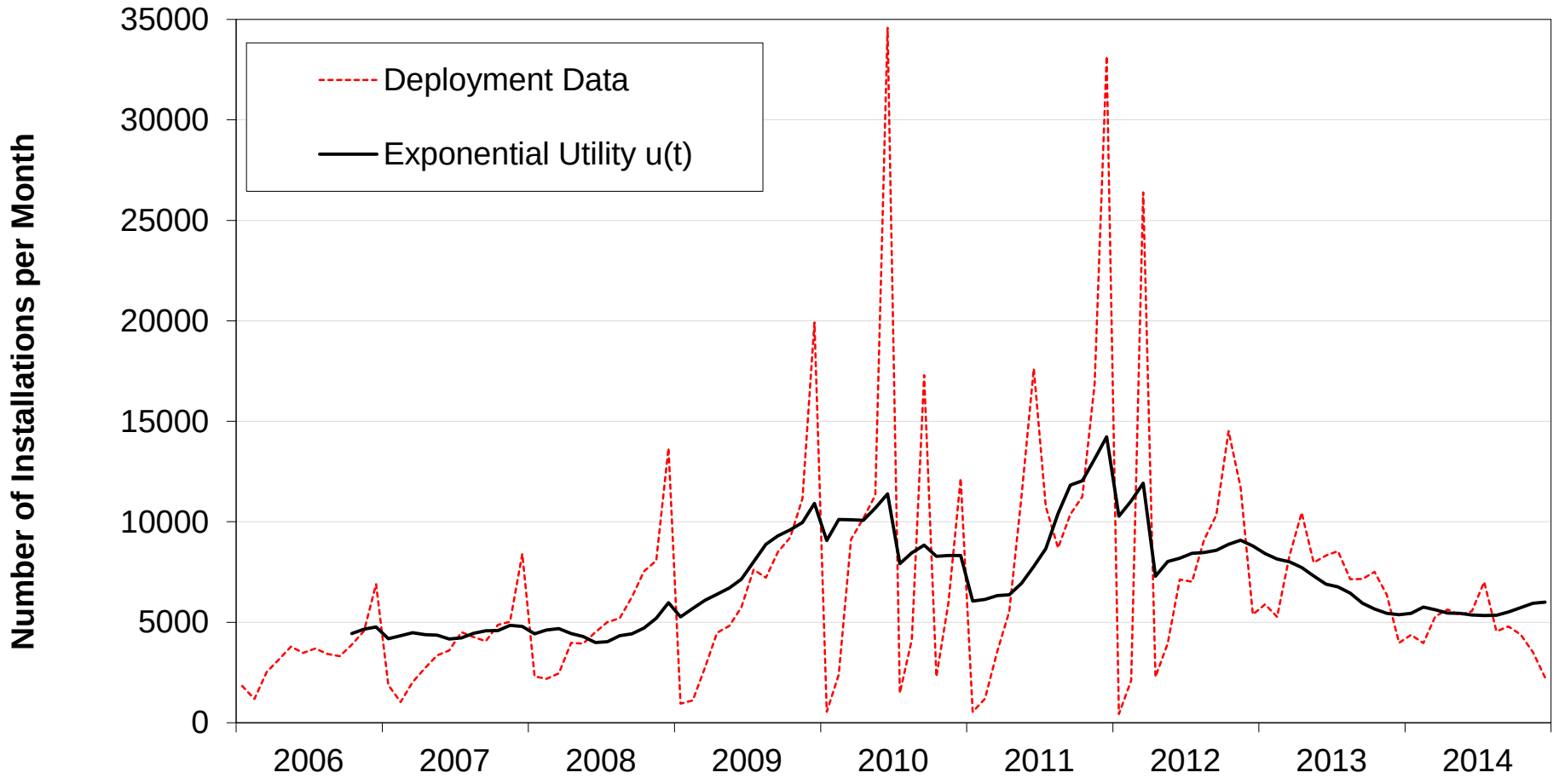


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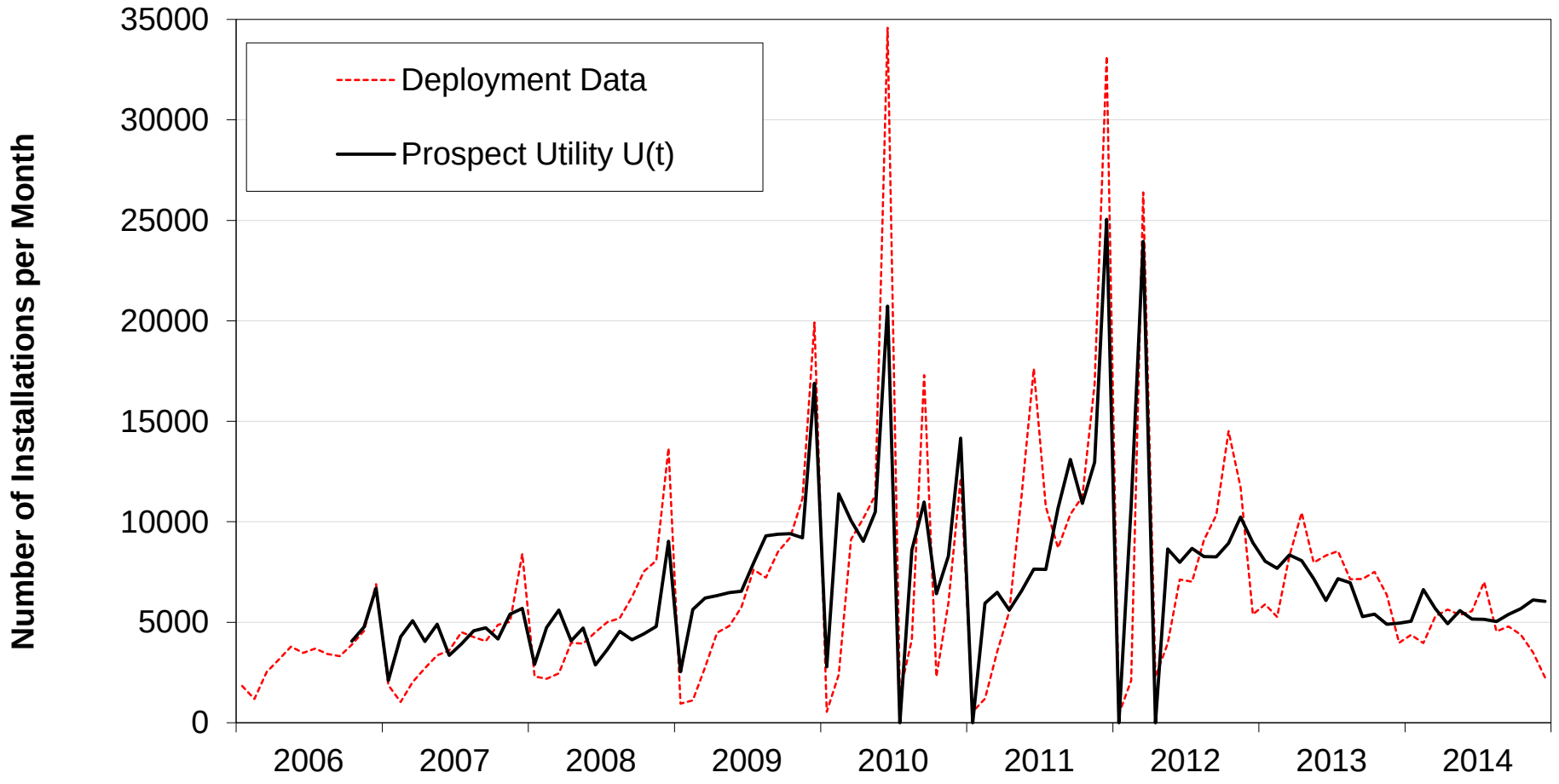
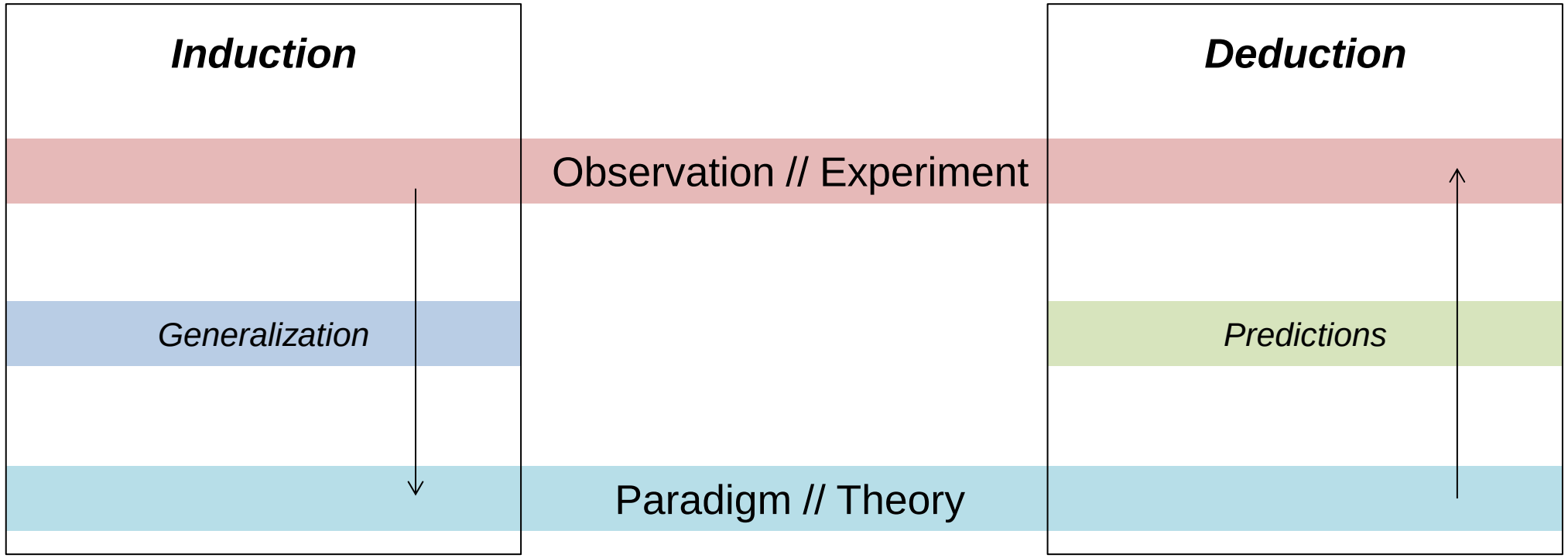
# Retrospective Analysis of Profitability incorporating Prospect Theory




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




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

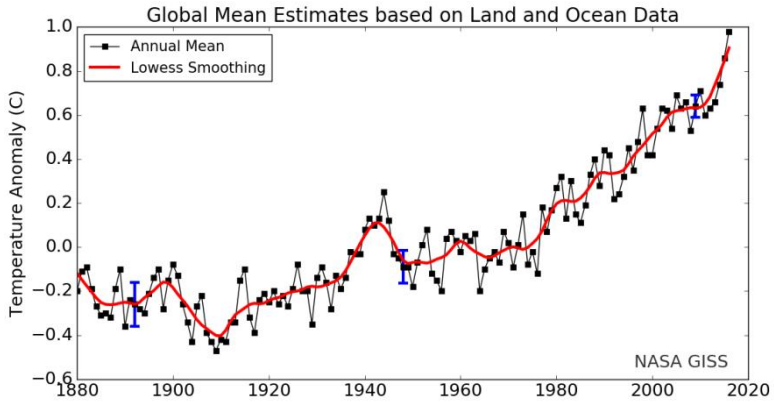
Given (Σ constraints), how does an optimal energy system look like?

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

# 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

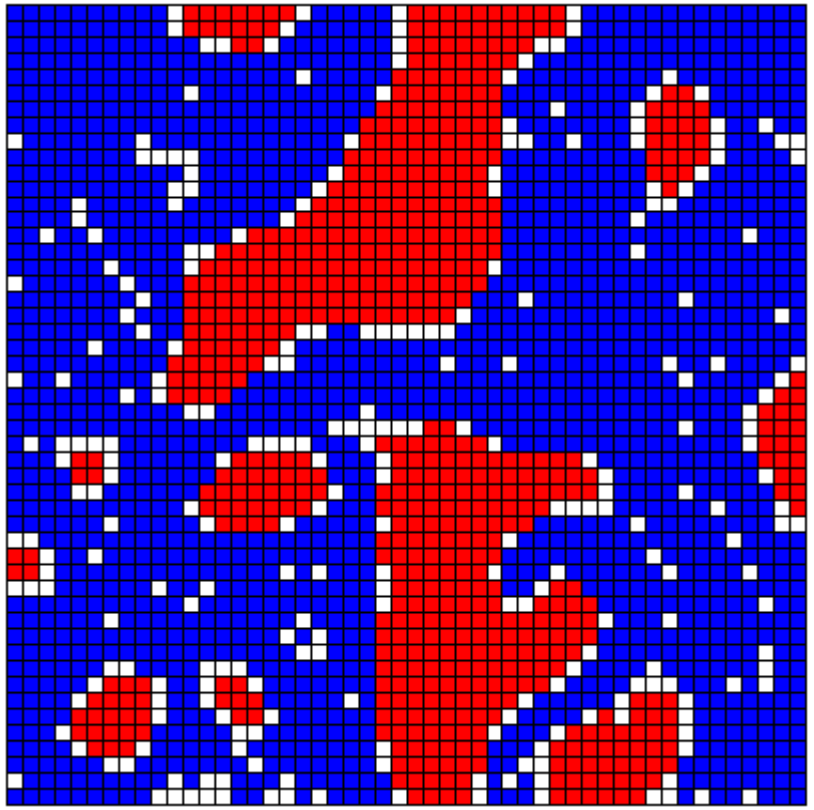



https://data.giss.nasa.gov/gistemp/graphs/

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

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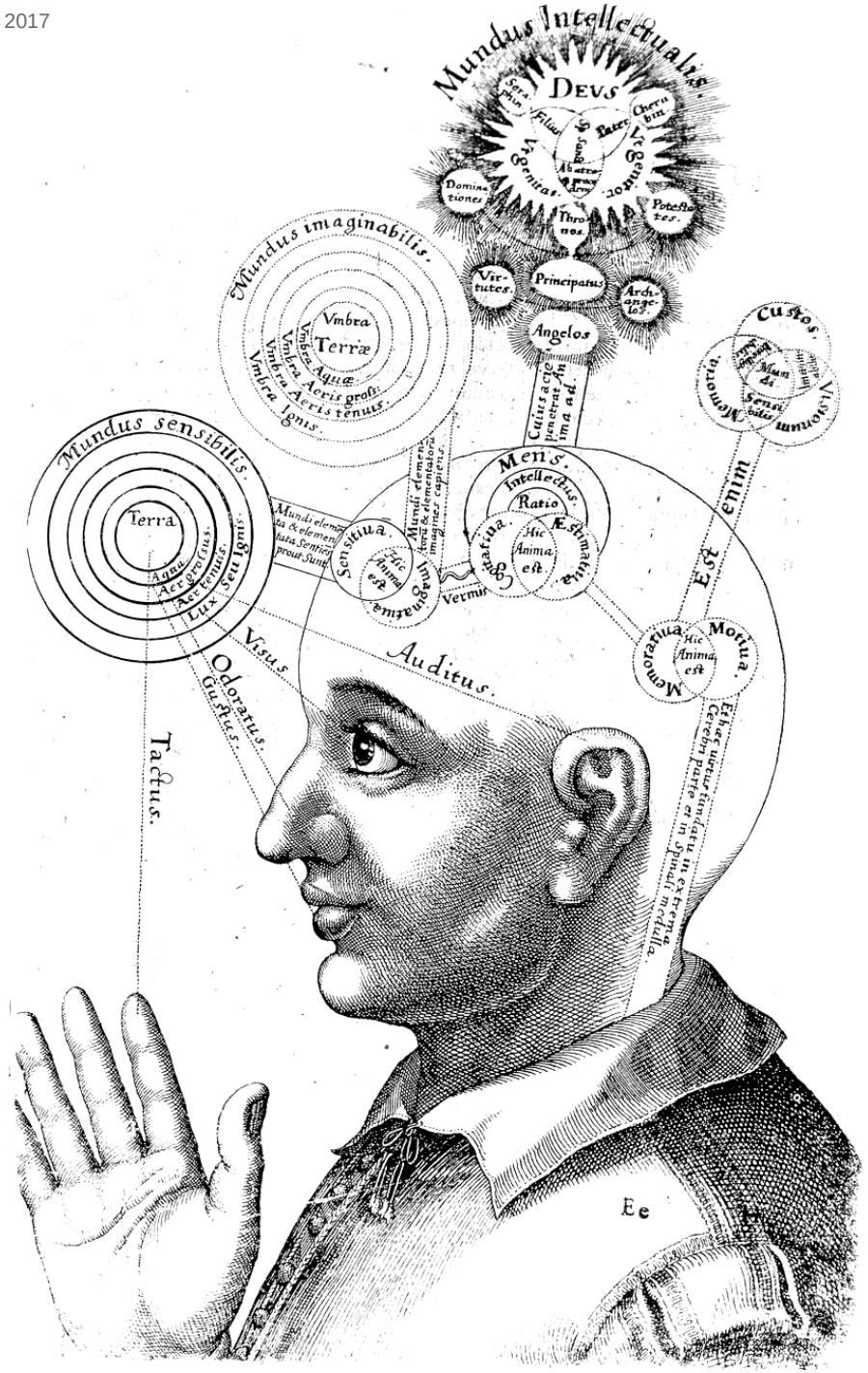


https://de.wikipedia.org/wiki/Bewusstsein#/media/File:RobertFuddBewusstsein173h.png

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


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# 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