



Agent-based Modeling of Urban Energy Supply Systems Facing Climate Protection Constraints

Prof. Dr. Thomas Bruckner and Dr. Tobias Wittmann

Chair for Energy Management and Sustainability
Institute for Infrastructure and Resources Management
University of Leipzig, Germany

Correspondence: bruckner@wifa.uni-leipzig.de
Website: <http://www.uni-leipzig.de/energiemanagement/>

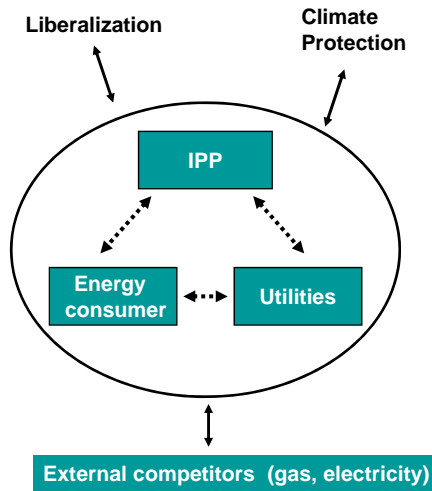
Germany's climate-related legislation

- ▶ Renewable Energy Act (EEG)
- ▶ Renewable Energies Heat Act (EEWärmeG)
- ▶ Combined Heat and Power Act (KWKG)
- ▶ Energy Saving Ordinance (EnEV)
- ▶ KfW Building Rehabilitation Programme
- ▶ Europe Emissions Trading Scheme



Source: Passivhaus-Institut

Interacting actors facing climate protection incentives or constraints



Climate protection incentives and constraints are influencing actors in the energy sector

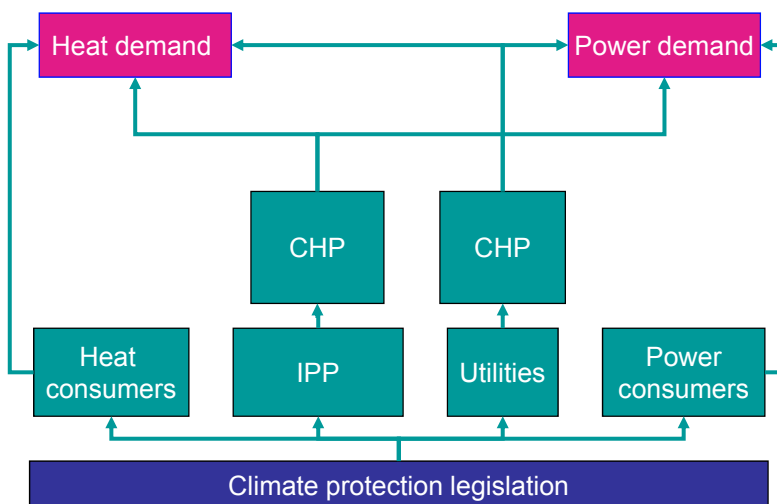
in a direct way:

- technical obligations
- incentives (EEG, KWKG, ...)
- carbon prices

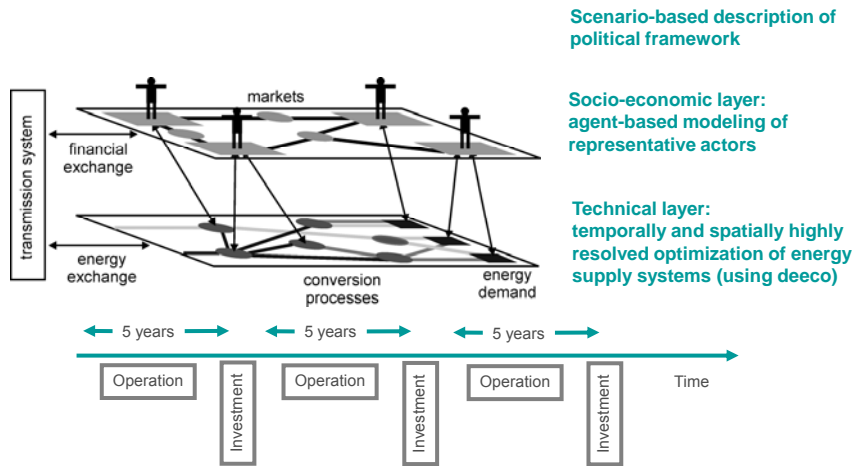
in an indirect way:

- via the market (support for competitors)
- via the technical infrastructure (measures supporting heat demand reduction)

Illustrative interaction

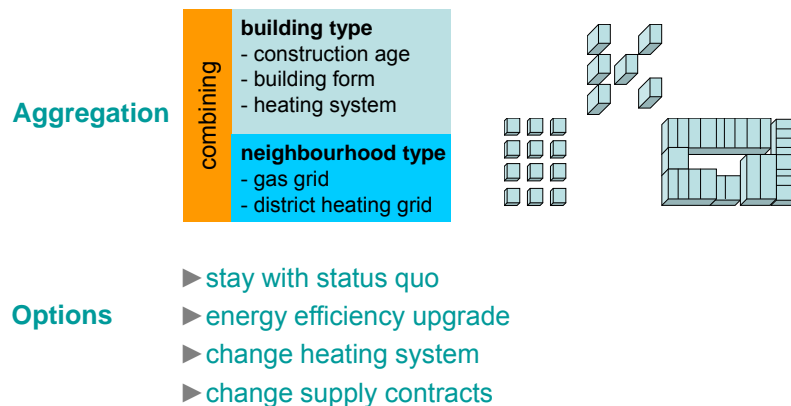


Agent-based hybrid modeling



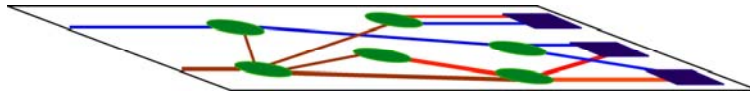
Source: T. Wittmann und T. Bruckner: Agenten-basierte Modellierung urbaner Energiesysteme, Wirtschaftsinformatik (2007).

Aggregation of infrastructure data



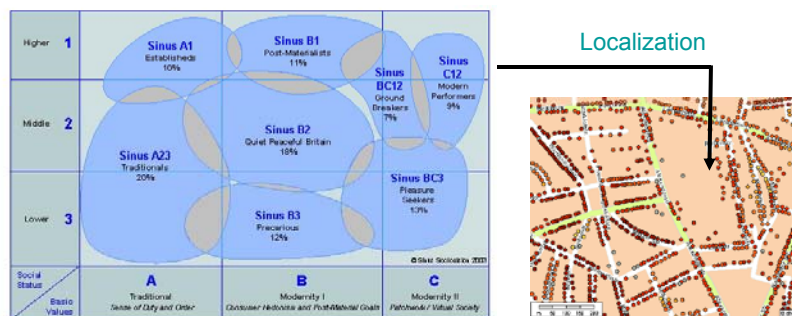
T. Wittmann, R. Morrison, J. Richter, T. Bruckner: A Bounded Rationality Model of Private Energy Investment Decisions, in: Proc. of the 29th IAEE International Conference: Securing Energy in Insecure Times, Potsdam (2006).

Modeling infrastructure operation



- ▶ Network of energy conversion processes
- ▶ Modeling the operation of the system by using temporally and spatially highly resolved energy system optimization models (e.g., the dynamic energy, emissions and cost optimization model *deeco*)
- ▶ Delivers energy flows, costs, and revenues
- ▶ Capable to carry out an assessment of investment options

Aggregation of socio-economic data

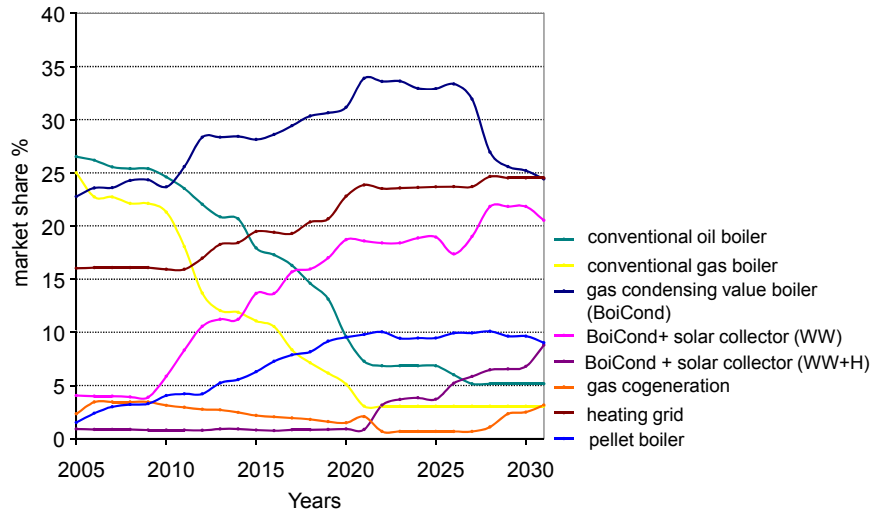


Source: www.sociovision.de; www.microm.de

- ▶ Identification of representative actors by clustering along lifestyle types (social milieus)
- ▶ Lifestyle dependent modeling of representative actors (taking bounded rationality into account)

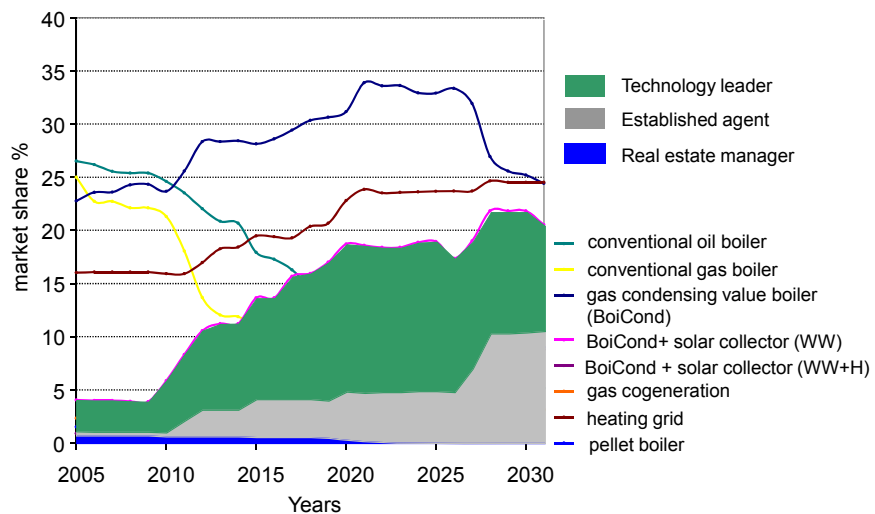
T. Wittmann, R. Morrison, J. Richter, T. Bruckner: A Bounded Rationality Model of Private Energy Investment Decisions, in: Proc. of the 29th IAEE International Conference: Securing Energy in Insecure Times, Potsdam (2006).

Proof of Concept: Diffusion Curves



Source: T. Wittmann und T. Bruckner: Agenten-basierte Modellierung urbaner Energiesysteme, Wirtschaftsinformatik (2007).

Proof of Concept: Diffusion Curves



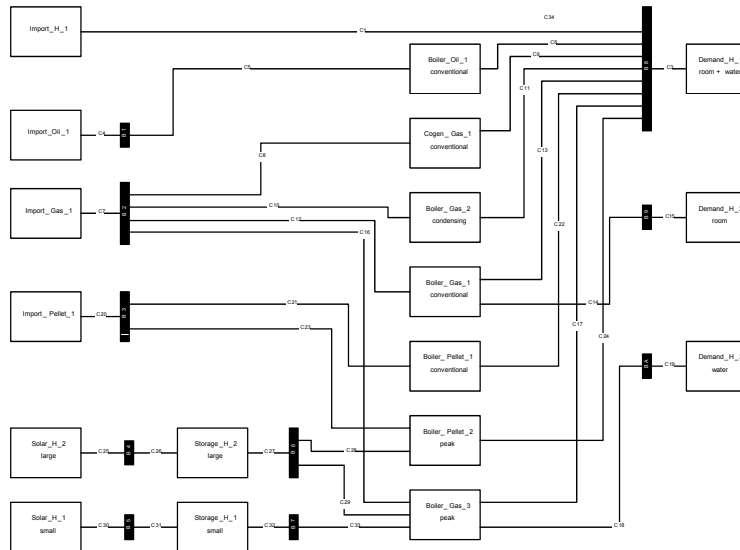
Source: T. Wittmann und T. Bruckner: Agenten-basierte Modellierung urbaner Energiesysteme, Wirtschaftsinformatik (2007).

Selected Literature

- Bruckner, T, H-M Groscurth, R Kümmel: *Competition and Synergy between Energy Technologies in Municipal Energy Systems*, Energy — The International Journal 22, 1005–1014 (1997).
- Bruckner, T, G Hooss, H-M Füssel, K Hasselmann: *Climate System Modeling in the Framework of the Tolerable Windows Approach: The ICLIPS Climate Model*, Climatic Change 56, 119-137 (2003).
- Bruckner, T, R Morrison, C Handley, M Patterson: *High-Resolution Modeling of Energy-Services Supply Systems using deeco: Overview and Application to Policy Development*, Annals of Operations Research 121, 151–180 (2003).
- Bruckner, T, R Morrison, T Wittmann: *Public Policy Modelling of Distributed Energy Technologies: Strategies, Attributes, and Challenges*, Ecological Economics 54, 328-345 (2005).
- Wittmann, T, T Bruckner: *Agenten-basierte Modellierung urbaner Energiesysteme*, Wirtschaftsinformatik 5/2007, 352-360 (2007).
- Wittmann, T, R Morrison, J Richter, T Bruckner: *A Bounded Rationality Model of Private Energy Investment Decisions*, in: Proc. of the 29th IAEE International Conference: Securing Energy in Insecure Times, Potsdam (2006).
- Wittmann, T: *Agent-based Models of Energy Investment Decisions*. Physica-Verlag Heidelberg (2007).

Additional foils

Aggregation of infrastructure data



Decision Rules

Search Rules

find all

find common

- peer group
- location
- past decisions
- topical

find by aspects

- as constraints or aspiration level
- with reference to the status quo, peer group

find next

- defined order over alternatives
- deviation from status quo

Analysis Tools

Cost

- investment cost
- payback-period
- net present value

Environmental Impact

- qualitative ranking (1-5)
- final energy
- CO₂-emissions

Comfort

- qualitative ranking (1-5)

Social Milieus

- **Technology Leader**
 - successful in life
 - professional career after she finished university
 - high quality and leading products
- **Traditionalist**
 - wants to provide for family security
 - older employee
 - good quality at low price
- **Established**
 - high personal reputation
 - a good job with a good income
 - comfortable products

Parameters from Social Milieus

		traditional	technology leader	established
goals (ordered)		cost, comfort	environment, cost, comfort	comfort, cost, environment
search domain		status_quo	topical	peer_group
constraint	budget	limited	considerable	some
	debt	no	yes	yes
	comfort (1-5)	≥ 3	≥ 3	≥ 4
	environment	–	legislation	legislation
rationality types		low, medium	medium, high	medium

Rationality Types

Low rationality

- has problems with decision making
- search focus on past decision
- has problems processing information

Medium rationality

- has decision making experiences
- search by consulting their friends
- can estimate the future consequences of their decisions

High rationality

- knows how to make decisions
- search by consulting friends, experts, and media
- can process information accurately

Parameters from Rationality Types

		low rationality	medium rationality	high rationality
search rule		find_next	find_common	find_all
analysis tool	cost	investment	payback	npv
	environment	qualitative	consumer_energy	cotwo
	comfort	qualitative	qualitative	qualitative
decision strategy		SAT	LEX	LEX

Parameters of Actors

		Private Building Owners					Landlords	
		traditional low rationality	traditionalist medium rationality	technology leader medium rationality	technology leader high rationality	established medium rationality	private landlord	real estate management company
search rule	rule	find next	find common	find common	find all	find common	type	find all
	search domain	x	peer group	topical	x	peer group	type	x
	search order	status quo	x	x	x	x	type	x
analysis tool	cost	investment	pay-back period	pay-back period	net present value	pay-back period	net present value	net present value
	discount factor	x	x	x	3%	x	3%	8%
	time horizon (years)	x	x	x	15	x	15	10
environment	environment	-	-	consumer energy	CO ₂ -emissions	consumer energy	type	CO ₂ -emissions
	comfort	qualitative	qualitative	qualitative	qualitative	qualitative	qualitative	qualitative
decision strategy	strategy	satisficing	lexicographic	lexicographic	lexicographic	lexicographic	type	lexicographic
	goal ranking	x	cost, comfort	environment, cost, comfort	environment, cost, comfort	cost, environment, comfort	type	cost, comfort, environment
	λ _{ND}	x	x	5%	5%	5%	type	5%
	aspiration-cost	-	≤ 10 years	≤ 20 years	≥ - 5000 €	≤ 15 years	type	≥ 0
	aspiration-environment	x	x	x	x	x	type	x
aspiration-comfort	> 3	≥ 3	≥ 3	≥ 3	≥ 4	type	≥ 3	
constraints	budget	≤ 125 €/m ²	≤ 125 €/m ²	≤ 250 €/m ²	≤ 250 €/m ²	≤ 250 €/m ²	type	≤ 500 €/m ²
	debt	no	no	yes	yes	yes	type	yes
	comfort	≥ 3	≥ 3	≥ 3	≥ 3	≥ 4	type	≥ 3
	environment	-	-	legislation	legislation	legislation	type	legislation