Karlsruhe Institute of Technology

JÜLICH FORSCHUNGSZENTRUM

Energy efficiency in industry

Analysing the potential by using an agent-based simulation

KoMSO Workshop „Mathematical MSO for Energy Conservation“ | October 9th, 2015

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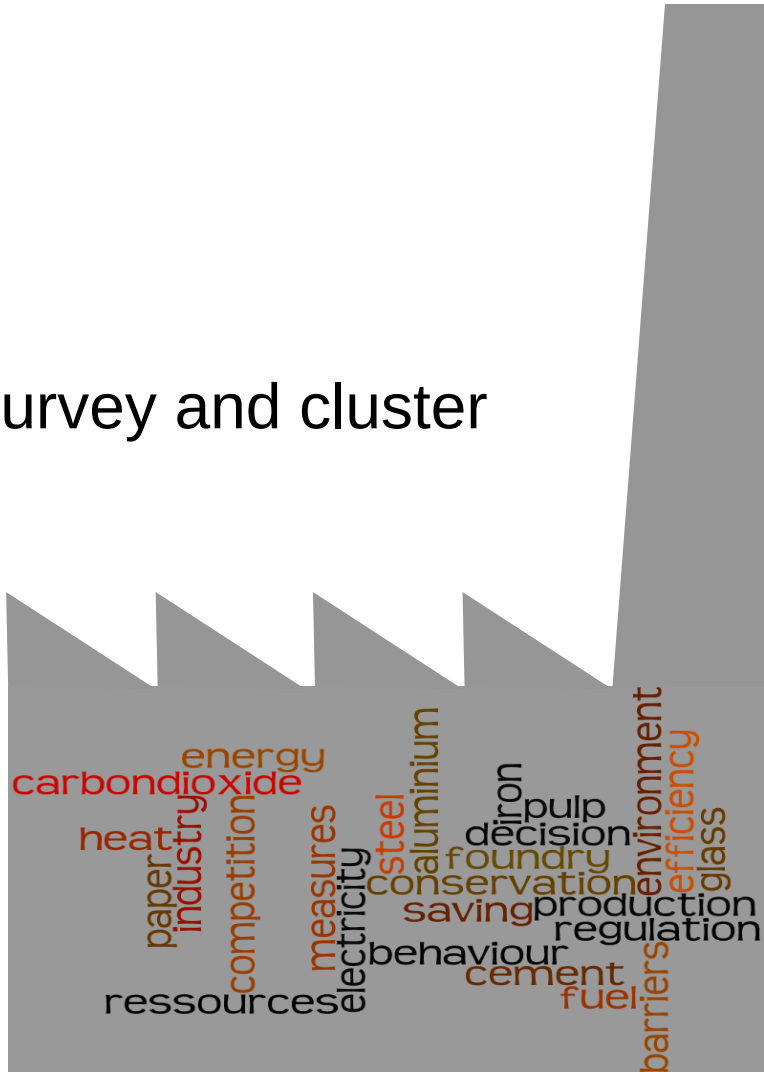
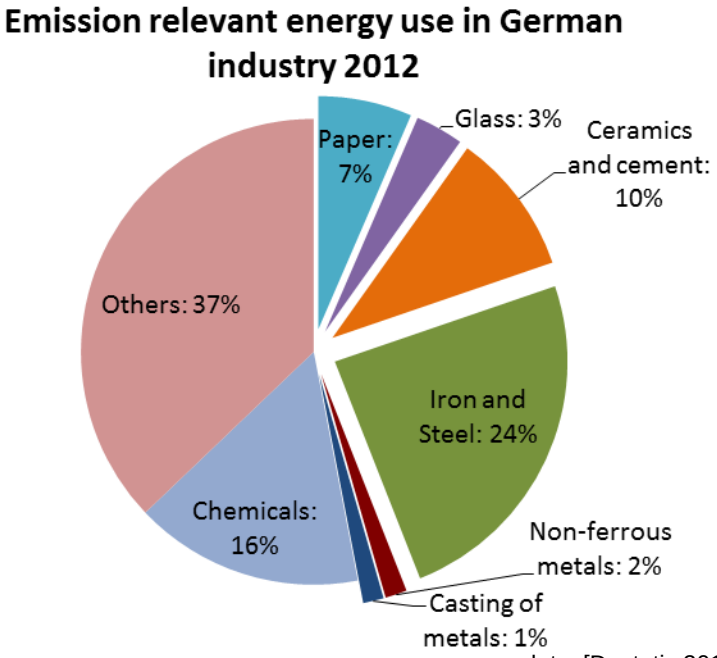
Outline

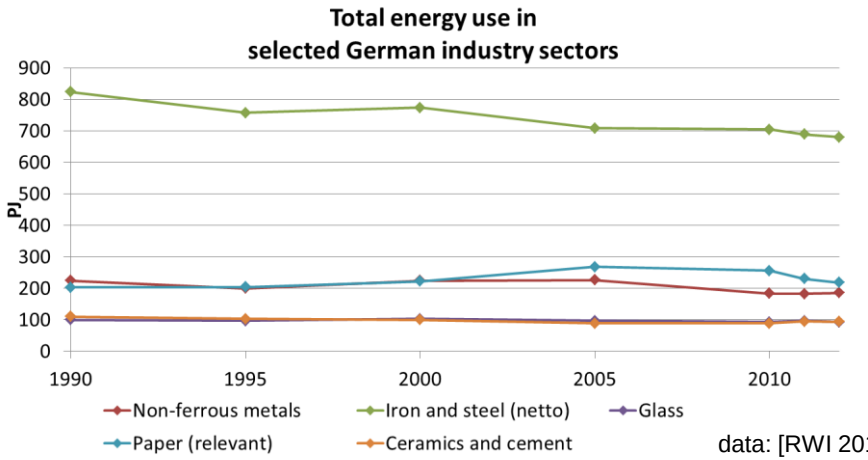
1. **Research Topic**
2. Material and Methods
    1. General approach
    2. Expert interviews, company survey and cluster analysis
    3. Agent-based simulation
3. Discussion and Outlook



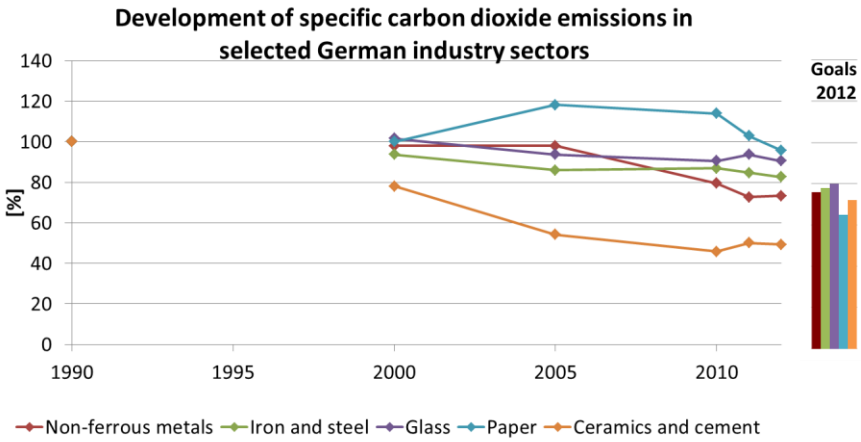
1.1 Energy use and greenhouse gas emissions



data: [Destatis 2014]



data: [RWI 2013]



data: [RWI 2013]

- **Criteria for choice of sectors:**
  - Rather homogenous products
  - Specific energy use
  - Size of sector (employees, gross value added, revenues, …)

Future goals Germany (not industry specific):

- GHG: 2020: -20%, 2050: -80% (vs. 1990)
- Primary energy use: 2020: -20%, 2050: -50% (vs. 2008)

[BMWi & BMU 2011]

1.2 Studies on energy efficiency potentials

Article/thesis	# Sector		Focal point			Method							Sector insights
	One sector	More than one sector	Diffusion of energy efficiency technologies	Analysing historical development	Potential of energy efficiency and future carbon dioxide emissions	Bottom-Up				Top-Down		Hybrid approach	Sophisticated differentiation of companies
						Optimization	System Dynamics	Simulation	Others	General equilibrium models	Input Output		
[Arens & Worrel 2014]	X		X						X				
[Böhringer et al. 2002]		X		X						X			
[Breun et al. 2014]		X			X	X					X	X	
[Brunke & Blesl 2014a , b]	X		X		X							X	
[Fleiter et al., 2013]		X			X				X				
[Ilsen, 2011]		X			X			X			X	X	
[Pardo & Moya, 2013]	X				X			X					
[Schaffer 2002]		X									X		
[Schneider et al. 2014]		X			X				X				
[Seitz 2015]	X		X				X						X

1.3 Objective of research project

- The studies do not (or only to a small extent) differentiate between company types or pay attention to human behaviour
  - → What are behavioural and decision aspects when analysing investments in energy efficient technologies?
- Analysing barriers and drivers and interdependencies for investments in energy efficiency
- Is an agent-based simulation a suitable tool for doing so?

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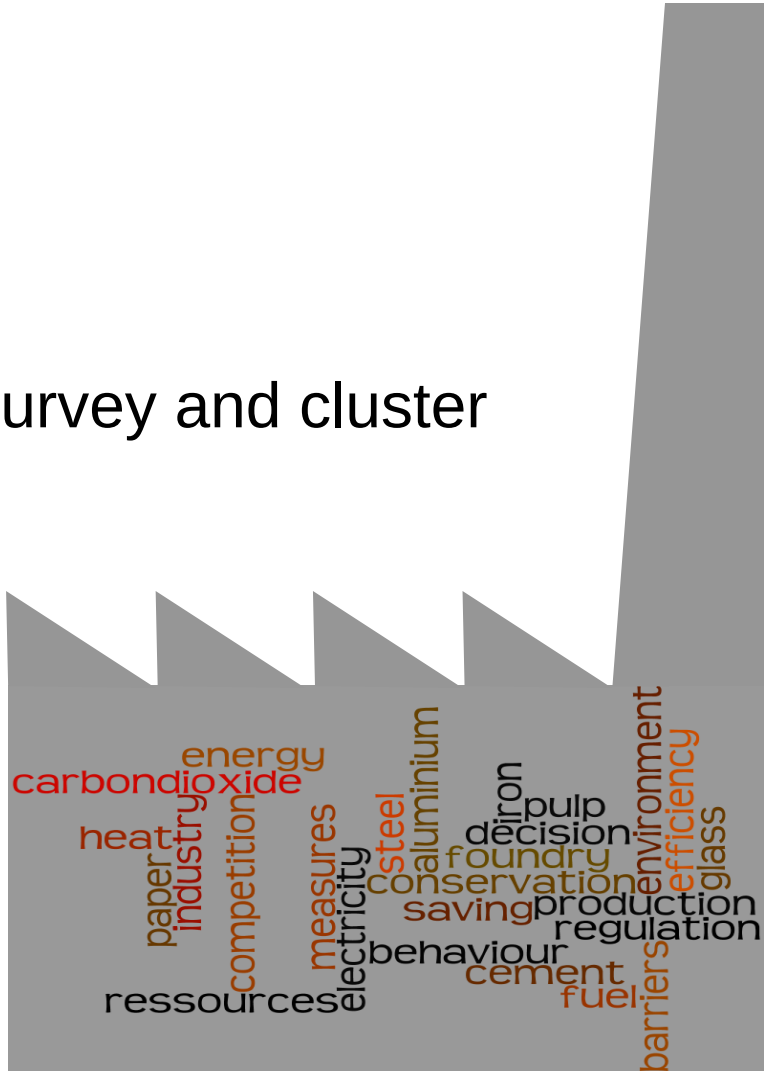
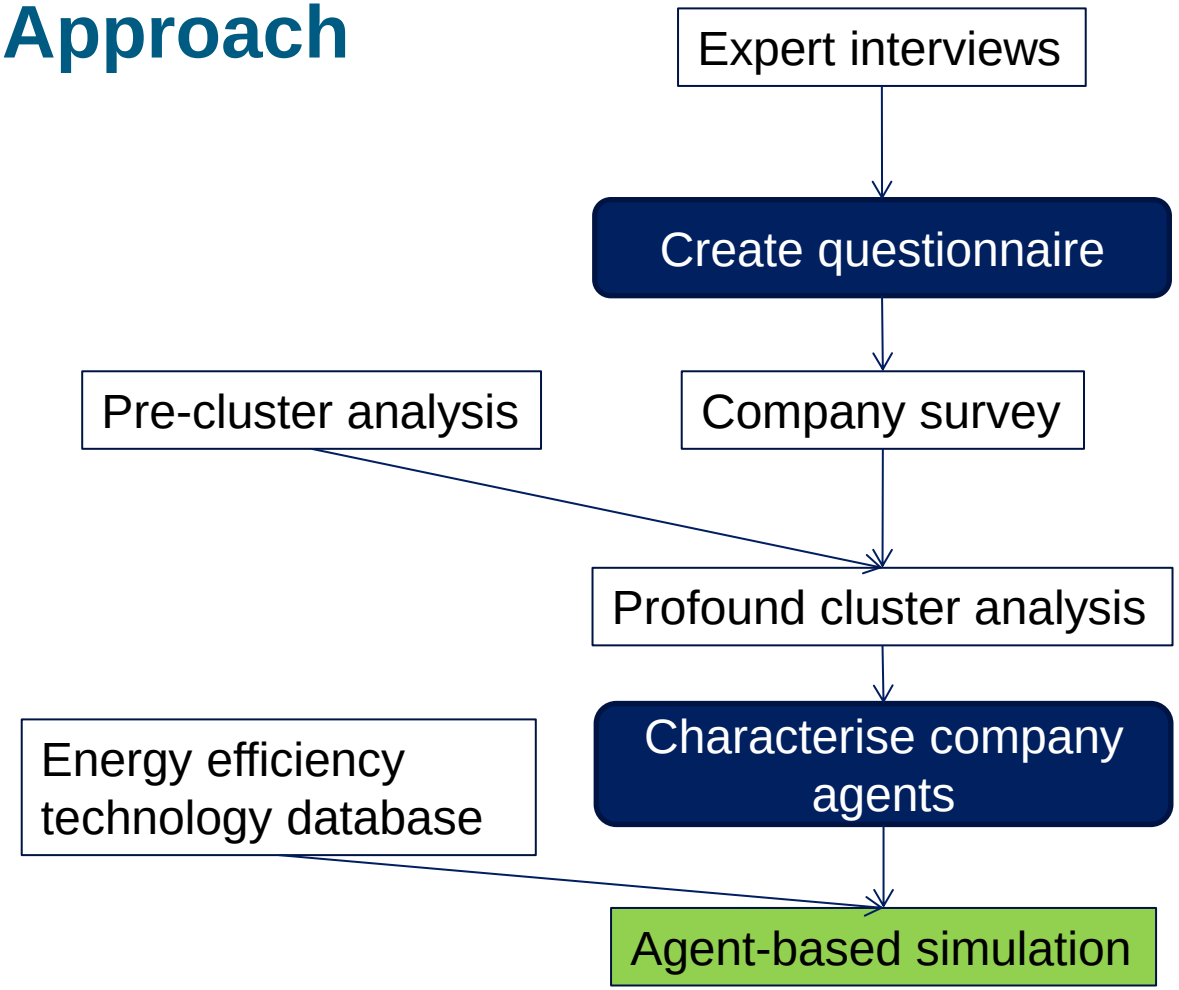
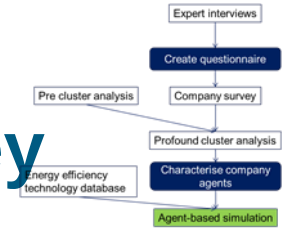


2.1 Approach





2.2 Expert interviews and company survey

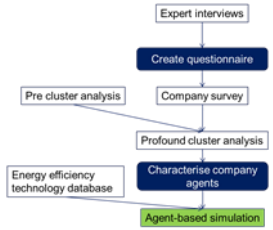
Analysed Sectors according to WZ 2008 [Destatis 2015]:

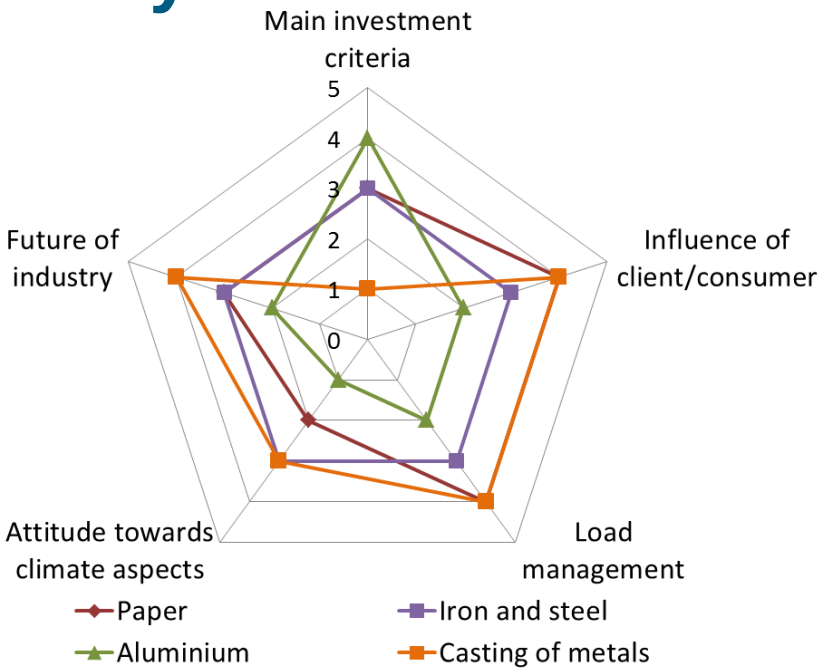
- Manufacture of pulp, paper and paperboard
  - 189 companies (> 9 employees)
- Manufacture of glass and glass products
  - 216 companies (> 9 employees)
- Manufacture of cement
  - 28 companies (> 9 employees)
- Manufacture of basic iron and steel
  - 177 companies (> 9 employees)
- Aluminium production
  - 116 companies (> 9 employees)
- Casting of metals
  - 485 companies (> 9 employees)

1. Interviews with one representative of industry associations and one representative of a company in each analysed sector → 12 interviews.
2. Survey with approx. 200 companies out of 1,211.

Topics: energy efficiency technologies, investment parameters, energy policy, future expectations

2.2 Expert interviews and pre-cluster analysis

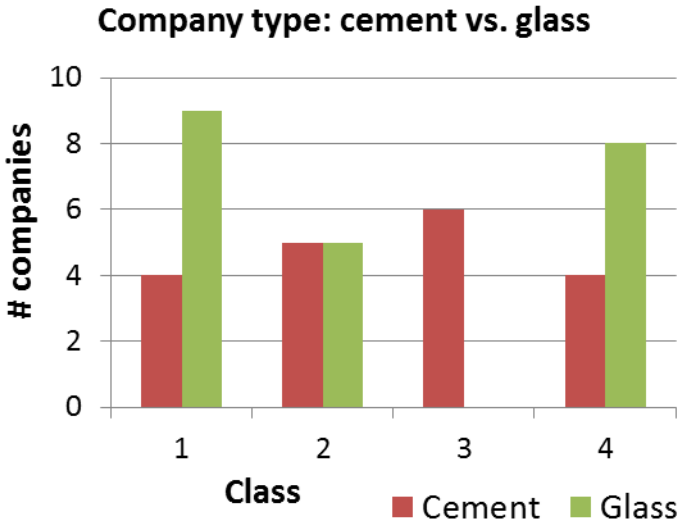




[Own data]

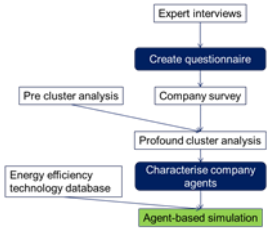
- **Investment criteria:**
  1: monetary, 2: monetary + image, 3: monetary + quality,
  4: environment + monetary, 5: environment + image
- **Influence:**
  1: very high,…, 5: very low
- **Load management:**
  1: very high potential,…, 5: very low potential
- **Attitude and future:**
  1: very positive,…, 5: very negative

- **Source:** annual financial statements, company information (homepage,…)
- **Parameters:** company type, #facilities, own electricity generation, products, #employees, revenue, fixed capital, environmental affinity
- **Method:** distance and similarity measures



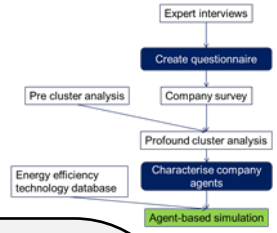
1: Part of international group, head office abroad
2: Part of international group, head office in Germany
3: German group, only German sites
4: Single company with one site

data: [Bundesanzeiger 2015]

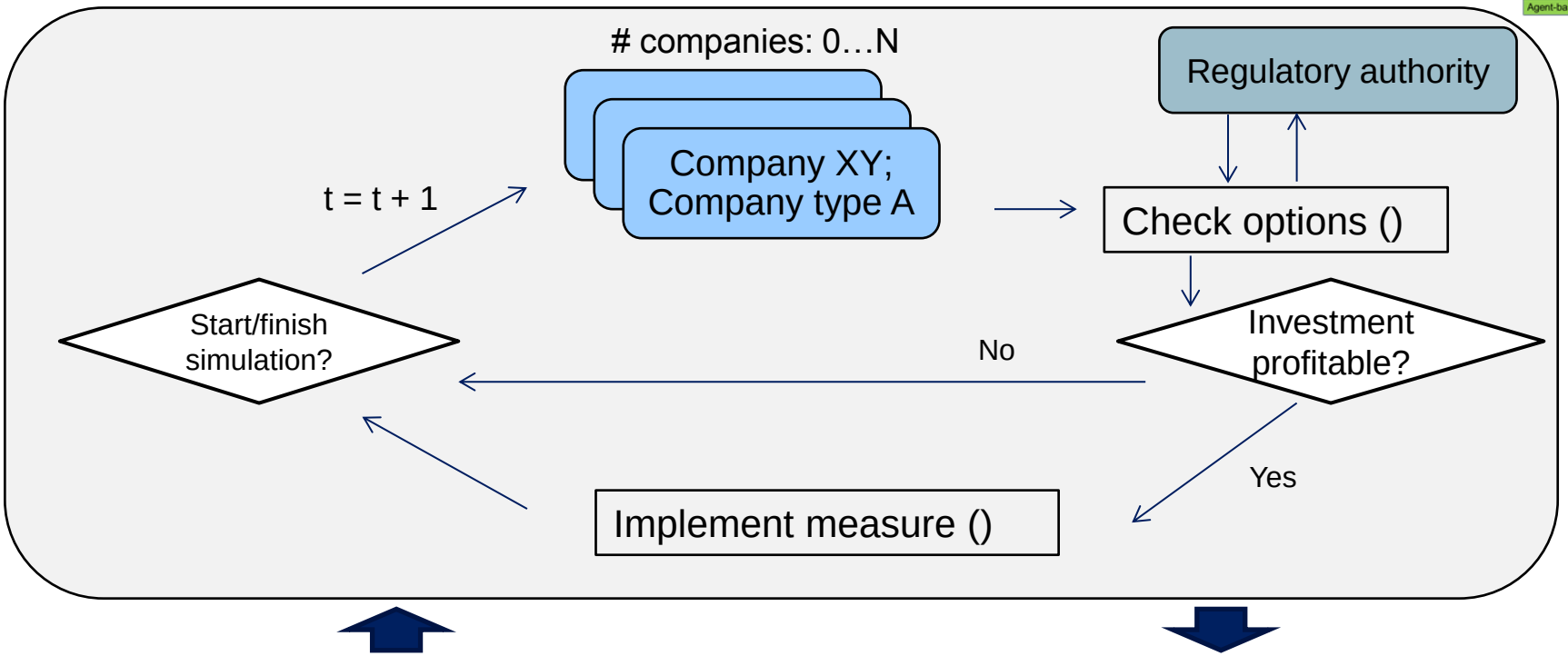


2.3 Agent-based simulation (ABS)

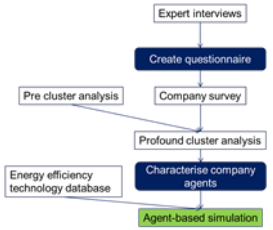
- **Explanation:**
  - Simulation to explain and understand complex systems
  - Each agent interacts with its environment (Agent is a representation of a distributed and autonomous entity)
  - The sum of the actions of each single agent determines the system behaviour
- **Advantages:**
  - Different entities (companies, regulatory authority, distributer of technologies,…) can be represented
  - Agents can be modelled with different character and behaviour
  - Agent can adapt its behaviour (learning effect, interaction)
- **Disadvantages:**
  - High effort for calibration and validation
  - No sufficing possibility for induction → Which agent is responsible for system behaviour?



2.3 ABS – basic model



Database (different often inhomogeneous and ill-matched data):
Company details: size, costs, age of facilities, …
Energy efficiency measures: performance, price, …
Economic development: prices of commodities, development of production, …
Political instruments: taxes, emission trading, penalties, guidelines,…
…



2.3 ABS – basic model

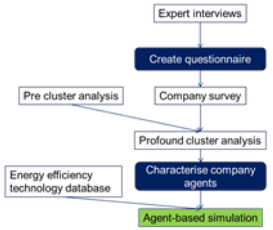
Indirect interaction of agents (not yet implemented):

- Characteristics of efficiency measures can change according to the number of companies implementing this measure
- Share of production for companies can change according to behaviour of other companies
- Interaction with regulatory authority that can change the rules of the game

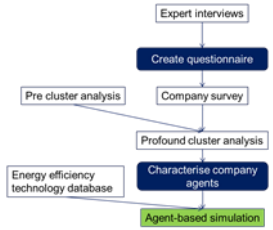
Methods:

- Check options ():
  - Evaluation of different possible measures by using the set investment calculation methods
  - Choice of measure that fulfils the conditions the best
- Implement measure ():
  - Update characteristics of facility (remove data of old machine/measure and adjust data for energy use, emissions, productivity,…)
  - Update production costs of facility

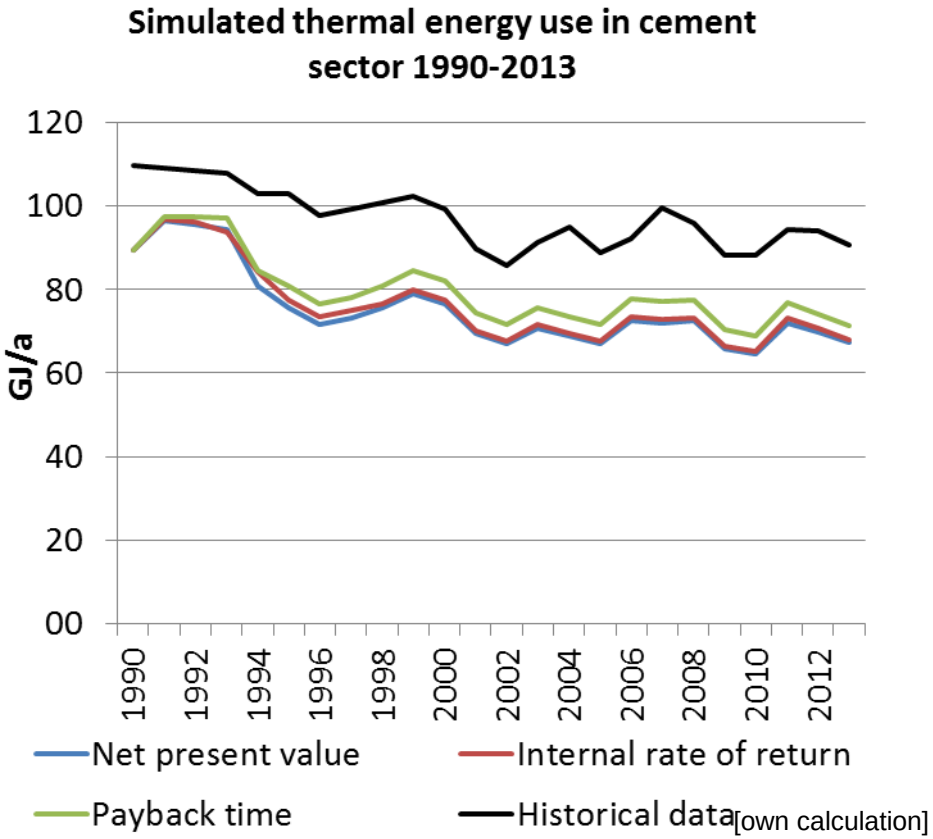
2.3 ABS – evaluation of efficiency measures:



1. **Check age of machine/facility**
   - For each company {
     For each facility/machine {
     If AgeOfFacility/machine == 1 {
     then checkRestrictionsOfMeasures () }}};
2. **Check type of machine/facility**
   - Company X: For each measure {
     requirements ok ();
     conflicts ok ()};
3. **Calculate the net present value of possible measures and chose the measure with the highest value**
   - Company X and measures type Y:
     Chose max (NPV Y_1, NPV Y_2, …, NPV Y_n)
     NPV: $C_0(i) = \sum_{t=0}^{T} \frac{Z_t}{(1+i)^t}$, C_0: net present value at time t=0, i: interest rate, T: periods, Z_t: Cash flow in period t



2.3 ABS – first results (calibration)



Interest 15%, different investment calculation rules for replacement investments, payback time is used for additional investments (within the life cycle of machine)

- No consideration of financing aspects
- Deterministic development of production and prices
- All companies use the same calculation method for investment decisions
- Constant supply of measures with constant characteristics (performance, price)

- **Thermal energy use**, **electricity use** and **carbon dioxide emissions** are examined

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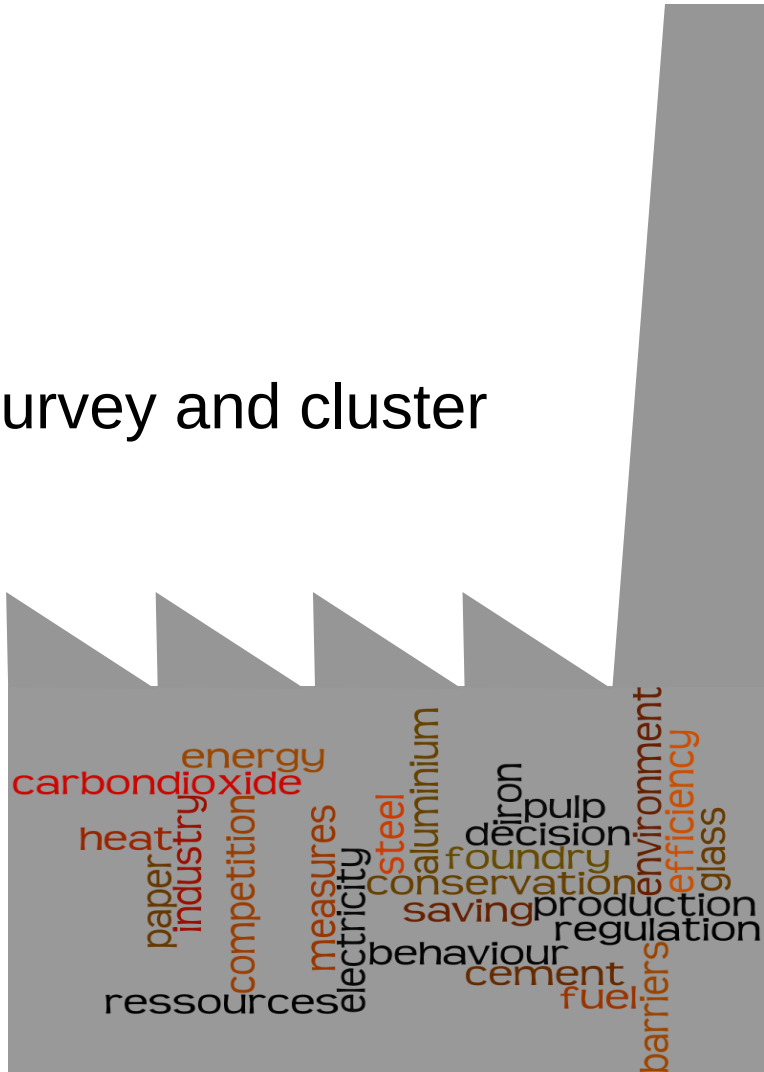

3 Discussion

- Will the outcome of the company survey be sufficient to identify different company types and strategies to implement different investment behaviour?
- Will the data about energy efficiency measures be adequately detailed (performance, price, complexity)?
- Are the most important parameters and barriers identified for the purpose of the study?
- Is agent-based simulation a suitable method for this subject?

3 Outlook

- run different scenarios up to 2050

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Thank you very much for your attention!

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