# *Modelling market participants and market designs in the process of market integration of renewable energies from an agent-based perspective*

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DLR

# Static Equilibrium Economics

- Economic actors continually adjust their market moves (investments, prices, forecasts etc.)

↳ **Individual behaviour collectively creates an aggregated outcome.**

- **General equilibrium** theory asks: “What prices and quantities of goods produced and consumed are consistent with the overall pattern of prices and quantities in the economy’s markets?” 1)
- **Game theory** asks: “What strategies, moves or allocations would be the best course of action for an agent given the strategies, moves, allocations his rivals might choose?” 1)
- **Rational expectations** theory asks: “What expectations are consistent with the outcomes these forecasts and expectations together create?“ 1)

↳ Approaches follow the concept of **rational expectations/behaviour** under the paradigm of **perfect information.**

1) Arthur (2005) p. 1554

# Out of Equilibrium Economics as Generative Approach

Characteristics of complex systems like carbon markets:

- Often not at equilibrium but under on-going change
- States are results of a multitude of small events and are not determinate up front ("Feedback-Loops")
- Economic actions depend on expectations and actions of others
- Strategic behaviour of market participants

↳ Agent-based Modelling (ABM) or Agent-based Computational Economics (ACE) tries to analyse **the dynamics between** the equilibriums ("generative approach")[1),2)]

- Includes inductive behaviour
- No a-priori "solution" → learning by doing

↳The generative approach might converge to the rational expectations norm **but does not have to!**

1) Holland et al. (1986), 2) Sargent (1994)

# Basics of Agent-Based Modelling (ABM)

- **Bottom-up Approach** from the field of Artificial Intelligence (AI).
- **Autonomous Agents** acting in a changing environment.
- **Event based** simulation

Typical characteristics of Agents[1),2)]:

- „World view“ as internal representation of outside world
- Autonomous behaviour with own goals
- Development and adjustment of strategies through learning processes
- Communication and cooperation

↳**Turning away from the general principle of the „homo oeconomicus“:**

- limited information and bounded rationality
- Heterogeneity of actors
- Taking into account of social processes.

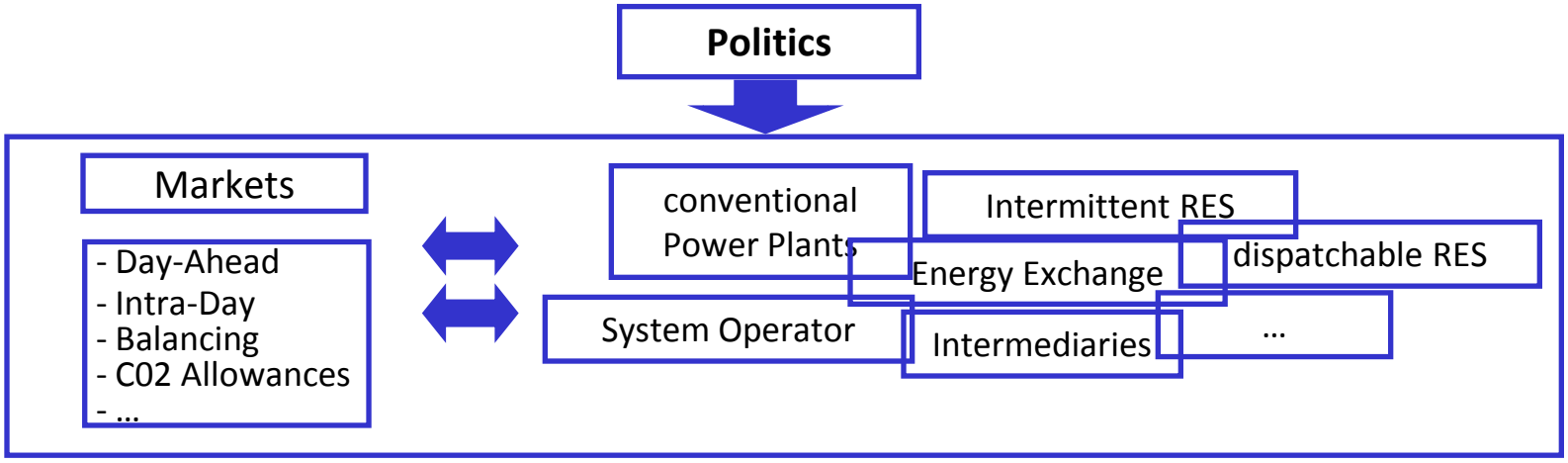
↳**Analysis of complex** („emergent“) **systems**.

1) Wooldridge (2002); 2) Schmidt (2000)

# Energy Economic Background

- Reorganization of institutional, technical and financial aspects is needed to achieve political goals of the “Energiewende” (Energy Transition)[1)]
  - GHG emissions: – 80%
  - RES share: 80% of gross electricity consumption

  } by 2050
- In this process of transition
  - a huge **variety of actors** from different social arenas is involved, which
  - are connected via **complex interdependencies** and
  - react very differently to changes in the **energy policy framework**




1) BMWi / BMU (2010)

# AMIRIS - Our Agent-Based Modelling Approach

**Need for sound scientific policy advice for the energy transition**

1

We use advantages of ABM to model agents with:

- Autonomous behavior
- Own goals
- Adaptation of strategies
- Cooperation
- Imperfect knowledge
- Heterogeneity
- Prototyped market orientated behavior

2

We conduct sound actor analysis based on theoretical assumptions derived from sociological neo-institutionalism with:[1)]

- Document analysis
- Semi-structured interviews
- Expert workshops

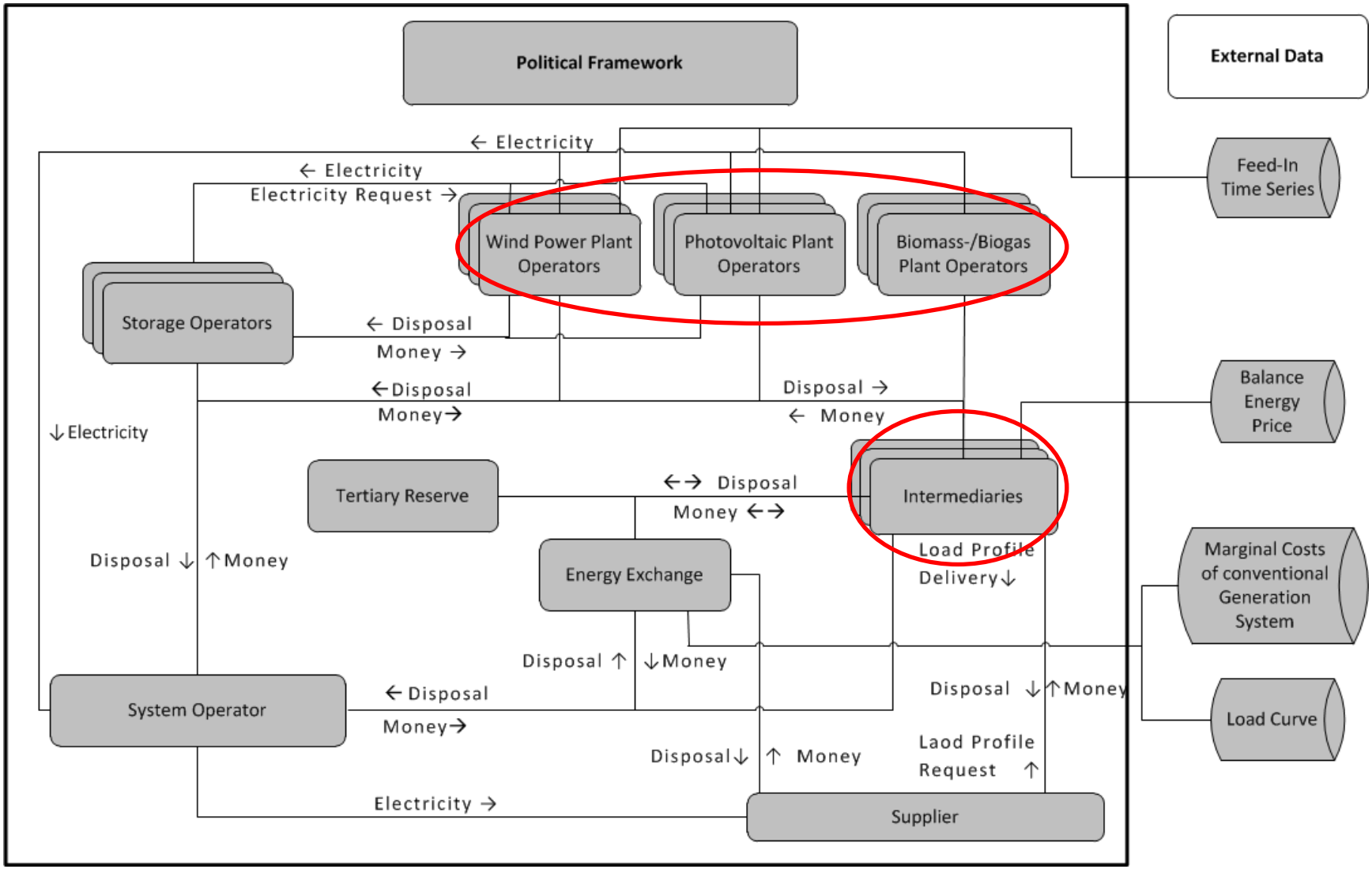
1) Performed by CIRIUS - University of Stuttgart

3

We build an agent-based Model as policy analysis and design tool to:

- Analyse impact on agents as result of changes in policy design (micro-economic effects)
- Analyse interdependencies and interactions of agents
- Analyse impacts on overall system (macro-economic effects)

# AMIRIS Model Structure




# Actor Analysis I - Intermediaries

- Differentiation and parameterisation of agents:

| | Prototype | Capital resources (m €) | Market premium | Green Electricity Priviledge | Bidding on Reserve Market | Tariff | Forecast quality | Searching cost for contract partners |
|---|---|---|---|---|---|---|---|---|
| (1) | Big national utility | 100 | 2012 | - | 2012 | FIT + Bonus | Good | Medium |
| (2) | International utility | 15 | 2012 | - | 2012 | FIT + Bonus | Good | Low |
| (3) | Big municipal utility | 15 | 2012 | - | 2012 | FIT + Bonus | Medium | Medium |
| (4) | Municipal utility “Pioneer” | 15 | 2012 | - | - | FIT + Bonus | Good | Low |
| (5) | Small municipal utility | 7 | 2012 | - | - | FIT + Bonus | Bad | Medium |
| (6) | Green electricity trader for households | 7 | - | 2007 | - | FIT + Bonus | Good | Low |
| (7) | Green electricity trader for business/industry | 7 | - | 2008 | 2012 | FIT + Bonus | Good | Low |
| (8) | Green electricity trader for local marketing | 1 | - | - | - | FIT + Bonus | Medium | - |
| (9) | Functional intermediary as spin-off from a big utility | 3 | 2012 | - | - | FIT + Bonus | Good | Low |
| (10) | Functional intermediary as start-up | 0,1 | 2012 | - | 2012 | FIT + Bonus | Medium | High |

# Intermediary Agents – Cost Structure

| | Fixed costs | | | | | Variable costs | | |
|---|---|---|---|---|---|---|---|---|
| 1. | Office rent | | 133 | €/a*m² | 1. | EEX Trading fee | 0,0075 | €/MWh |
| 2. | Office space factor: | | | | 3. | Specific labour costs (staff) | 0,052 | €/MWh |
| | Number of employees(E) | < 5 | 42 | m²/E | | Supervised volume / employee | 1.250.000 | MWh/E |
| | | 5 - 10 | 36 | m²/E | | | | |
| | | 10 - 20 | 35 | m²/E | 4. | Forecasting costs: | | |
| | | 20 - 50 | 26 | m²/E | | Small portfolio | 500-1500 MW | → 15 €/MW |
| | | > 50 | 25 | m²/E | | Medium portfolio | 1500-3000 MW | → 10 €/MW |
| 3. | EEX access | | 25.000 | €/a | | Big portfolio | 3000-5000 MW | → 5 €/MW |
| 4. | IT-/ Office equipment | | 10.000 | €/a*E | 5. | Forecasting quality: | | |
| 5. | Labour costs: | | | | | Good | → purchased forecasts: 3 | |
| | | Trader | 130.000 | €/a*E | | Medium | → purchased forecasts: 2 | |
| | | Other staff | 65.000 | €/a*E | | Bad | → purchased forecasts: 1 | |

At end of each year: intermediary agents carry out balance check and calculate EBIT per employee.

↳ According to EBIT the tariff is adjusted if necessary:

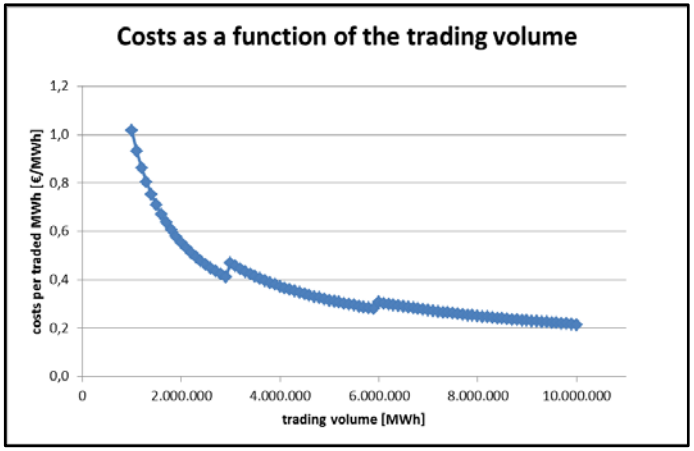
€ 200,000-300,000: bonus remains the same

€ 300,000-400,000: bonus is risen by 10 %

…

€ 100,000-200,000: bonus is lowered by 15 %

€ 50,000-100,000: bonus is lowered by 30 %




# Actor Analysis II – Power Plant Operator

- Differentiated by received FIT remuneration
  - Each class represents a certain amount of installed capacity

| €/MWh | Class 1 | Class 2 | Class 3 | Class 4 (offshore) |
|---|---|---|---|---|
| 2006 | 61,90 | 86,15 | 90,62 | 150,00 |
| … | … | … | … | … |
| 2020 | 59,31 | 84,21 | 91,14 | 173,91 |

- Further differentiated by owner structure:
  - Private persons
  - Farmers
  - Fonds
  - Project developers
  - Municipal utilities
  - Big utilities

- Characterized by:
  - Risk orientation
  - Return expectations
  - 1st, 2nd and 3rd Mover

# Summery and Conclusion

- With ABM one can:
  - analyse the dynamics between equilibriums
  - turn away from the principal of the “homo oeconomicus”
  - cope with the heterogeneity of market participants
  - Analyse the macro as well as micro economic effects

- ABM is suitable for systems with:
  - complex interdependencies
  - on-going environmental changes
  - developing market structures
  - new/evolving market participants

↳ **One can model in a more “realistic” way…**

# Thank you very much for your attention…

## …Questions?

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# Literature


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