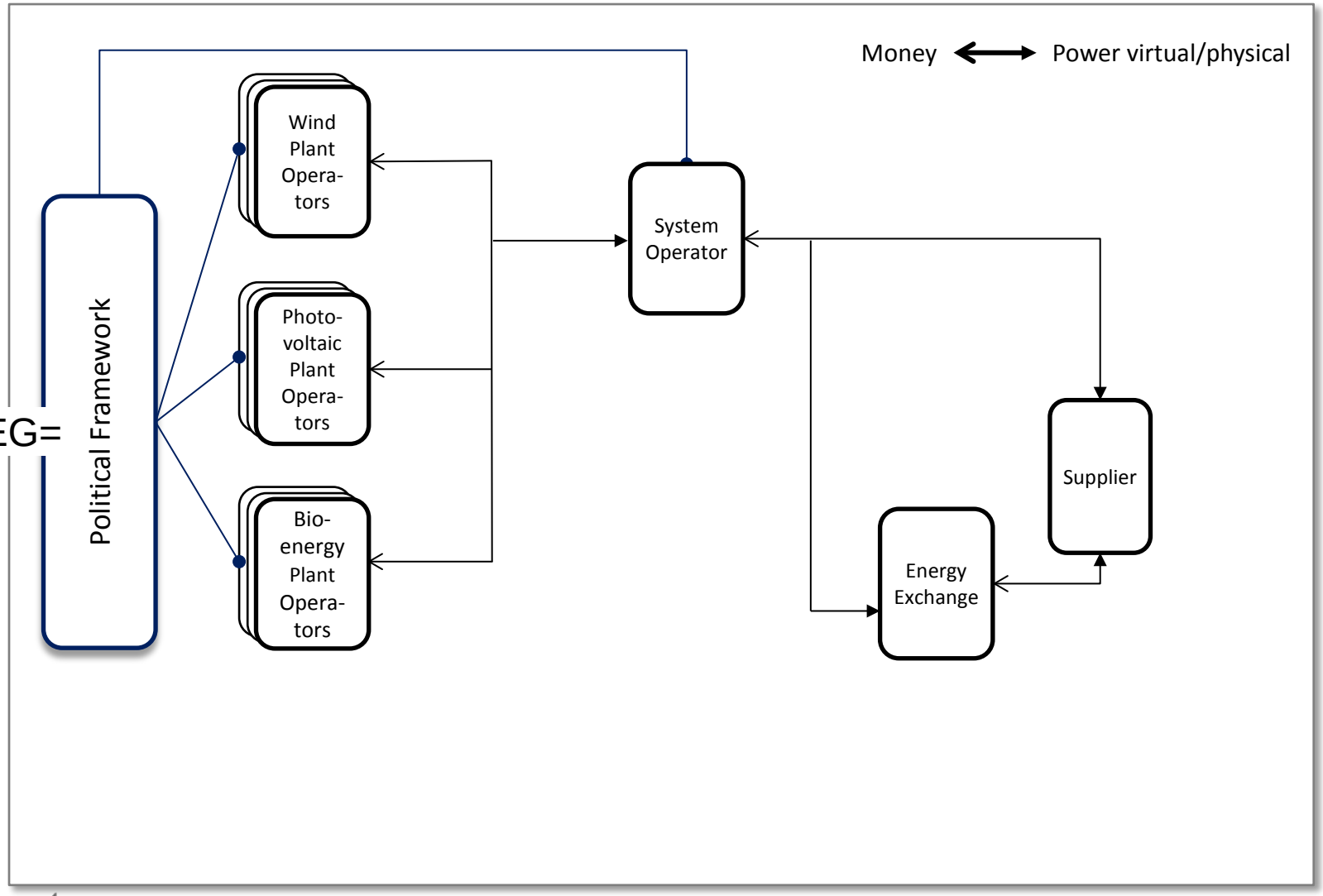
Agent-based simulation of business cases using energy storage to optimize marketers' renewable energy portfolio

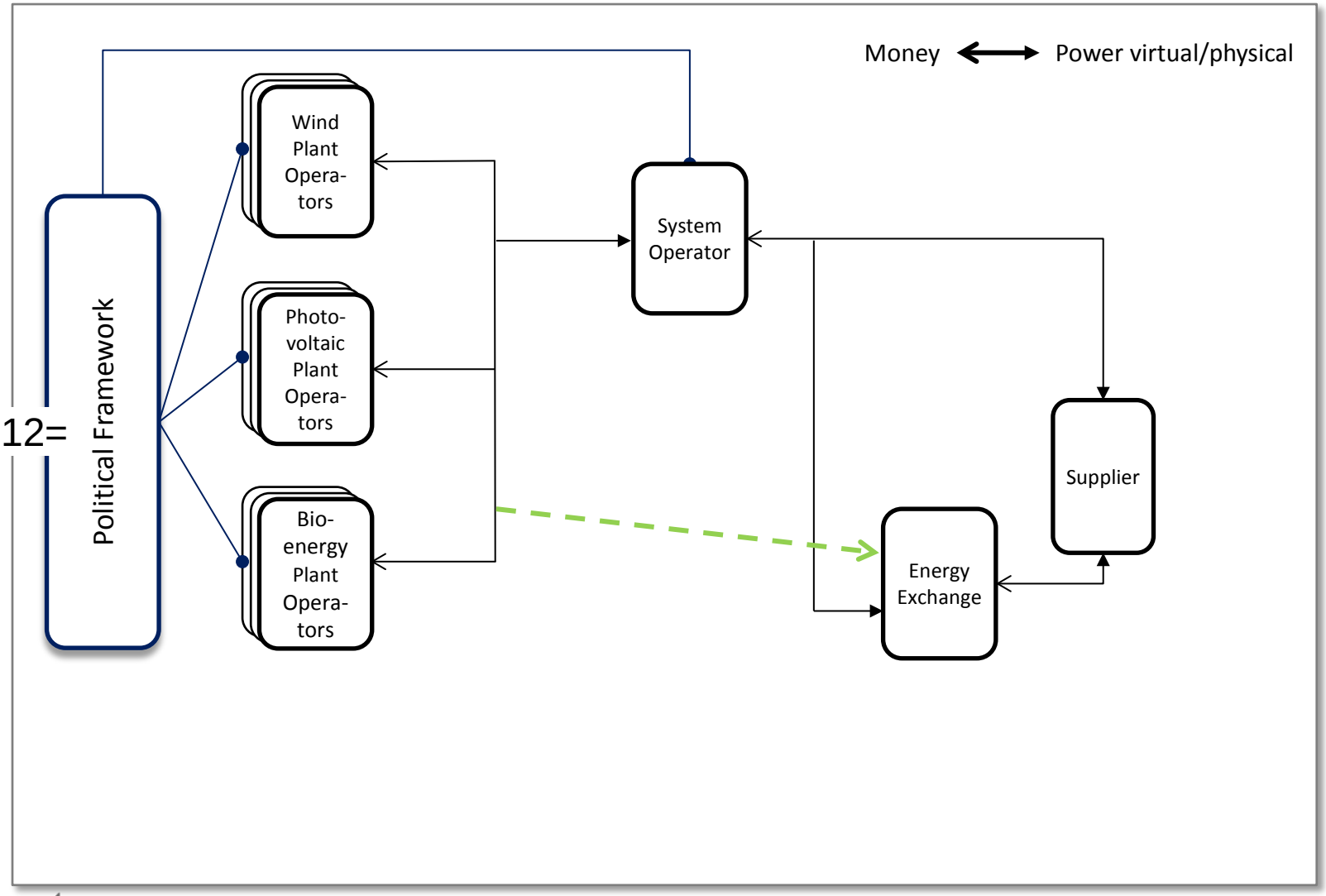
Dr. Marc Deissenroth & Nikolai Klempp
DLR – German Aerospace Center
Institute of Engineering Thermodynamics
Systems Analysis and Technology Assessment

IRES
Düsseldorf, 10 March 2015

German Renewable Energy Act – Part I

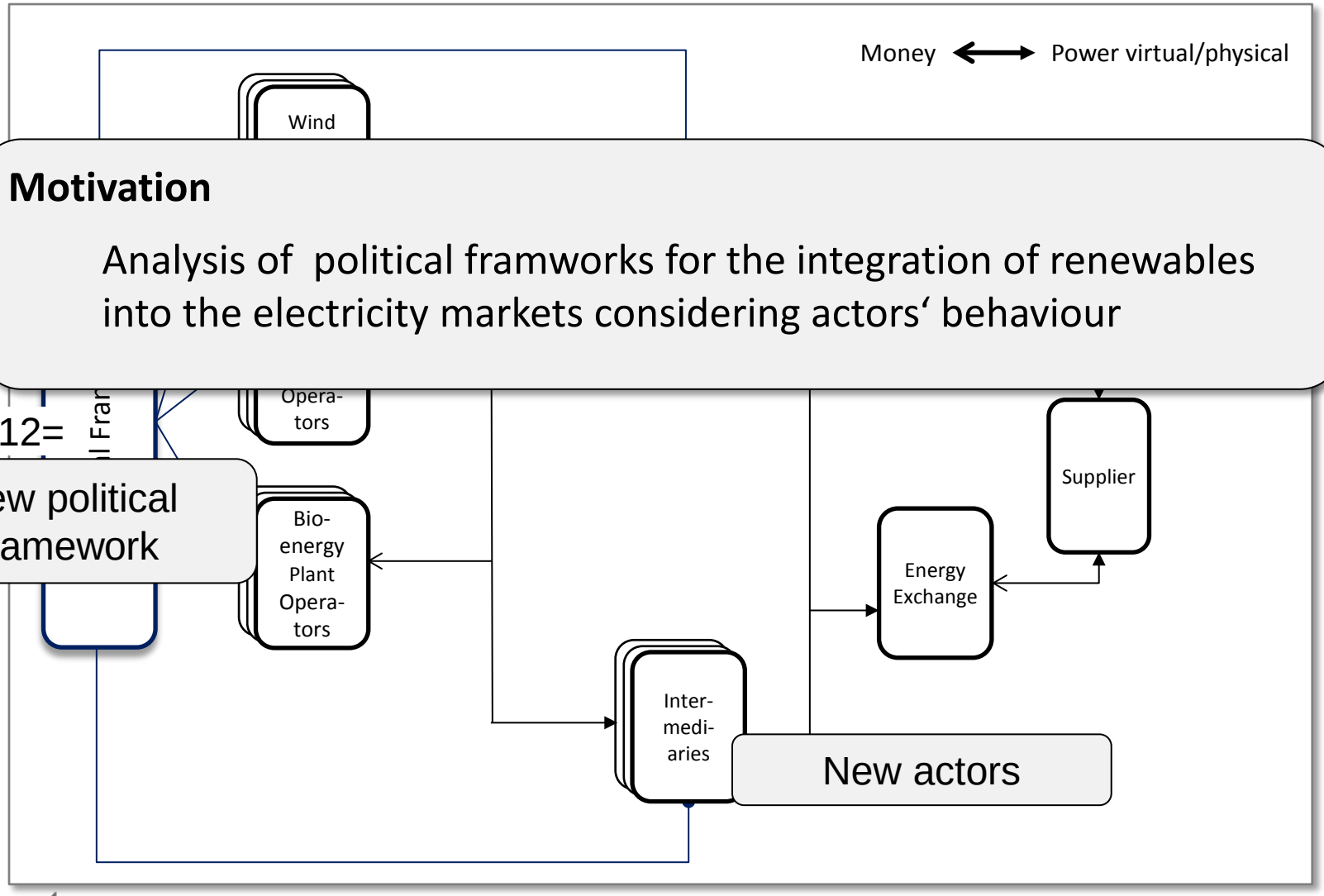


German Renewable Energy Act – Novel 2012



EEG 2012=

German Renewable Energy Act – Novel 2012



Motivation

Analysis of political framworks for the integration of renewables into the electricity markets considering actors‘ behaviour

EEG 2012=

New political framework

AMIRIS – Policy analysis and design tool

Integration of new technologies into existing markets

Open Questions

- What policy instruments support new technologies?
- Which markets are necessary for (new) actors?
- Market or regulation – What's the effect on all actors?

Solution Approach

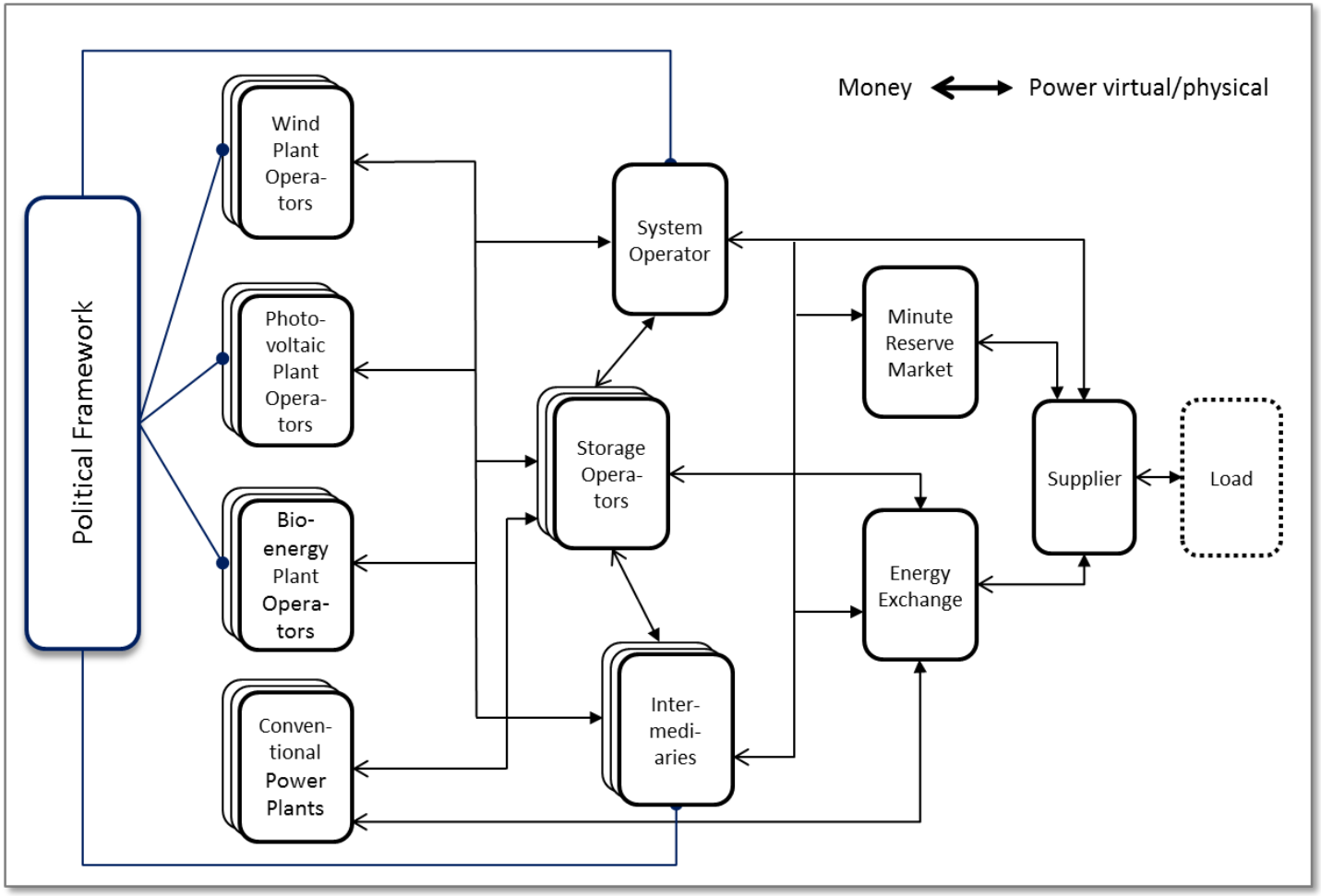
- Analyze actors and their interdepen-dencies and inter-actions
- Study impact of changes in policy & market design on actors
- Evaluate impact on overall system

Methodology

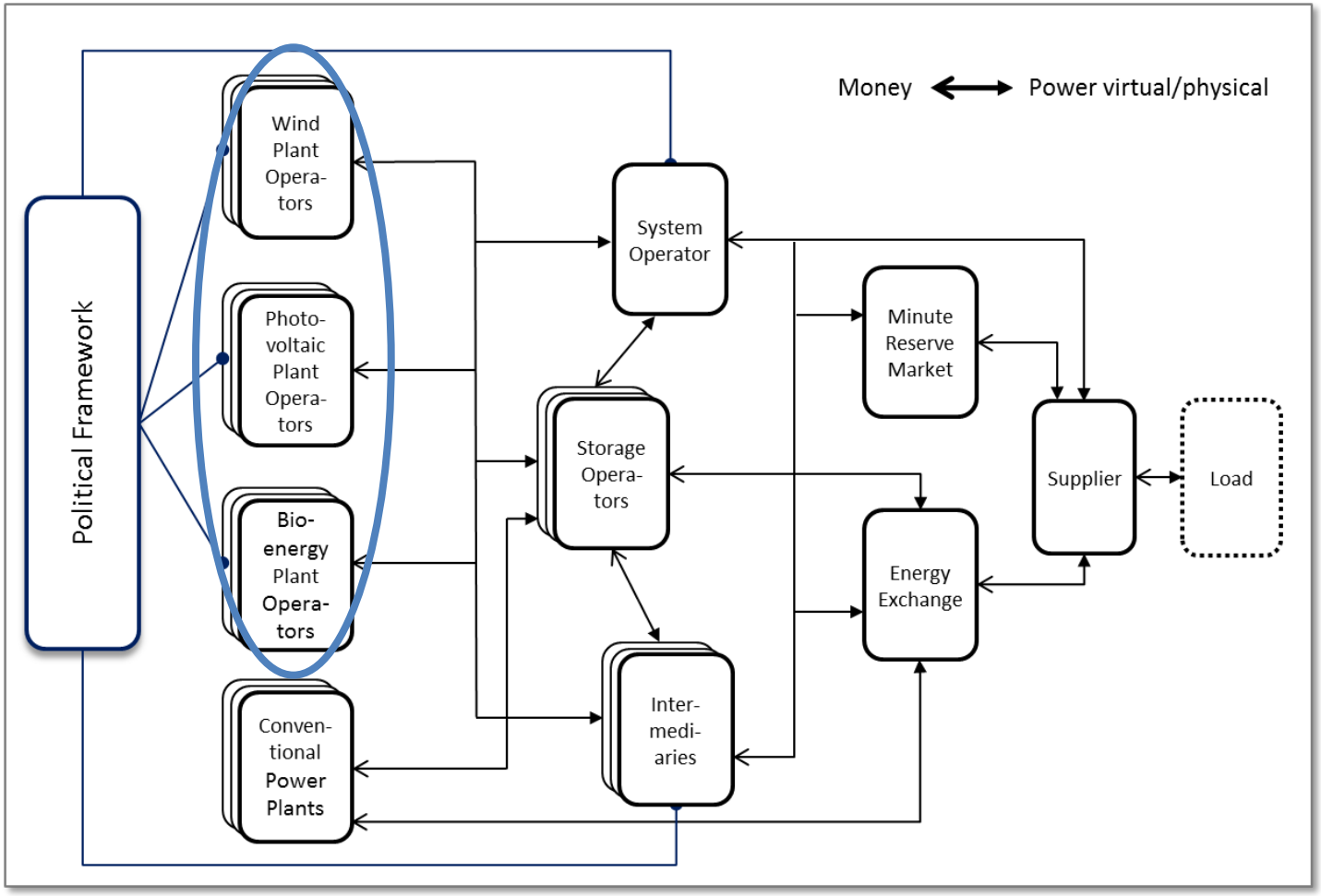
- Document research, interviews and expert workshops
- Review and study of markets and policy instruments

→ Agent-based model (agents with **autonomous** behavior, **own goals**, **imperfect** knowledge, adaptation of strategies)

AMIRIS model



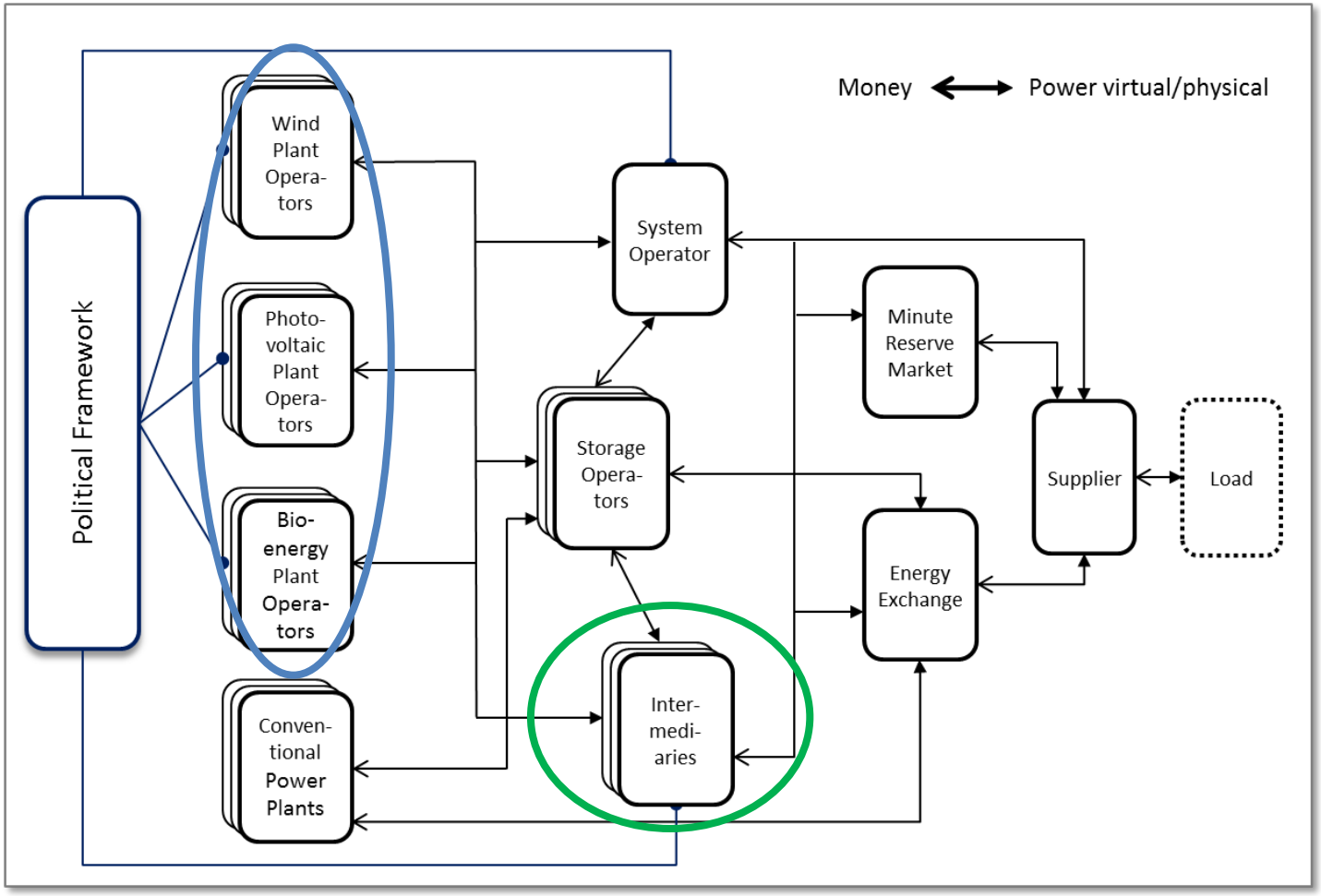
AMIRIS model



Remuneration Classes of Power Plants in the AMIRIS Model

Remuneration Class	Wind	PV	Biomass (BM)
RC 1	Basic FIT	Roof-top < 30 kW since 2012 < 10 kW	Solid biomass 5-20 MW (matured wood, forest residues)
RC 2	Starting FIT (low average)	Roof-top 30-1000 kW, since 2012 10-1000 kW	Wood gasification
RC 3	Starting FIT (high average)	Roof-top > 1000 kW	Biogas 50-350 kW (liquid manure und re-growing resources)
RC 4	Offshore	Conversion and open space	Biogas > 350 kW (liquid manure, re-growing resources, organic waste)

AMIRIS model

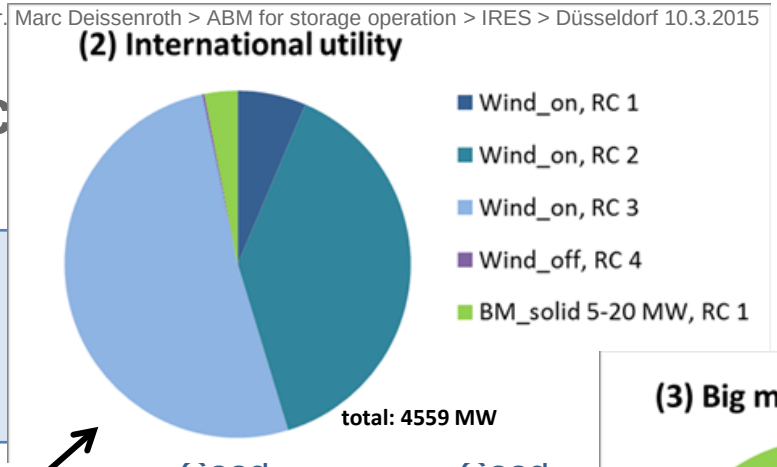


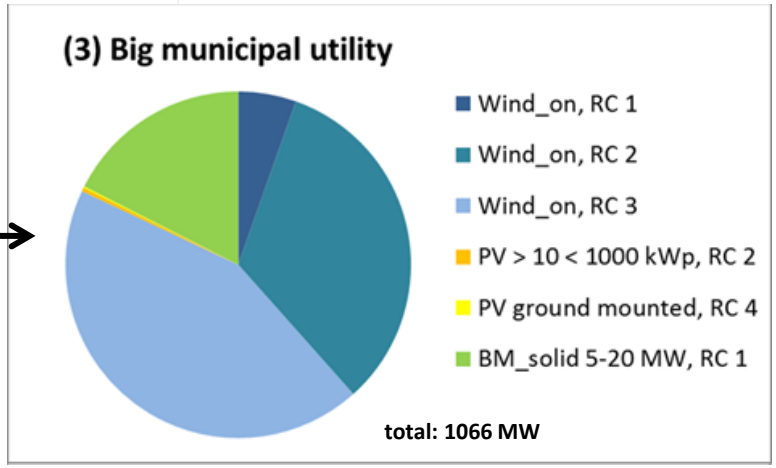
Types of direct marketers

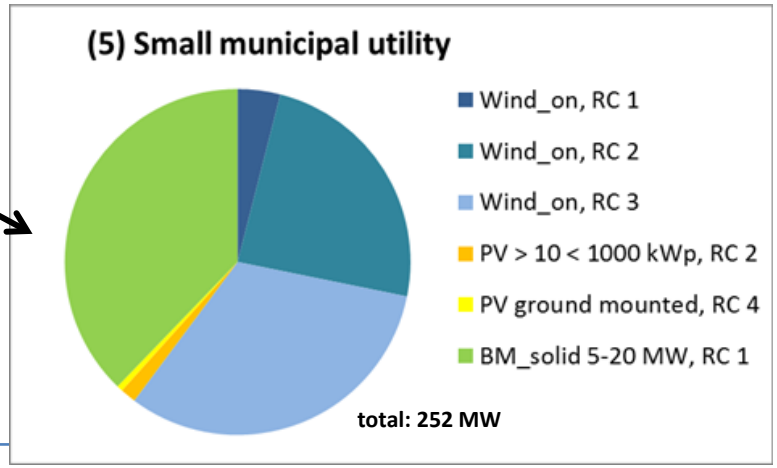
	Types of **direct marketers**	Output Forecast quality	Price Forecast quality
(1)	Big national utility	Good	Good
(2)	International utility	Good	Good
(3)	Big municipal utility	Medium	Good
(4)	Municipal utility “Pioneer”	Good	Good
(5)	Small municipal utility	Bad	Bad
(6)	Green electricity trader for households	Good	Medium
(7)	Green electricity trader for business/industry	Good	Medium
(8)	Specialised intermediary with experience	Good	Good
(9)	Specialised intermediary without experience	Medium	Medium

Types of direc

	Types of **direct marketers**		
(1)	Big national utility	Good	Good
(2)	International utility	Good	Good
(3)	Big municipal utility	Medium	Good
(4)	Municipal utility “Pioneer”	Good	Good
(5)	Small municipal utility	Bad	Bad
(6)	Green electricity trader for households	Good	Medium
(7)	Green electricity trader for business/industry	Good	Medium
(8)	Specialised intermediary with experience	Good	Good
(9)	Specialised intermediary without experience	Medium	Medium







Types of direct marketers

	Types of **direct marketers**	Output Forecast quality	Price Forecast quality
(1)	Big national utility	Good	Good
(2)	International utility	Good	Good
(3)	Big municipal utility	Medium	Good
(4)	Municipal utility “Pioneer”	Good	Good
(5)	Small municipal utility	Bad	Bad
(6)	Green electricity trader for households	Good	Medium
(7)	Green electricity trader for business/industry	Good	Medium
(8)	Specialised intermediary with experience	Good	Good
(9)	Specialised intermediary without experience	Medium	Medium

Income
Exchange market
Power balancing market
Remuneration
Management premium
Expenses
Staff & office
Trading
Forecast
Balance Energy

Types of direct marketers

	Types of **direct marketers**	Output Forecast quality	Price Forecast quality
(1)	Big national utility	Good	Good
(2)	International utility	Good	Good
(3)	Big municipal utility	Medium	Good
(4)	Municipal utility “Pioneer”	Good	Good
(5)	Small municipal utility	Bad	Bad
(6)	Green electricity trader for households	Good	Medium
(7)	Green electricity trader for business/industry	Good	Medium
(8)	Specialised intermediary with experience	Good	Good
(9)	Specialised intermediary without experience	Medium	Medium

Income

- Exchange market
- Power balancing market
- Remuneration
- Management premium

Expenses

- Staff & office
- Trading
- Forecast
- Balance Energy

Storage Parameters

Pumped-storage Hydroelectricity (PSH)	unit	(2010)
Round-trip efficiency	%	77%
Maximum depth of discharge (dod)	%	90%
Self-discharge	%/d	0,013%
Cycle life	# cylces	1.000.000
Calendar life - storage unit	a	90
Calendar life - charging unit*	a	35
Power installation costs*	€/kW	300
Energy installation costs	€/kWh	10
Fixed O&M costs	% Inv/a	1%
Capacity*	kW	1.000.000
Energy capacity	kWh	1.000.000
E2P ratio	h	1
Spread_min	€/kWh	15

* Consider the same value for charge & discharge

Storage Strategy for exchange market

Dynamic programming method

Estimate exchange market prices for next 24 hours

For state at time t get the optimal state at time t+1

Time \ State	0	1
25		x
24		
…		
1	x	x
0	x	x

Storage Strategy for exchange market

Dynamic programming method

Estimate exchange market prices for next 24 hours

For state at time t get the optimal state at time t+1

Time \ State	0	1
25		x
24		
…		
1	x	
0	x	x

Storage Strategy for exchange market

Dynamic programming method

Time \ State	0	1
25		x
24	x	x
…		
1		
0		

Storage Strategy for exchange market

Dynamic programming method

Time \ State	0	1
25		x
24	x	x
…		
1		
0		

Storage Strategy for exchange market

Dynamic programming method

Time \ State	0	1
25		x
24	x	x
…	x	x
1		
0		

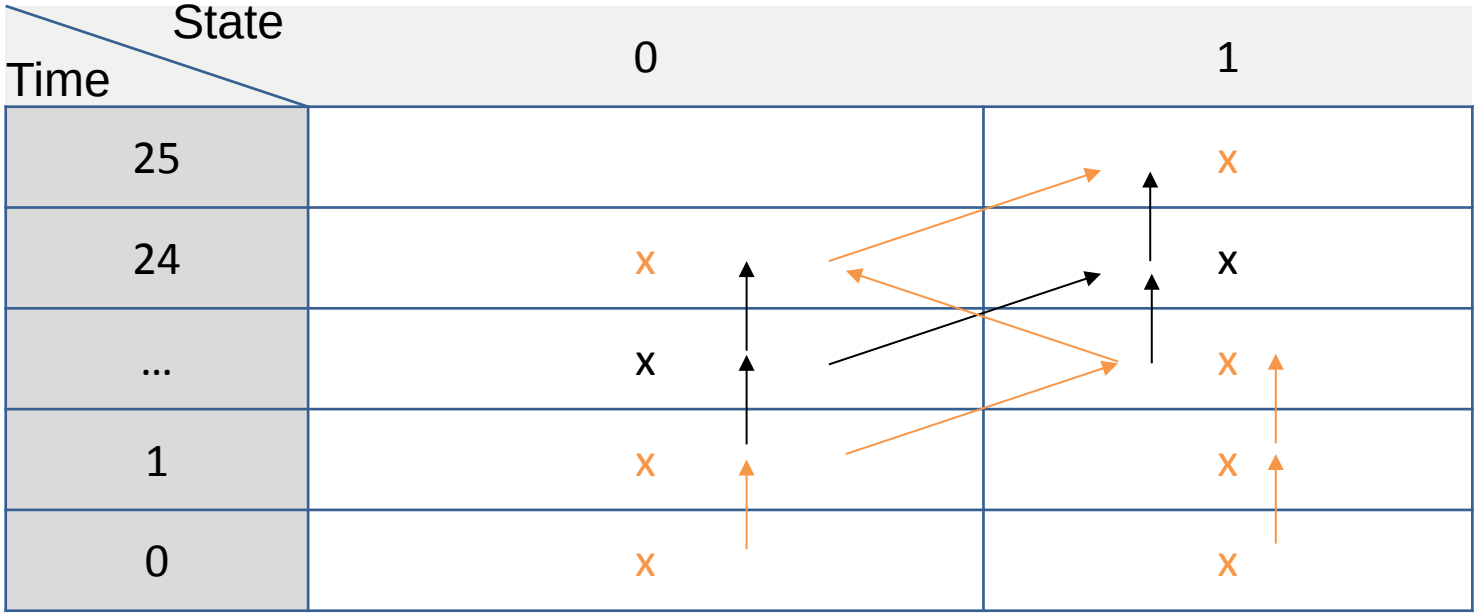
Storage Strategy for exchange market

Dynamic programming method

Time \ State	0	1
25		x
24	x	x
…	x	x
1		
0		

Storage Strategy for exchange market

Dynamic programming method

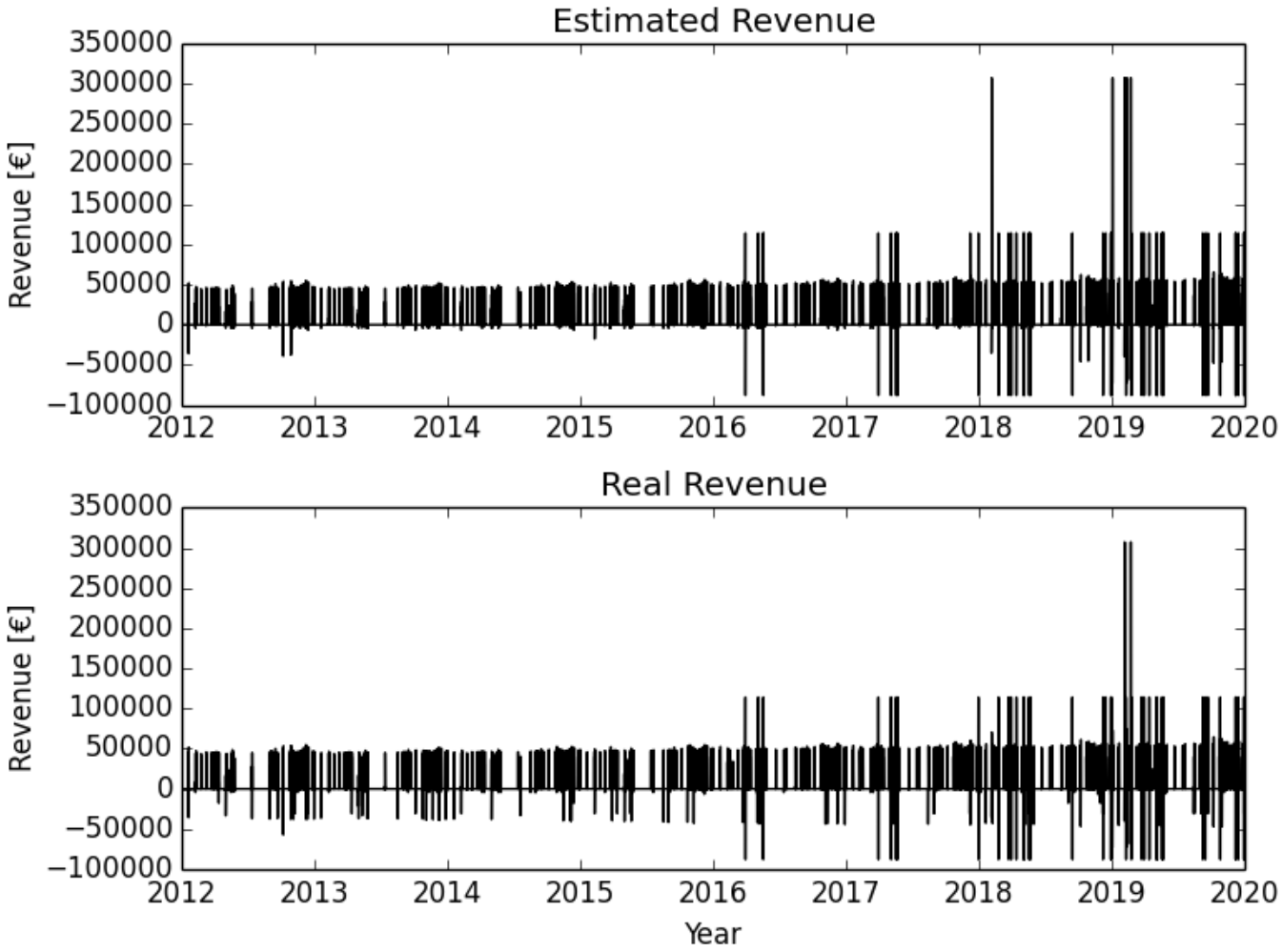


Input and assumptions of simulation

- Renewable energy and conventional power plants installations according to Leitstudie 2012, Szenario A*
- Fossil fuel and CO2-price according to Leitstudie 2012 Preispfad A*
- Renewable energy generation from DLR energy system model REMix
- Load according to ENTSO-E
- EEG-remuneration and market premium from 2012 and variants
- Hourly simulation steps for the years 2012-2019

* Nitsch, J. et al. ‚Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global, *Deutsches Zentrum für Luft- und Raumfahrt (DLR), Fraunhofer Institut für Windenergie und Energiesystemtechnik (IWES), Ingenieurbüro für neue Energien (IFNE), Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU),* **2012**

Revenue of Storage at Exchange Market

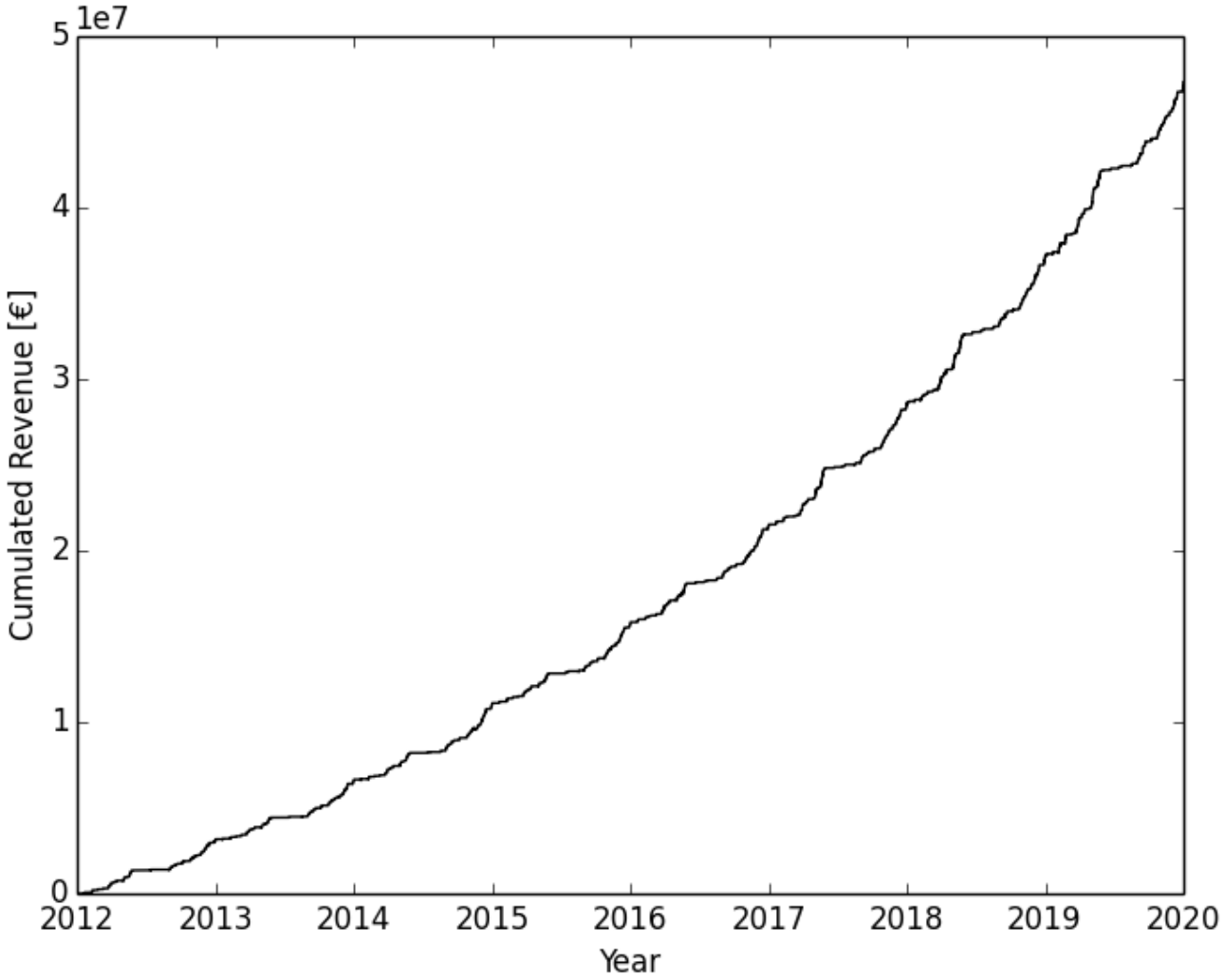


Imperfect forecast of market prices used for dynamic strategy

Estimated revenues

Revenues with „real“ model market prices

Cumulated Revenue of Storage



Initial investment of 310 Mio €

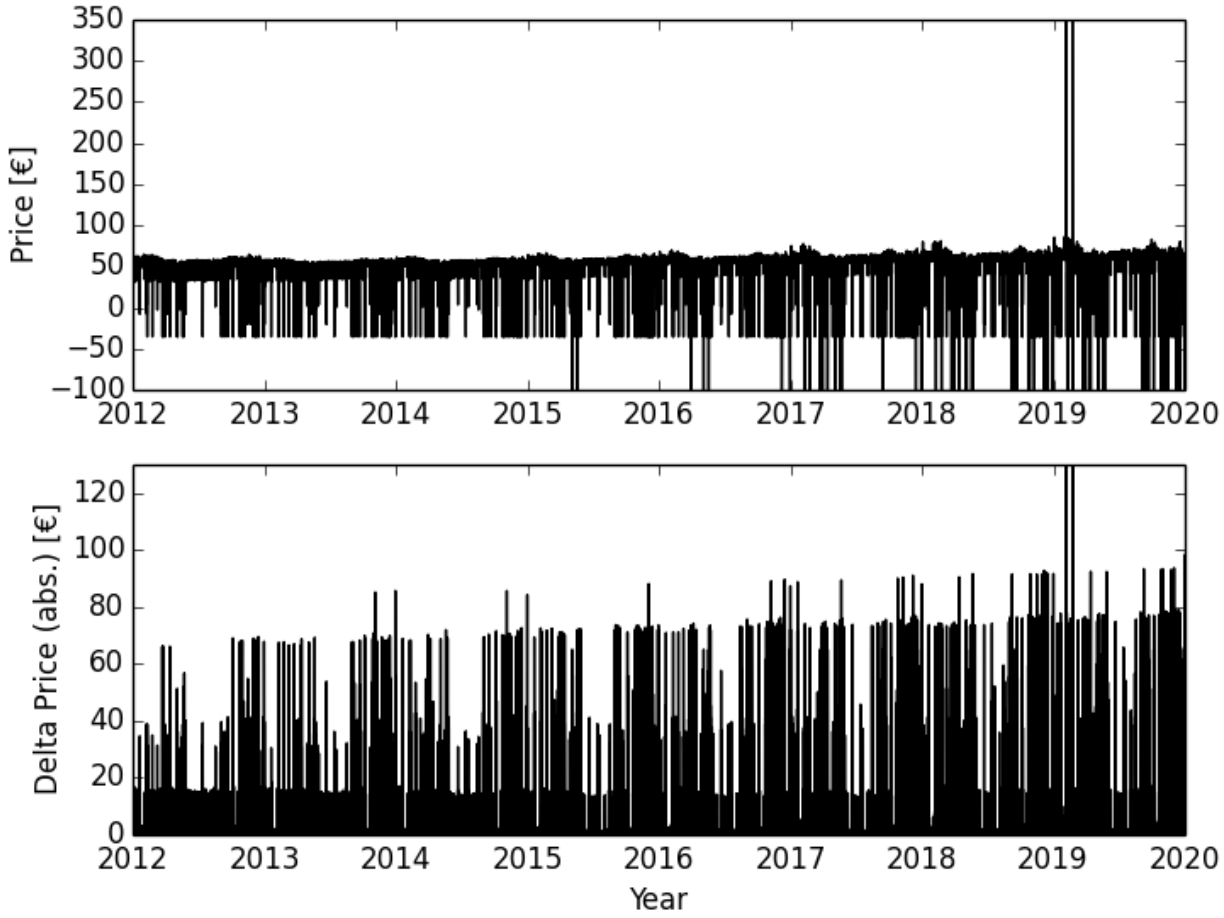
vs

Cumulated revenue of about 46 Mio €

Overall profits from market premium are in the order of 1e7 Mio € per year *

* Direct Marketer Typ 2

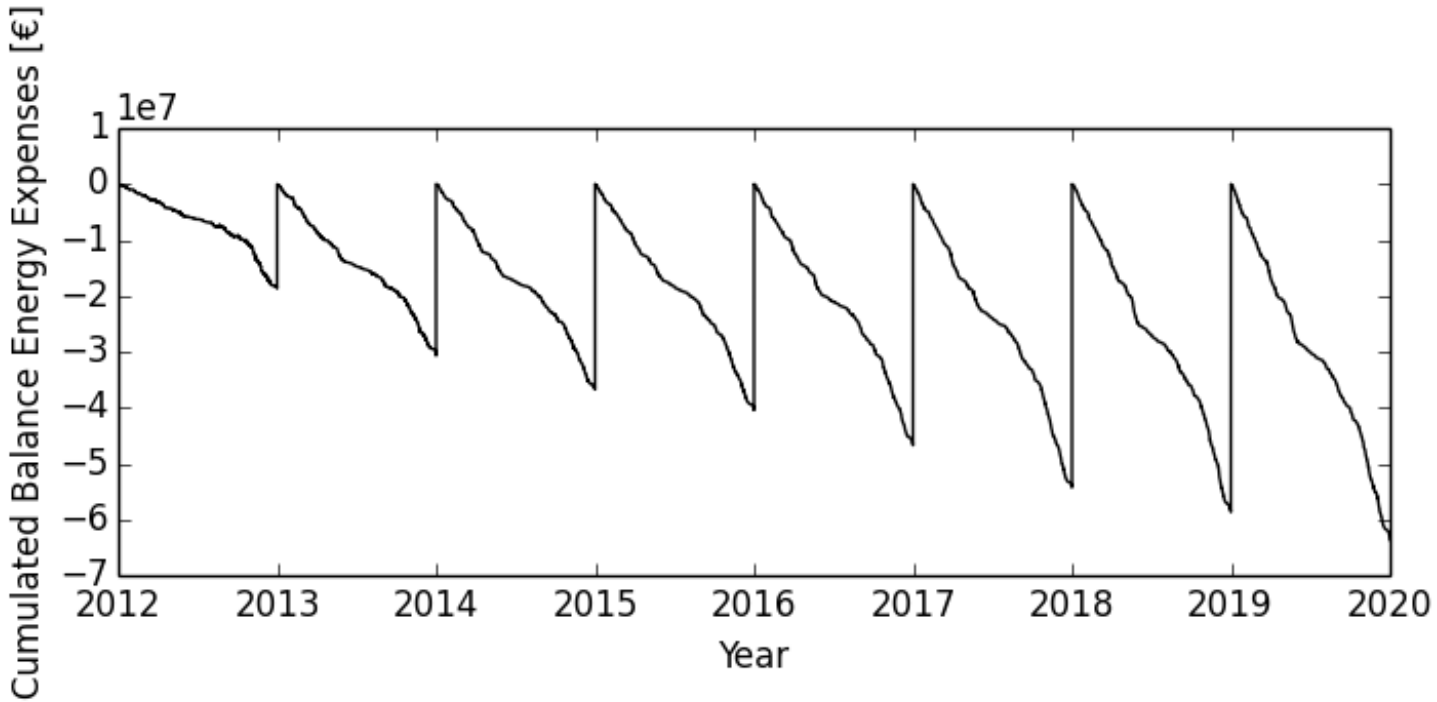
Exchange market prices



- Simulated exchange market price too „flat“
- Merely curtailment in the modelled scenario

- Fossil fuel price should be more dynamic
- Extend simulation time period

Planned: Use storage to minimize balancing power costs



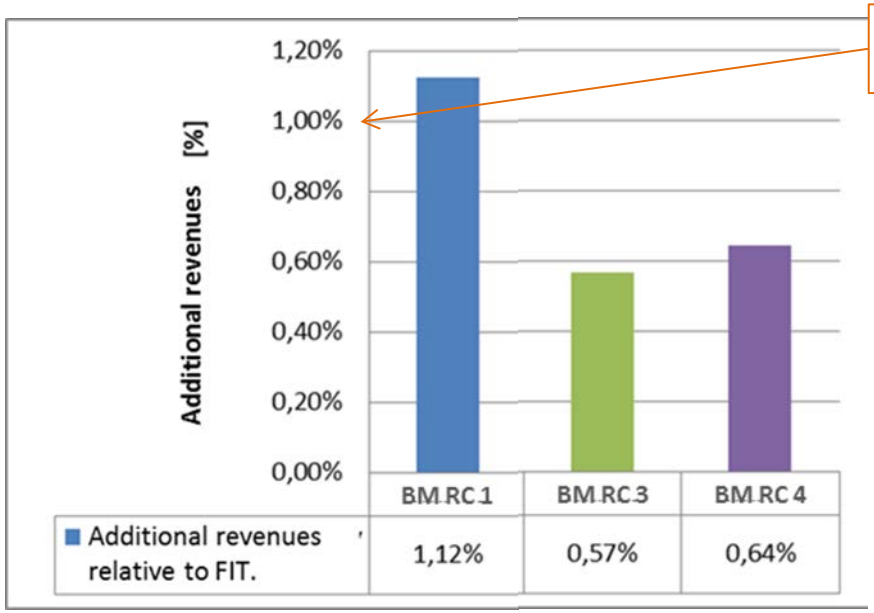
Balancing power varies between min./max**. -1500 MW and 1500 MW** per hour

Expenses of up to 60 Mio € in 2020 could be reduced

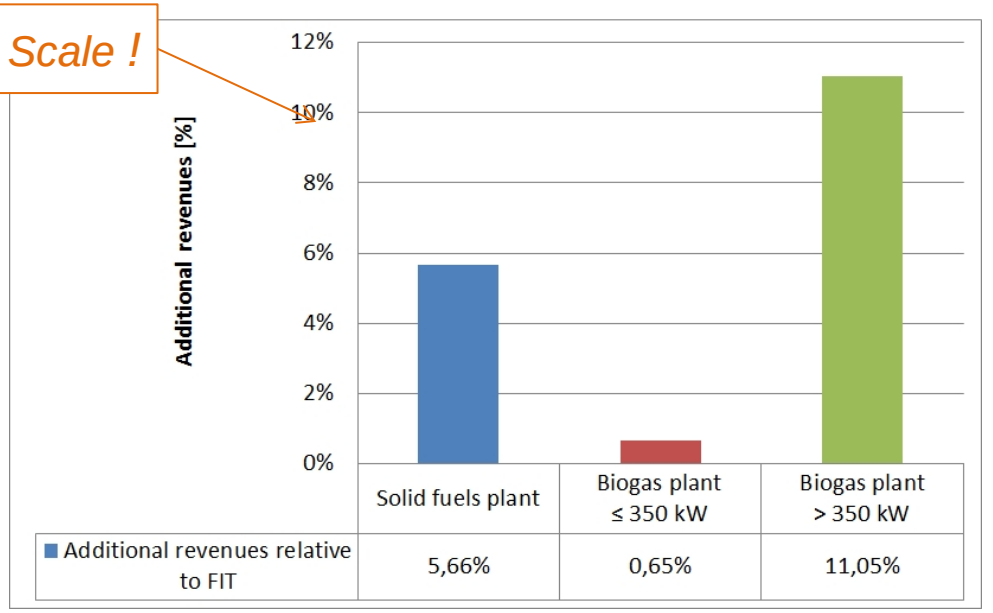
Planned: Use storage to trade on balancing power market

Trading at minute reserve market

Model shows improved income for biomass power plants



Scale !



Participation in direct marketing

Participation in direct marketing & negative minute reserve market

Thank you very much for your attention!

Contact:

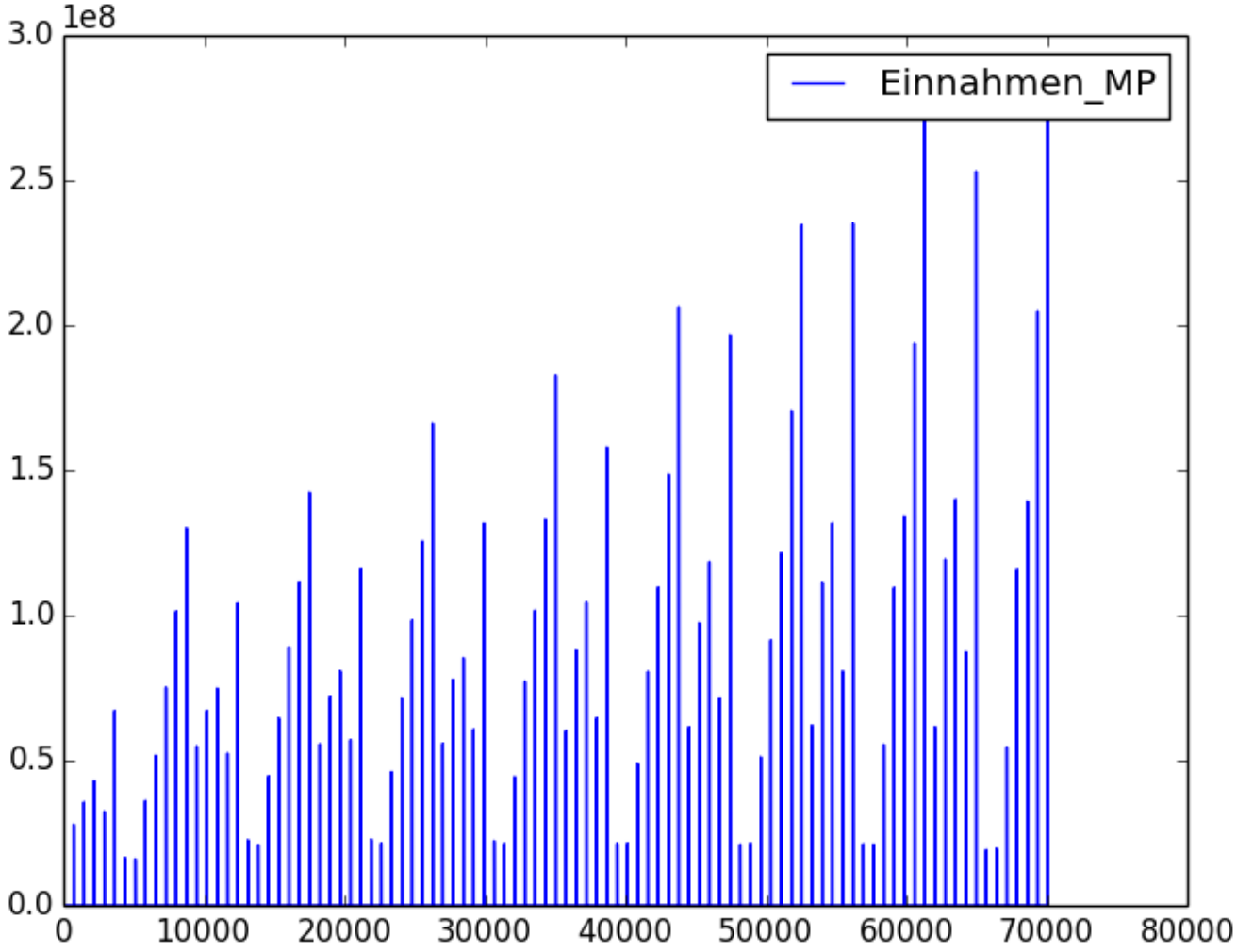
Dr. Marc Deissenroth

DLR - German Aerospace Center
Institute of Engineering Thermodynamics
Systems Analysis and Technology Assessment
Wankelstraße 5, D - 70563 Stuttgart
Tel.: +49.711.6862-8139

marc.deissenroth@dlr.de

www.dlr.de

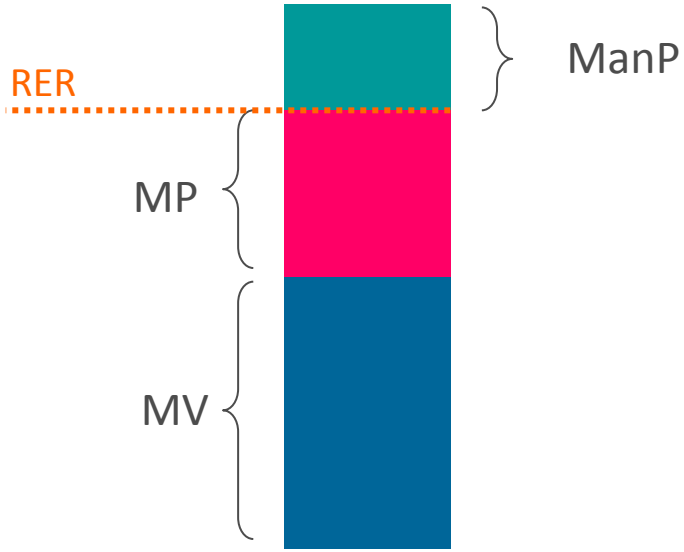
Appendix


1e8
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10000
20000
30000
40000
50000
60000
70000
80000
Einnahmen_MP

Direct marketing and the sliding market premium

$$MP = RER - MV$$
$$MP_{all} = MP + ManP$$

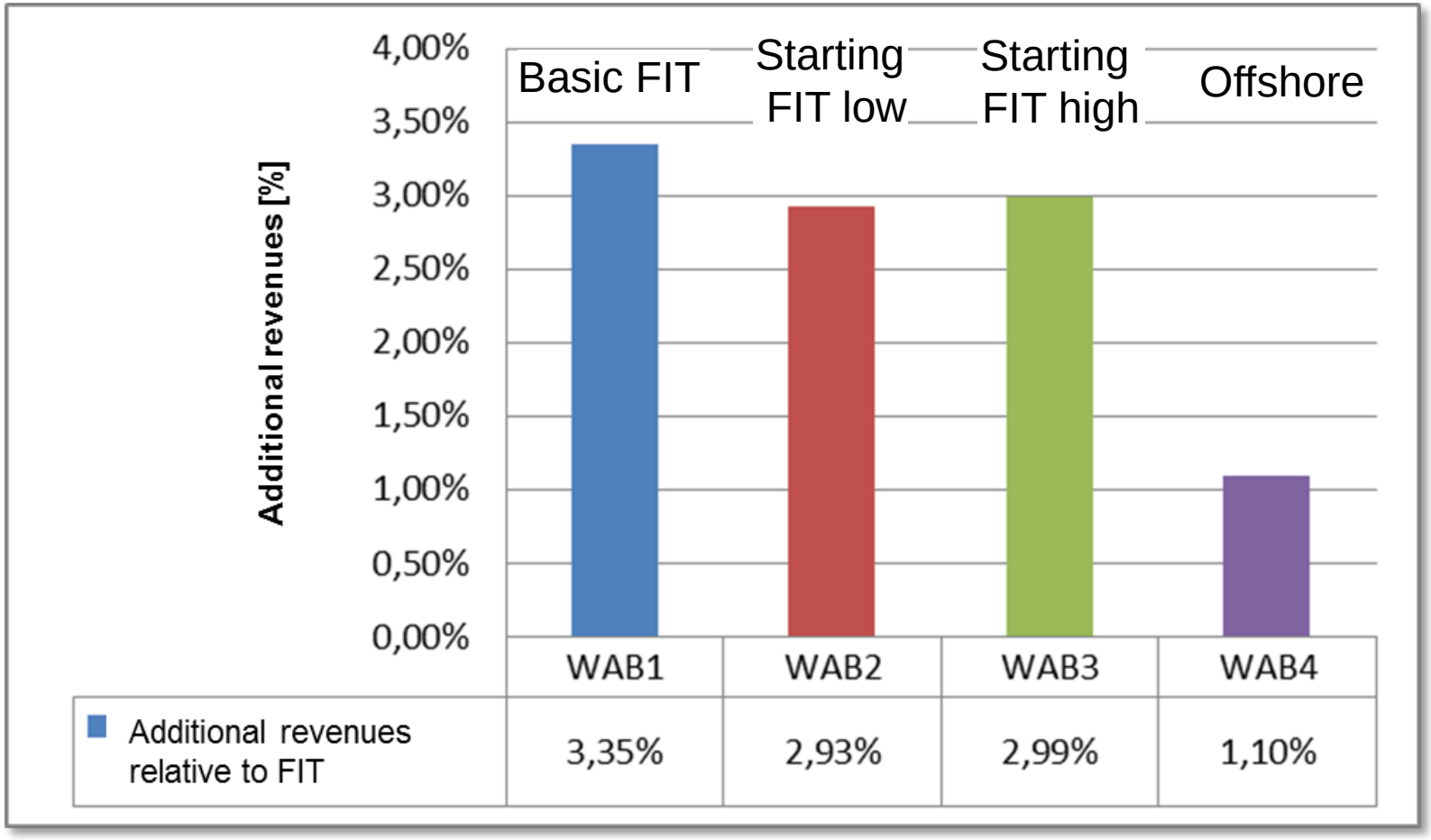
MP	$Market\ Premium$
RER	$RE\ renumeration$
MV	$Monthly\ market\ value$
$ManP$	$Management\ premium$



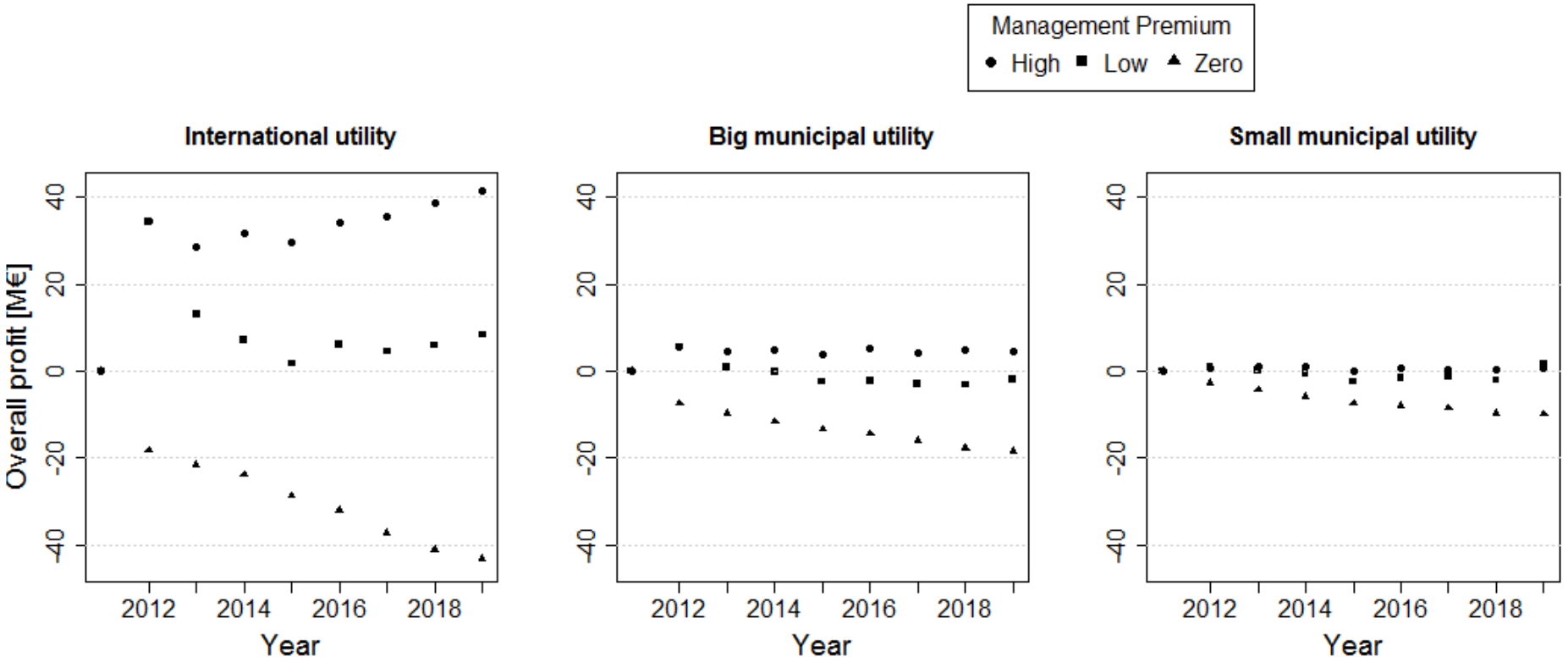
Focus of study:
Direct marketing of RE electricity making use of the sliding market premium, regarding three variants of the management premium:

EEG 2012 (high) | MaPrV 2012 (low) | no ManP (zero)

Additional revenues of wind power plant operators by participating at direct marketing (ManP low)



Profits of selected direct marketers



The profits include all incomes and expenses that are accumulated per accounting year and which are directly or indirectly related to direct marketing issues.

DLR

Outlook

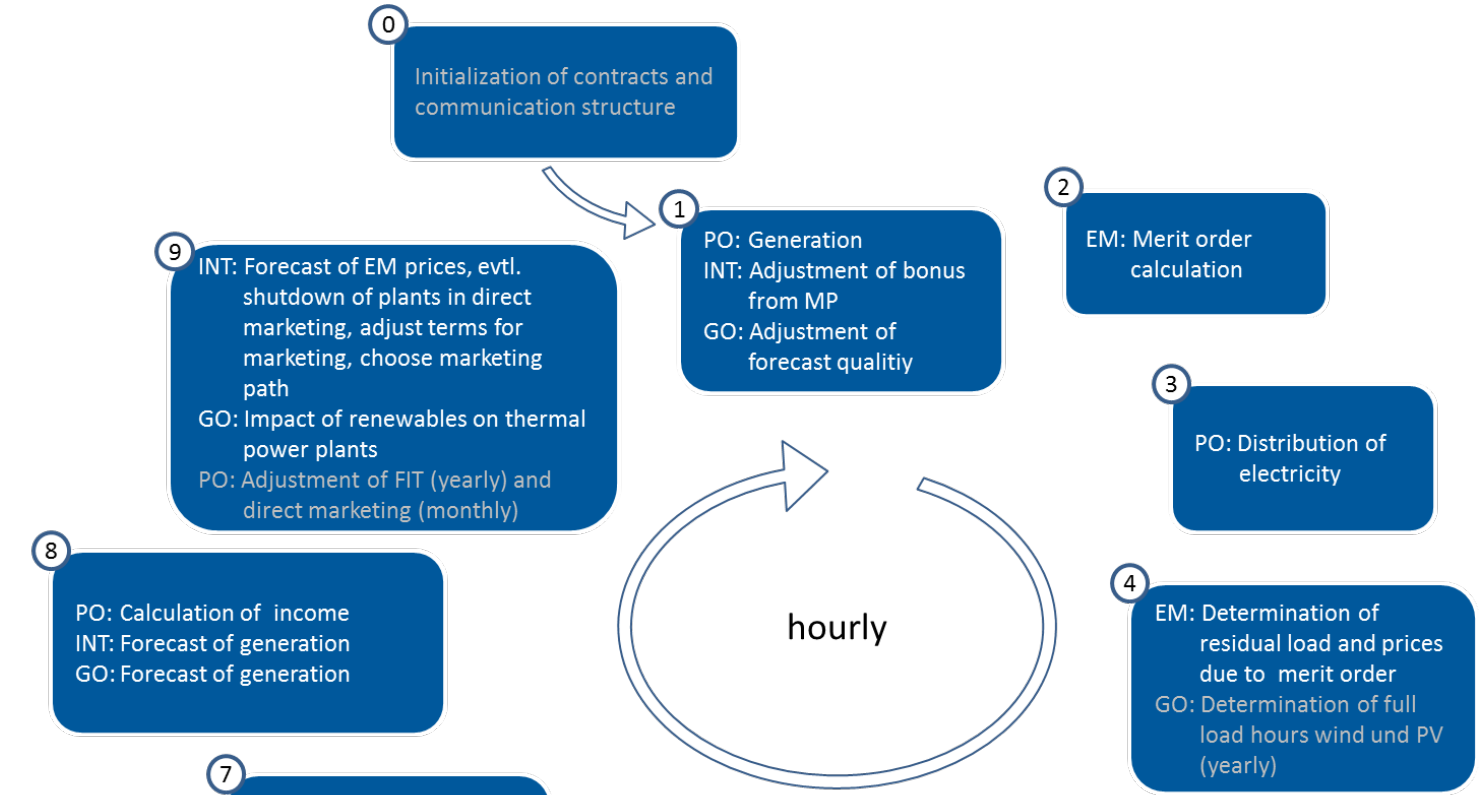
Ongoing developments

- Storage units for optimisation of power plant operation.
- Implementing detailed load and demand response.

Planned developments

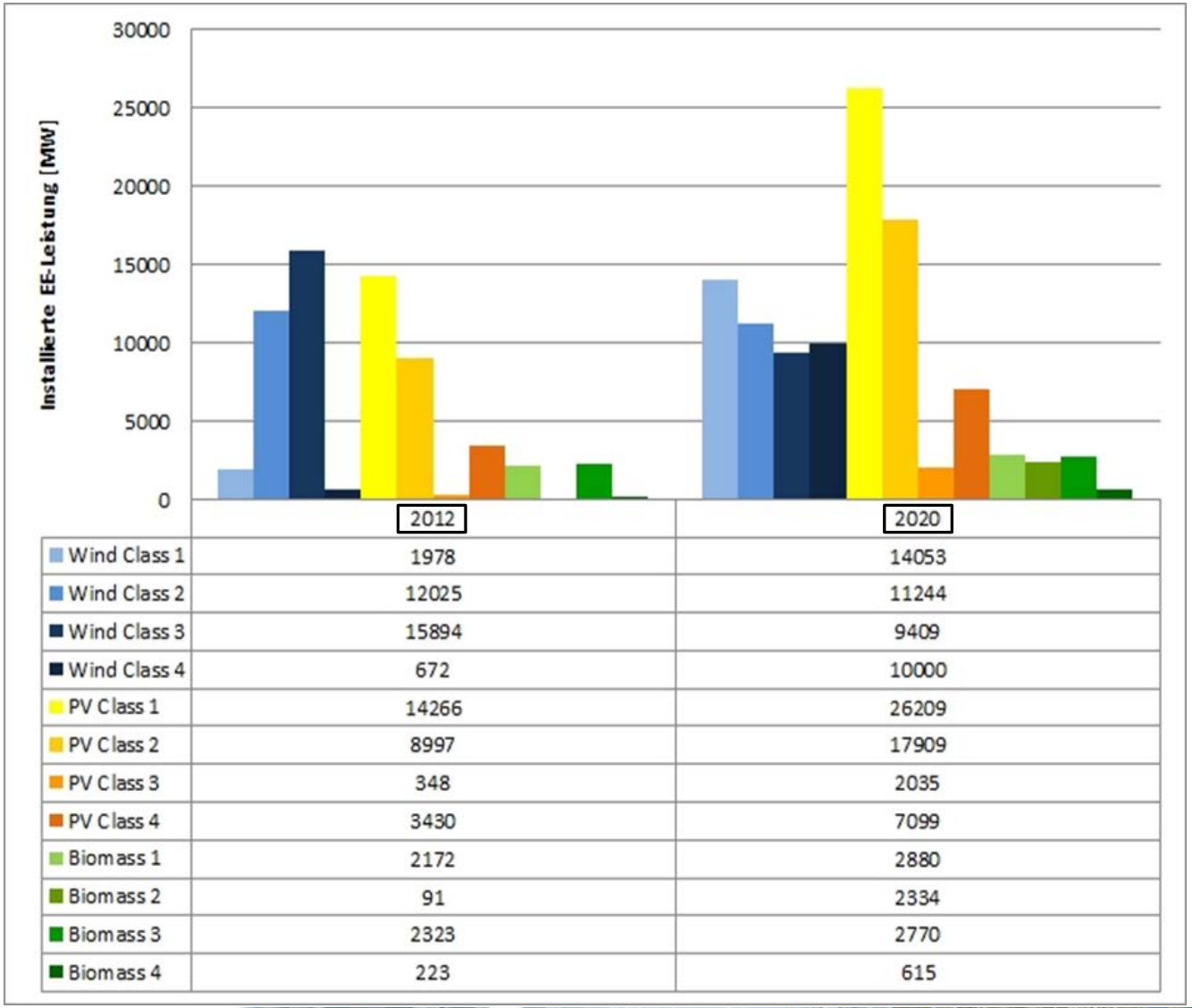
- More sophisticated mapping of conventional power plants.
- Mapping of intraday market.
- Development of an investment agent.
- Analyzing other market structures and policy instruments.

Simulationsprozess



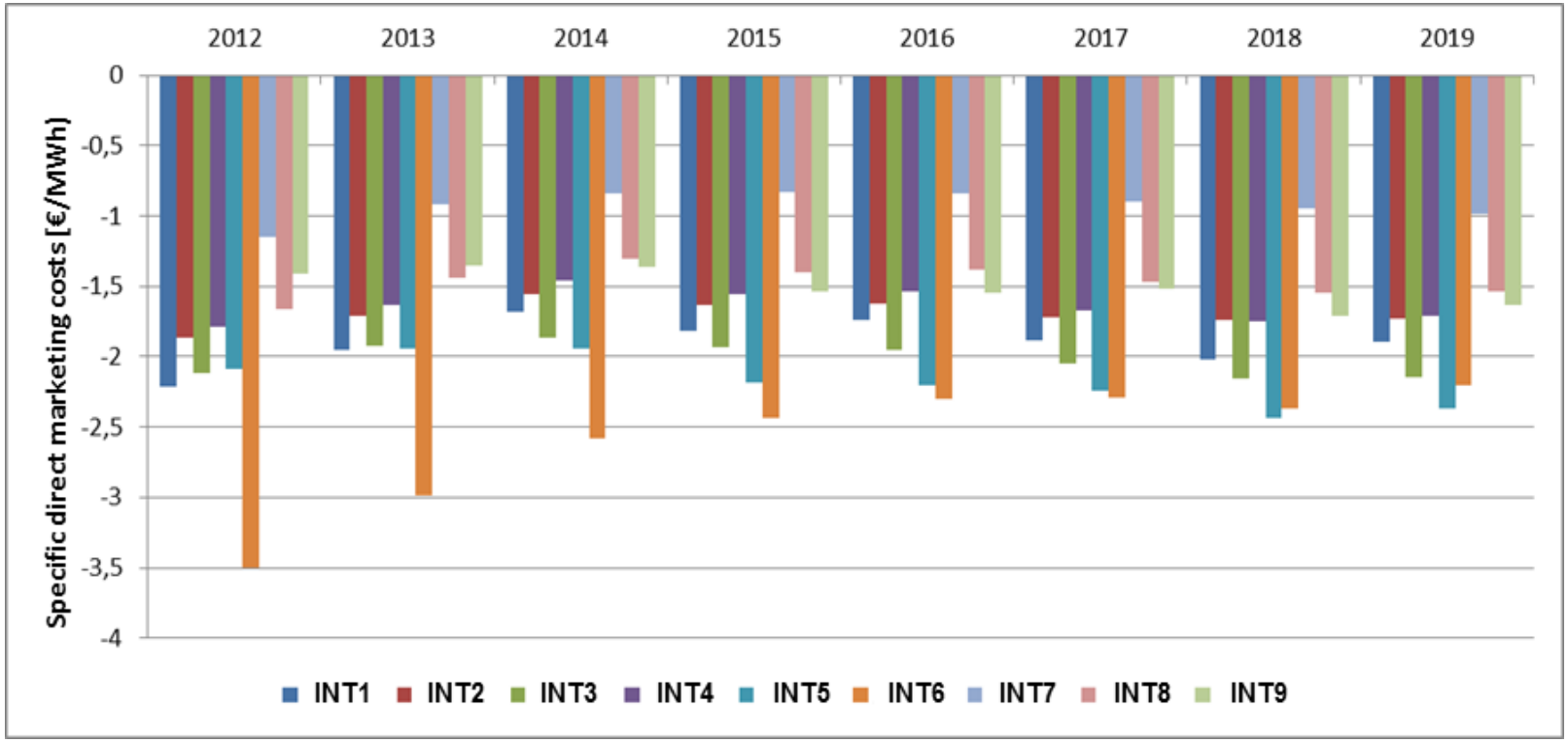
PO:	Plant Operator	REF:	Renewable Energy Framework
INT:	Intermediary		
GO:	Grid Operator	MP:	Market Premium
EM:	Electricity Market	FIT:	Feed-In-Tariff

Installierte Leistung der EE nach Vergütungsklassen in AMIRIS in den Jahren 2012 und 2020.



	2012	2020
Wind Class 1	1978	14053
Wind Class 2	12025	11244
Wind Class 3	15894	9409
Wind Class 4	672	10000
PV Class 1	14266	26209
PV Class 2	8997	17909
PV Class 3	348	2035
PV Class 4	3430	7099
Biomass 1	2172	2880
Biomass 2	91	2334
Biomass 3	2323	2770
Biomass 4	223	615

Specific costs for direct marketing for different types of intermediaries in case of obligatory direct marketing without compensation for marketing costs



Conclusion

- The agent-based model AMIRIS analyses the impact of political frameworks on the micro- as well as on the macro level.
- The agent-based perspective allows research respecting the interdependencies of the involved actors.

- For plant operators of fluctuating RE it is financially attractive to take part in direct marketing supported by the floating market premium.
- However, biomass power plant operators which actually are well suited for demand oriented generation profit least - as long as they do not take part at the market for negative minute reserve.
- The participation of RES in direct marketing is profitabel for intermediaries as long as a premium is paid for it. In case of a low or even an abatement of the premium it seems likely that several actors encounter severe losses, thus leading to market concentration.

Forecasting

- Forecast quality for feed-in: 15 - 25 % nRMSE
  - > good forecast quality: 15 % nRMSE (three external predictions)
    Expectation Value = 0.05
  - > medium forecast quality: 20 % nRMSE (two external predictions)
    Expectation Value = 0.10
  - > poor forecast quality: 25 % nRMSE (one external prediction)
    Expectation Value = 0.15

- $Forecast_{Feed-in} = Generatrion\,(t_{24}) * ((1 + E_{Forecast}(INT)) + \sigma_{Forecast}(INT) * G)$

mit: $E_{Forecast}$ - Expectation value [0,05 ; 0,15]

$\sigma_{Forecast}$ - Feed-in forecast error (nRSME) [0,15 ; 0,25]

G – normal distributed random draw