AMIRIS – An Agent-Based Simulation Model to Analyse Support Schemes for the Integration of Renewable Energies

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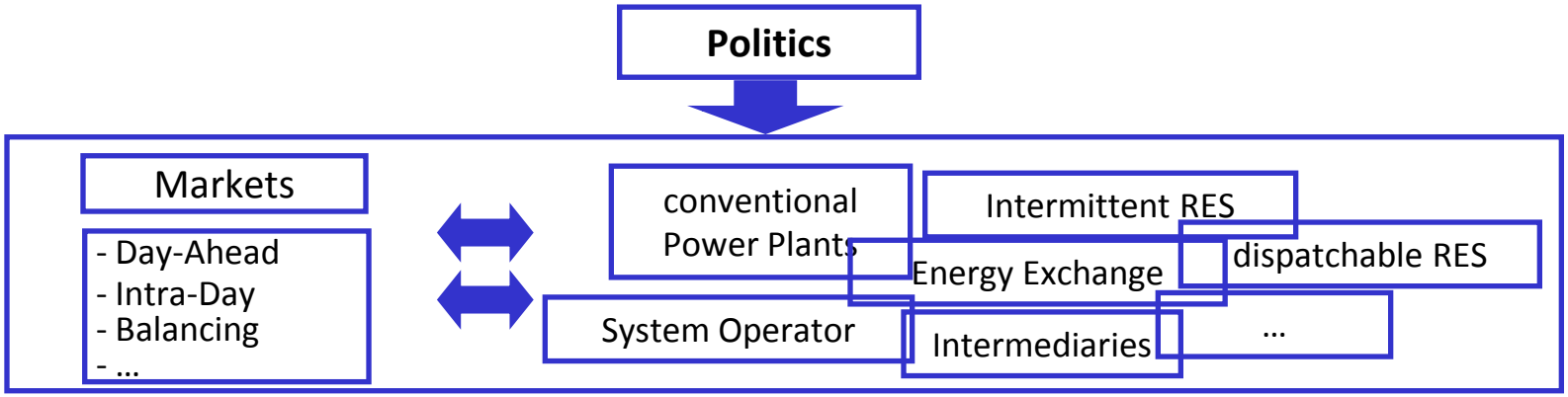
Energy Economic Background

- Electricity generation from renewable energy resources (RES) in Germany has now reached a relevant magnitude for the energy sector: 20 % in 2011[1]
- Reorganization of institutional, technical and financial aspects is needed to achieve political goals
  - GHG emissions: – 80%
  - RES share: 80% in electricity production

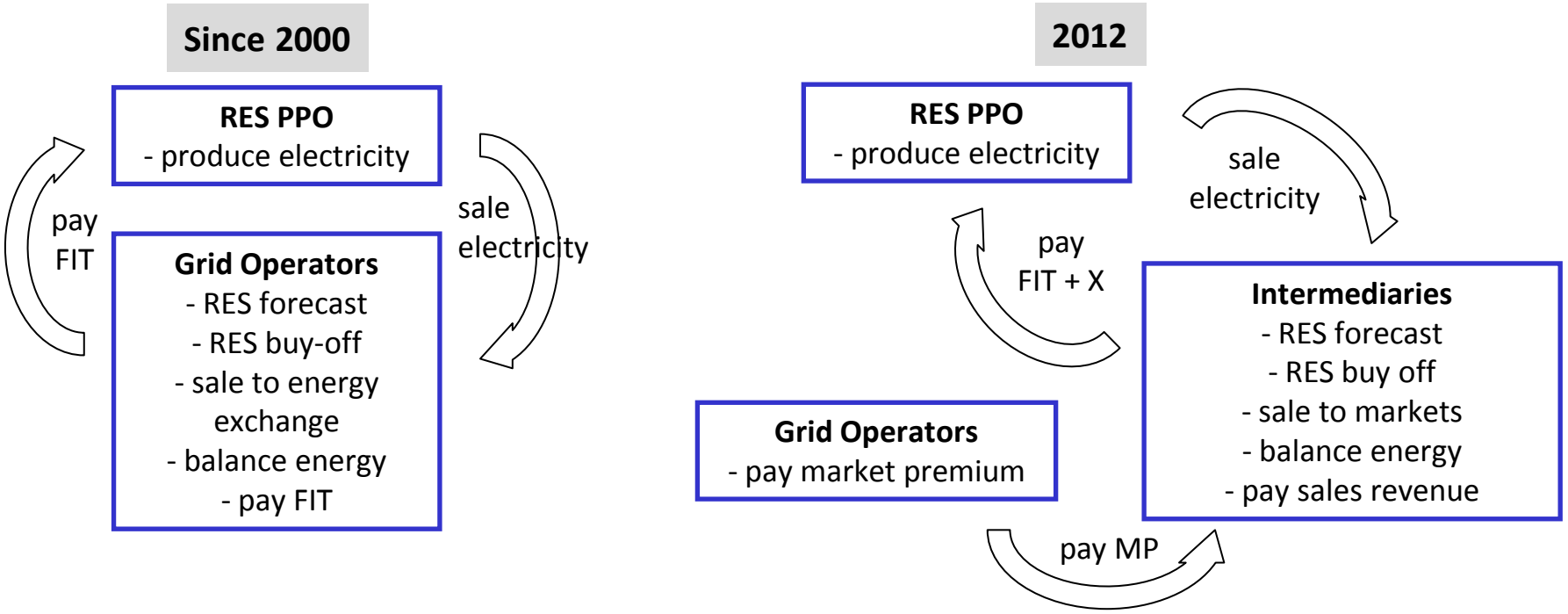
  } by 2050
- In this process of transformation
  - ➢ a huge **variety of actors** from different social arenas is involved, which
  - ➢ are connected via **complex interdependencies** and
  - ➢ react very differently to changes in the **energy policy framework**



[1]BMU (2012): Erneuerbare Energien in Zahlen

EEG 2012 Amendment – Market Premium

- German Renewable Energy Source Act (EEG) provides feed-in-tariffs (FIT) and buy-off of electricity by the transmission system operator (TSO) for the RES power plant operator (PPO) since 2000.
- After successful market introduction of RES, market integration is seen as next big step.
- Since 2012: Direct marketing of RES is supported by the optional 'market premium' (MP)



→ Criticism that market premium will only cause find-fall profits

AMIRIS - Our agent-based modelling (ABM) Approach

► **AMIRIS as a sound scientific policy device 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:

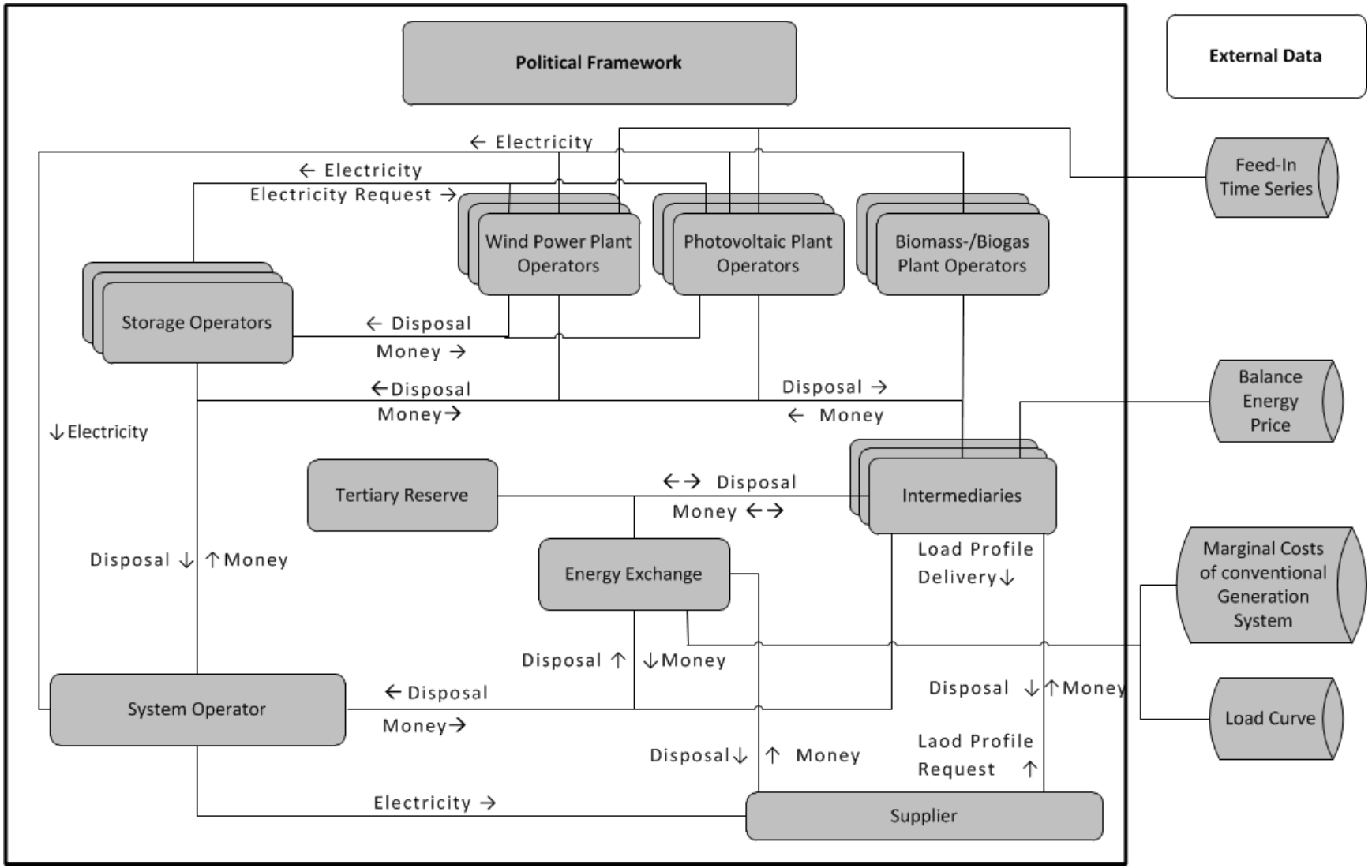
- Document analysis
- Semi-structured interviews
- Expert workshops

3

We build an ABM 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

1. Differentiation for first static simulation runs (no competition):

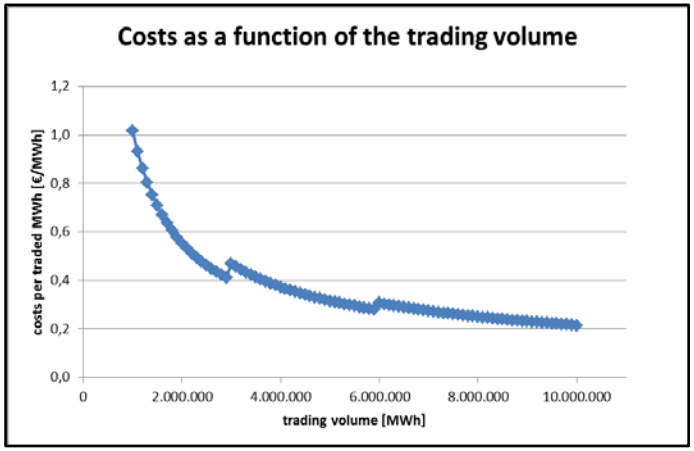
	Prototype	Capital resources (million €)	Market premium	Tariff	Forecast quality
(1)	Big national utility	100	2012	FIT+X	Good
(2)	International utility	15	2012	FIT+X	Good
(3)	Big municipal utility	15	2012	FIT+X	Medium
(4)	Municipal utility “Pioneer”	15	2012	FIT+X	Good
(5)	Small municipal utility	7	2012	FIT+X	Bad
(6)	Green electricity trader for households	7	2012	FIT+X	Good
(7)	Green electricity trader for business/industry	7	2012	FIT+X	Good
(8)	Green electricity trader for local marketing	1	-	FIT+X	Medium
(9)	Functional intermediary as spin-off from a big utility	3	2012	FIT+X	Good
(10)	Functional intermediary as start-up	0,1	2012	FIT+X	Medium

2. Further differentiation for dynamic simulation runs (with competition):
   - Searching cost for contract partners
   - Multiple marketing strategies: market premium, green electricity privilege, local direct marketing, bidding on reserve and balancing energy market

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:		€/MW	
		20 - 50	26	m²/E		Small portfolio	500-1500	MW --> €/MW:	15
		> 50	25	m²/E		Medium portfolio	1500-3000	MW --> €/MW:	10
3.	EEX access		25.000	€/a		Big portfolio	3000-5000	MW --> €/MW:	5
4.	IT-/ Office equipment		10.000	€/a*E	5.	Forecasting quality:			
5.	Labour costs:					Good	Number of purchased forecasts:		3
		Trader	130.000	€/a*E		Medium	Number of purchased forecasts:		2
		Other staff	65.000	€/a*E		Bad	Number of purchased forecasts:		1

1. At end of each year: intermediary agents carry out balance check and calculate EBIT per employee.
2. According to EBIT the tariff is adjusted if necessary:
   - € 100,000-300,000: bonus remains the same
   - € 300,000-500,000: bonus is risen by 25 %
   - > € 500,000: bonus is risen by 50 %
   - € 50,000 - 100,000: bonus is lowered by 25 %
   - < € 50,000: bonus is lowered by 50 %



Actor Analysis II - Power Plant Operators

1. Differentiation by av. feed-in-remuneration, size of plant, technology and resource used:

Wind PPO:

Classes Year	1 [MW]	2 [MW]	3 [MW]	4 [MW]	Sum 1-3	1 [€/MWh]	2 [€/MWh]	3 [€/MWh]	4 [€/MWh]
2012	1978	12025	15894	242	29897	61,9	84,8	90,9	190,0
…	…	…	….	…	…	…	…	…	…
2020	14053	11244	9409	40000	34706	59,3	84,2	91,1	173,9

Class 1: 'basic remuneration' level, class 2 and 3 'increased starting remuneration' level and class 4 off-shore wind turbines

PV PPO:

Classes Year	1 [MW]	2 [MW]	3 [MW]	4 [MW]	Sum 1-4	1 [€/MWh]	2 [€/MWh]	3 [€/MWh]	4 [€/MWh]
2012	14266	8923	348	3444	26981	305,4	333,8	253,7	253,0
…	…	…	….	…	…	…	…	…	…
2020	27372	17835	872	7113	53192	196,9	217,1	158,4	163,8

Class 1: rooftops < 30 kW, class 2: rooftop 30-1000 kW, class 3: rooftop > 1000 kW and class 4: PV on conversion and free space

Biomass/ Biogas PPO:

Classes Year	1 [MW]	2 [MW]	3 [MW]	4 [MW]	Sum 1-4	1 [€/MWh]	2 [€/MWh]	3 [€/MWh]	4 [€/MWh]
2012	2172	91	2522	25	4810	97,0	164,1	175,6	142,3
…	…	…	….	…	…	…	…	…	…
2020	2880	2334	3048	338	8599	97,5	168,2	178,8	129,9

Class 1: co-generation 5-20 MW fed with old wood and forest residues; class 2: innovative technologies (e.g. wood gasification); class 3: biogas 50-1000 kW fed with liquid manure and renewable crop materials; class 4: biogas > 5 MW fed with bio-waste

2. Further differentiation for dynamic simulation runs (with competition):
   - Owner structure: private persons, farmers, funds, project developers, municipal utilities and big utilities.
   - Characterized by: expectations of return on investment, readiness to assume risk, 1st, 2nd and 3rd mover.

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Model Parametrisation

Jan 2012	Prototype	Wind (onshore)	Wind (offshore)	PV	Biomass	
					solid	biogas
(1)	Big national utility	5 %	35 %	-	20 %	30 %
(2)	International utility	40 %	-	-	35 %	-
(3)	Big municipal utility	1 %	-	0 %	5 %	5 %
(4)	Municipal utility “Pionier”	10 %	-	0 %	0 %	5 %
(5)	Small municipal utility	1 %	55 %	-	-	-
(6)	Green electricity trader for households	1 %	-	0 %	0 %	-
(7)	Green electricity trader for business/industry	2 %	-	0 %	15 %	50 %
(8)	Green electricity trader for local marketing	-	-	-	-	-
(9)	Functional intermediary as start-up	10 %	10 %	0 %	0 %	-
(10)	Functional intermediary as spin-off from a big utility	30 %	-	100 %	25 %	10 %
	Total initial capacity in direct marketing	12.050 (MW)	48 (MW)	58 (MW)	933 (MW)	
	Total share of installed capacity in direct marketing	40 %	24 %	1 %	19 %	

Following increase of direct marketed capacity until 2015 is assumed:

1. wind onshore (classes 1-3): from 40 % to 90 %
2. wind offshore: from 24 % to 100 %
3. PV class 1: will not opt for direct marketing at all
4. PV class 2: up to 80 %
5. PV class 3 and 4: up to 90 %
6. biomass class 1: up to 90 %
7. biomass class 2: will not opt for direct marketing at all
8. biogas classes 3-4: up to 76 %

} overall increase from 1 % to 40%

} overall increase from 19 % to 75 %

Management Premium: intermittent RES 2012: 12 €/MWh → 2015: 7 €/MWh
dispatchable RES 2012: 1 €/MWh → 2015: 0,25 €/MWh

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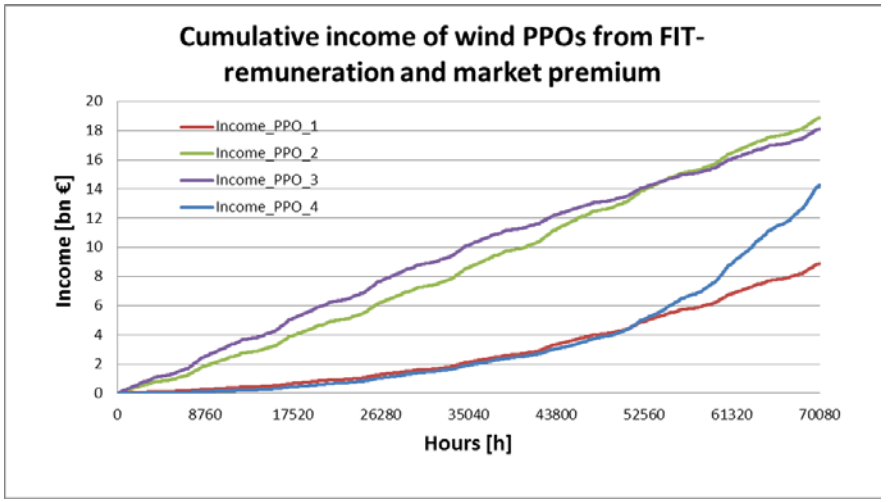
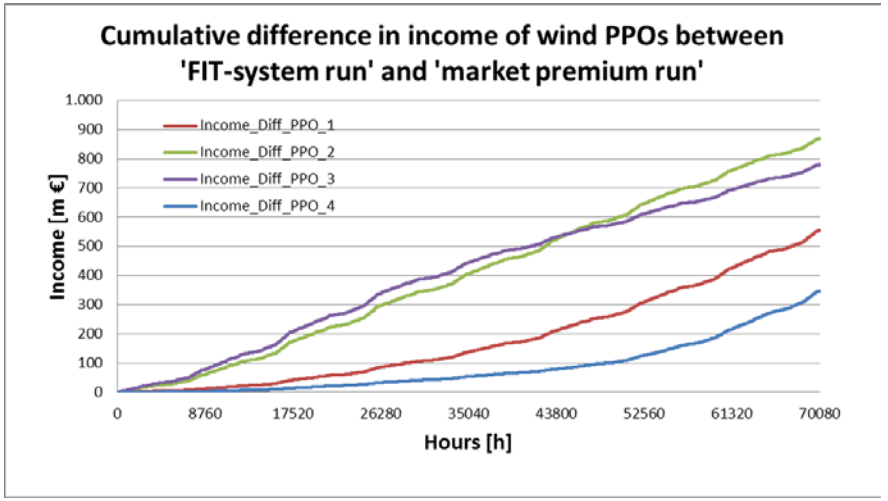
First Results I: Impact on Wind PPOs (static simulation run)

- Additional specific earnings in €/MWh by class compared to pure FIT-system run:
  1-3: about 5,1 €/MWh // 4: 4,2 €/MWh
- For example:
  1 MW turbine with 1500 full load hours earns about 7500 €/a extra.
- Investment for remote control[2]:
  old wind turbines: > 1000€ / turbine
  new wind turbine: < 1000€ / turbine
- Sufficient for extra investment in more demand orientated feed-in (e.g. storage)?



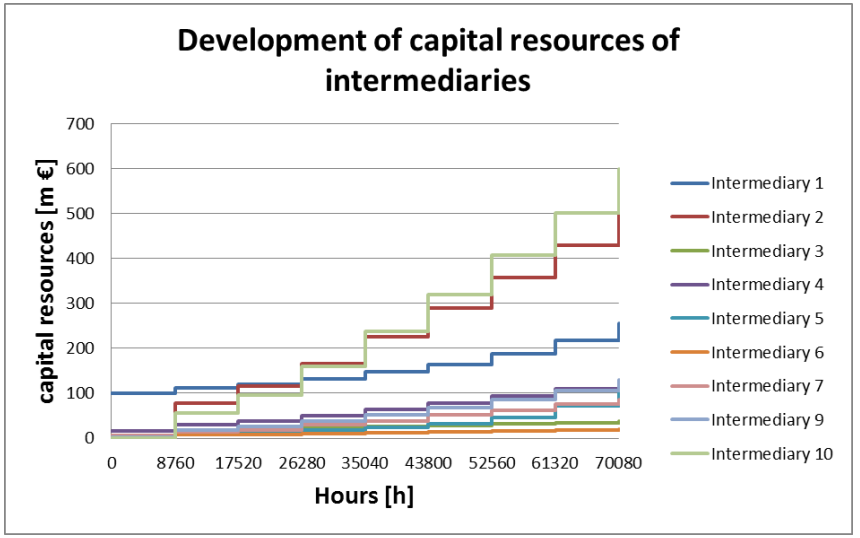


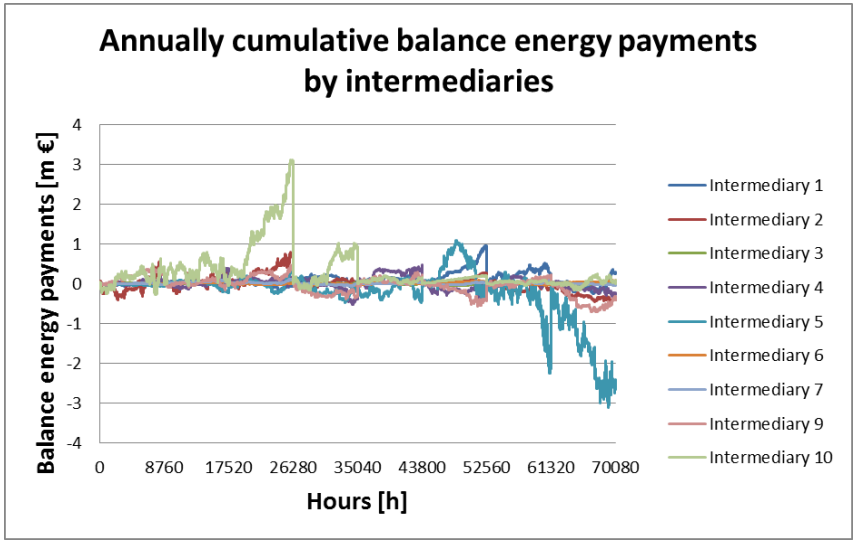
[2] Rostankoswki et al. (2012): Kurzgutachten: Anpassungsbedarf bei den Parametern des gleitenden Marktprämienmodells in Hinblick auf die aktuelle energiewirtschaftliche Entwicklung

First Results II: Impact on Intermediaries (static simulation run)

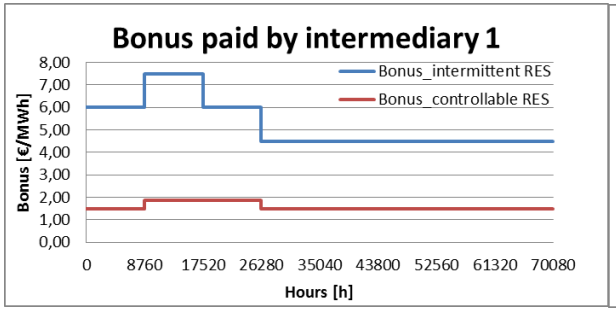
- Intermediaries 2 und 10 seem to profit the most from introduction of MP
- This is mainly due to fixed direct marketing shares at start of simulation
- No intermediary can pay higher bonus than these two (7,5 €/MWh in 2013, see next slide)

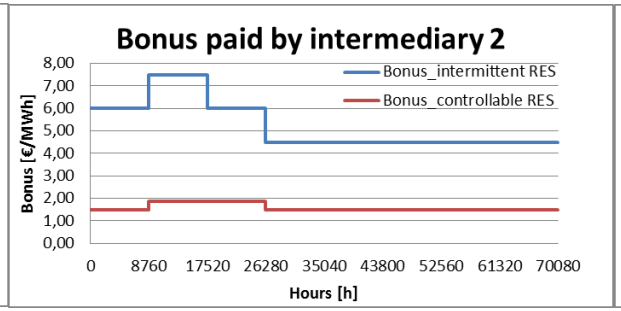
  → hint leading to the conclusion that these two will be able to defend their position.
- Compared to others, intermediary 10 also seems to profit from balance energy payments
- Results have to be interpreted with caution as revenues are highly dependent on balance energy payments

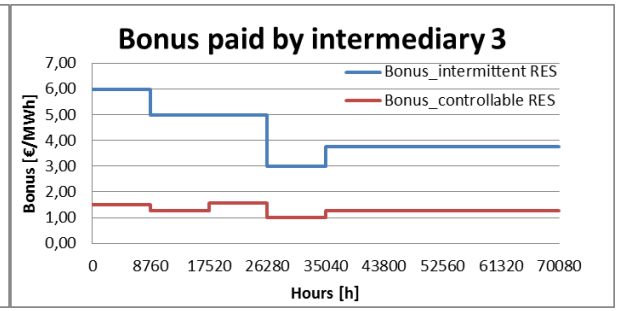


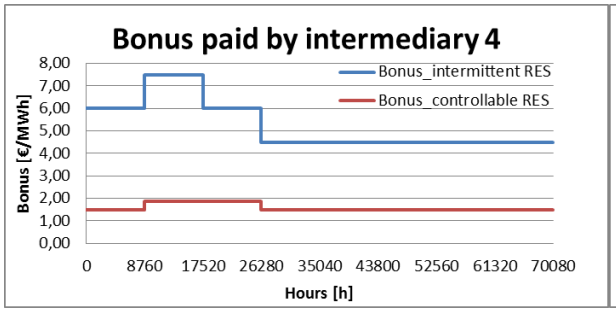


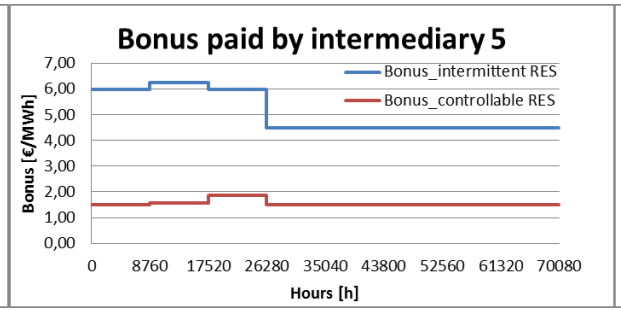
First Results III: Bonuses Paid by Intermediaries

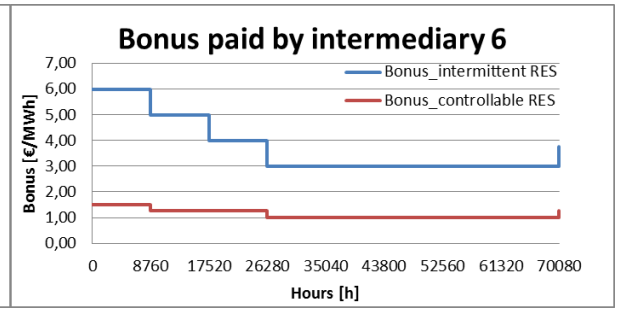


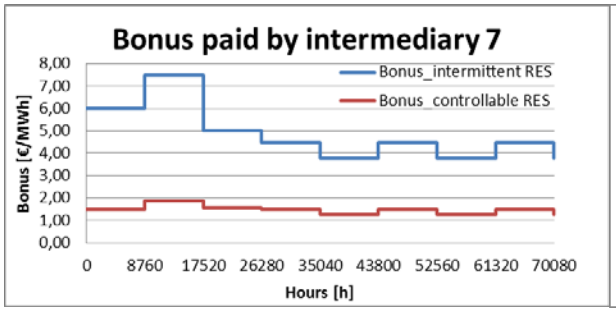


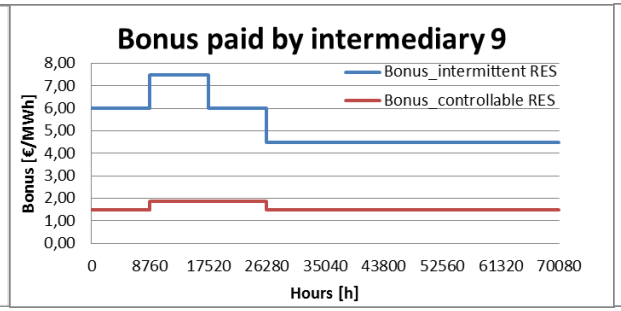


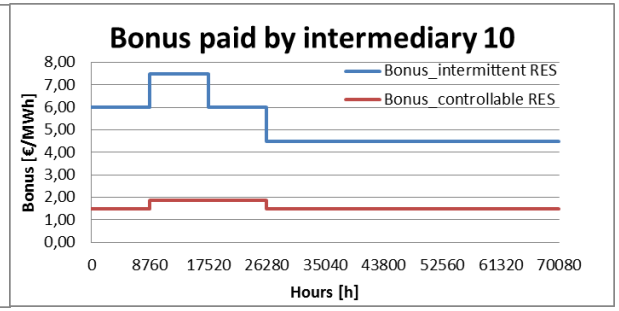












Conclusions

- New approach for sound policy advice which takes stakeholders perspective into account.
- New tool to “test” support schemes and market designs.

- Whether MP only produces wind-fall-profits depends on the question if actors will invest extra earnings on equipment for remote control and more demand oriented feed-in → so far they are not forced to do so!
- MP has definitely created a market for direct marketing, but height of support is questionable.

Outlook

- Future work will deal with more dynamic sampling of the model.
- Implementation and analysis of different market-designs for time periods when high shares of RES are integrated into the energy system.

Thank you very much for your attention…

…Questions?

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