OPTIMIZATION STRATEGIES FOR THE OPERATION OF RENEWABLE ENERGY UNITS IN SMART MARKETS

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AGENDA

Topic – Unit Commitment

- Part I – Markets Today
  - Specifications of Biogas CHP
  - Unit Commitment in the Day Ahead and Intraday Market
- Part II – Smart Markets
  - Smart Market Concepts
  - Unit Commitment Considering Smart Markets

Topic – FRR Pooling

- Part III – Flexibility Capacity of Energy Unit Portfolios Including Volatile Producers

Part I – Markets Today

Part I – Markets Today

Overview Major Markets

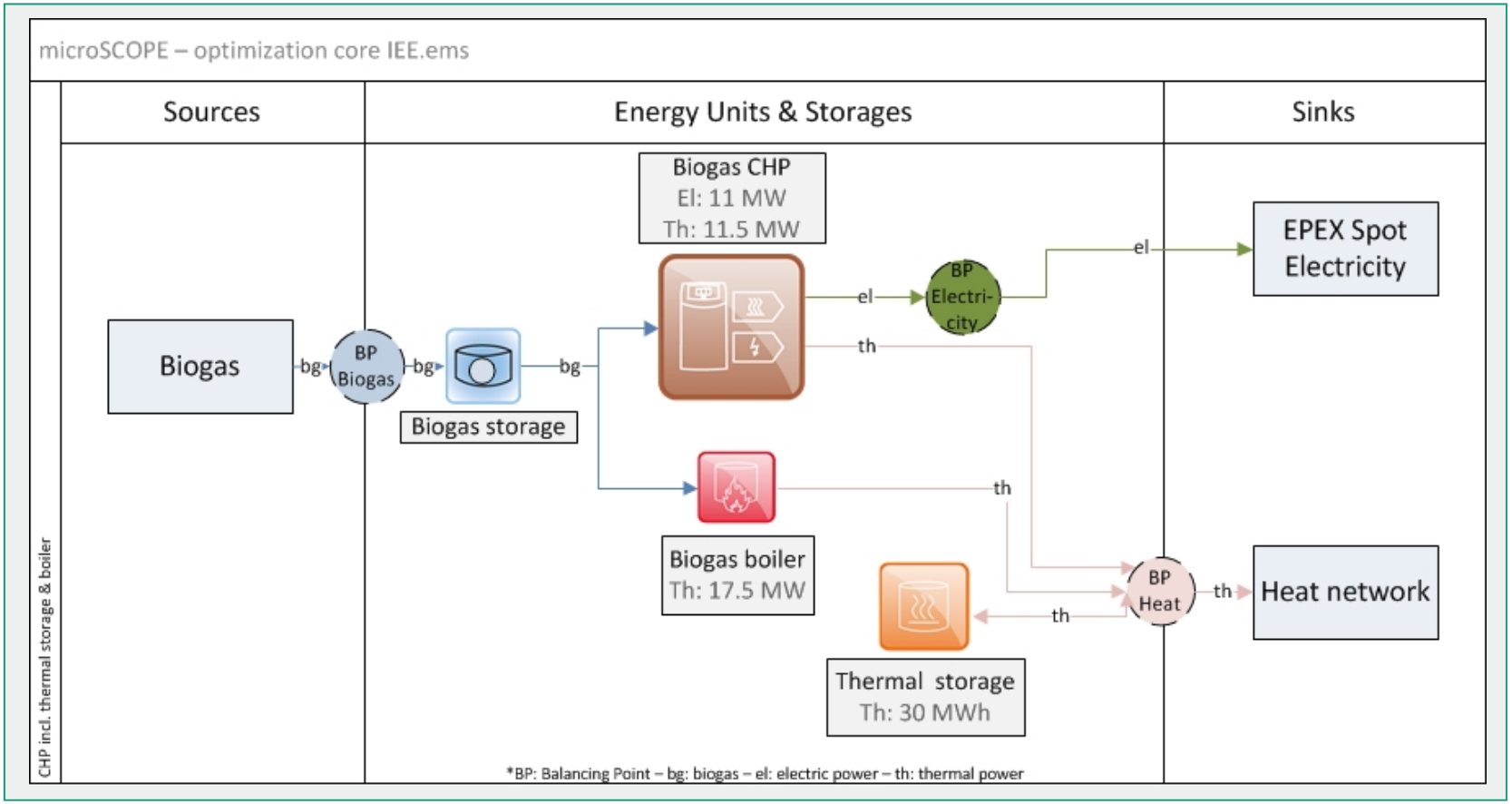
Market overview

Market type and time	FRR Auctions (aFRR, mFRR)	Day Ahead Auction EPEX Spot		Intraday Auction EPEX Spot	Intraday Trading EPEX Spot	Intraday Trading XBID
	10.00 a.m	12.00 p.m.		3.00 p.m.	Beginning at 3.00 / 4.00 p.m.	Beginning at 10 p.m.

Part I – Markets Today

CHP System for Unit Commitment

- Biogas CHP, biogas boiler, gas storage and thermal storage



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Part I – Markets Today

CHP System for Unit Commitment

- CHP specifications
  - $P_{el}: 11\ MW;\ P_{th}: 11.5\ MW$
  - Biogas fueled
  - Remuneration scheme: market premium for biogas plants (EEG 2014)
  - Startup and operational costs
  - Non-linear efficiency rates in electrical and thermal output
  - Load following rate
- Peak load heat boiler
  - $P_{th}: 17.5\ MW$
- Thermal storage
  - $Storage_{max}: 30\ MWh$ – up to 6 hours thermal output of CHP

Part I – Markets Today

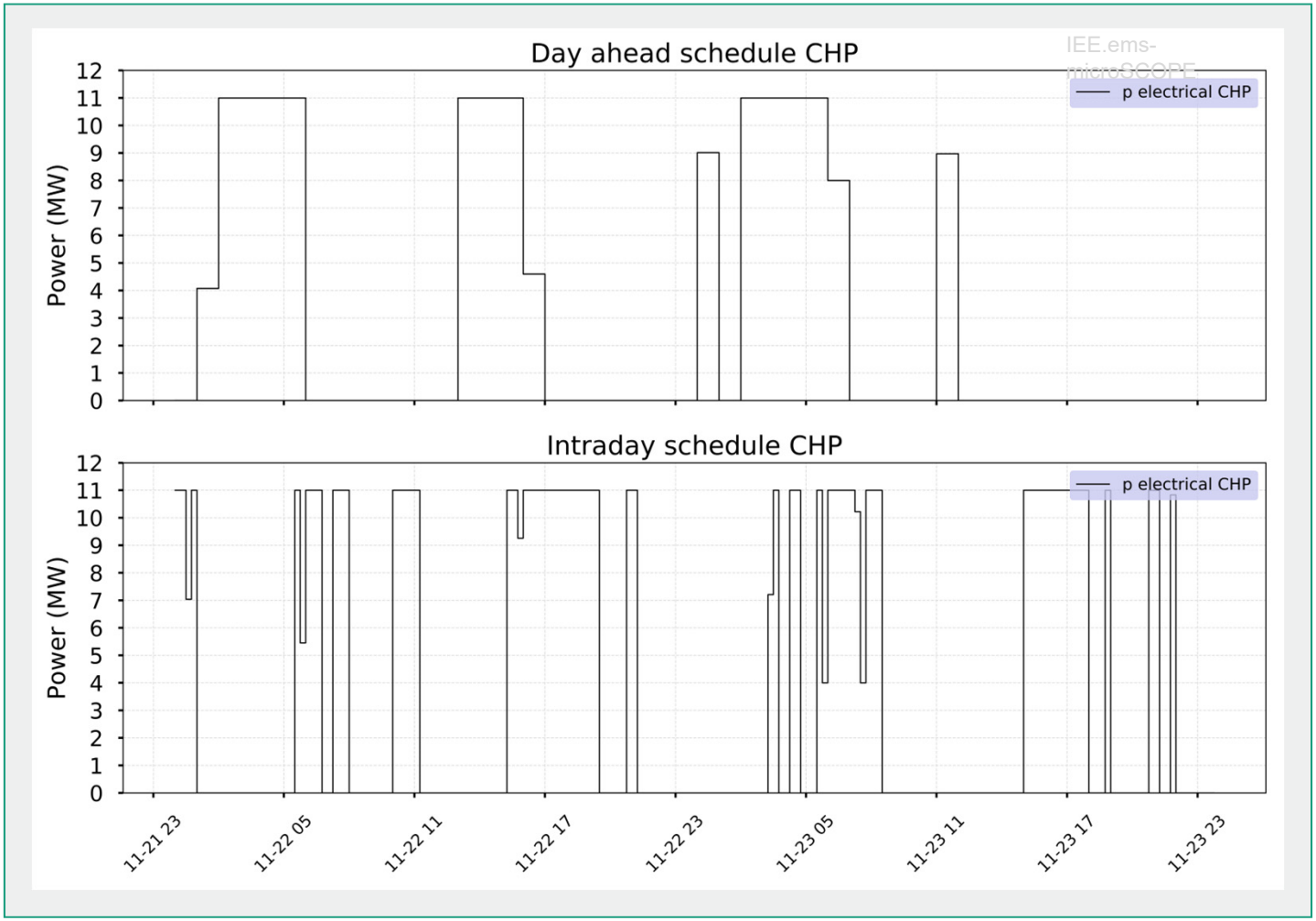
Optimization Approach for Unit Commitment

- Mixed integer linear programming (MILP)
- Optimization model microSCOPE (optimization core of IEE.ems)
- Optimization modelling language Pyomo (Python)
- Solver: Gurobi
- Objective function, maximizing gains:

$$maximizing\ g \coloneqq \sum_{t \in T}(i_t - c_t)$$

Part I – Markets Today

Unit Commitment Day Ahead and Intraday



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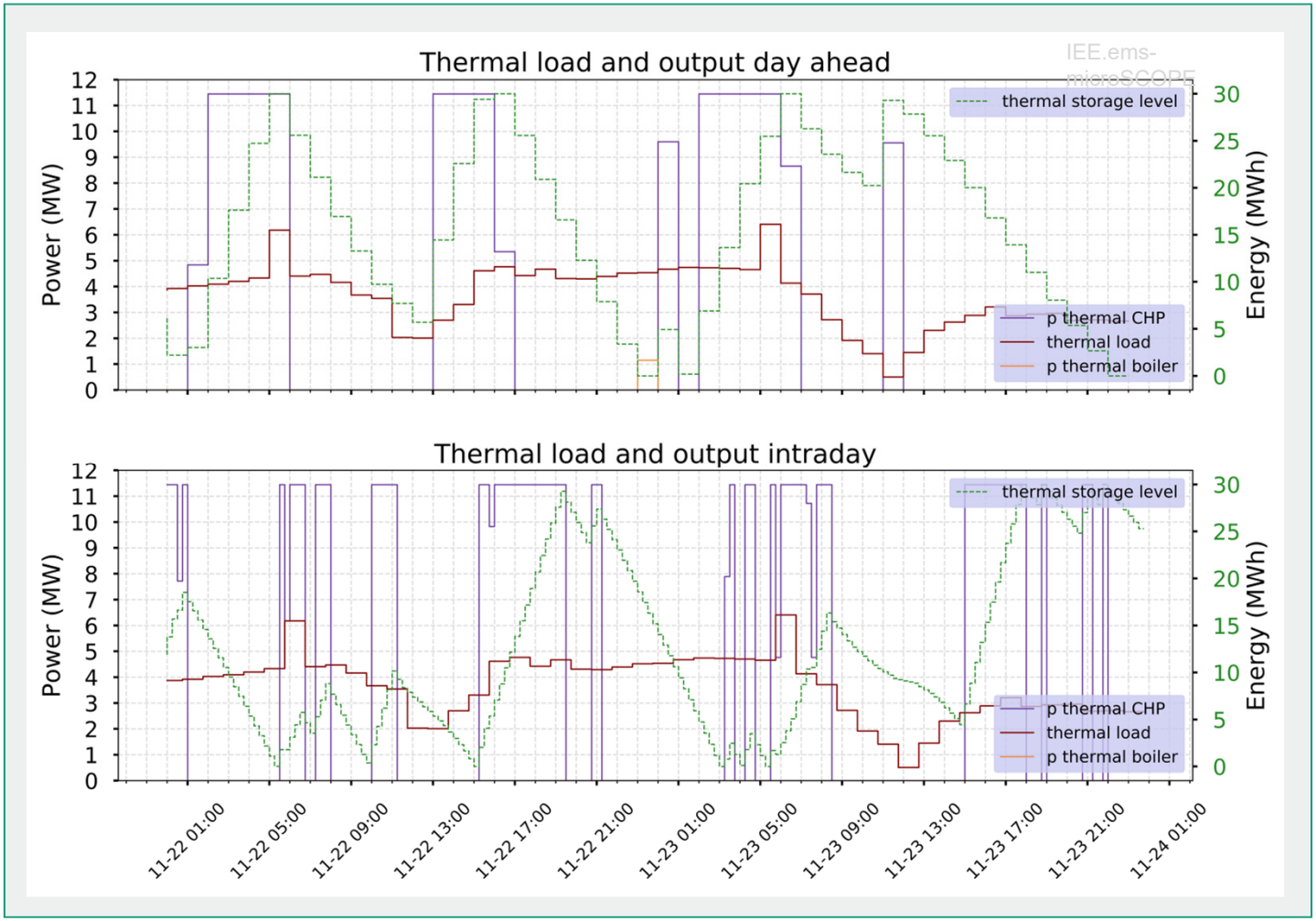
Part I – Markets Today

Unit Commitment Day Ahead and Intraday



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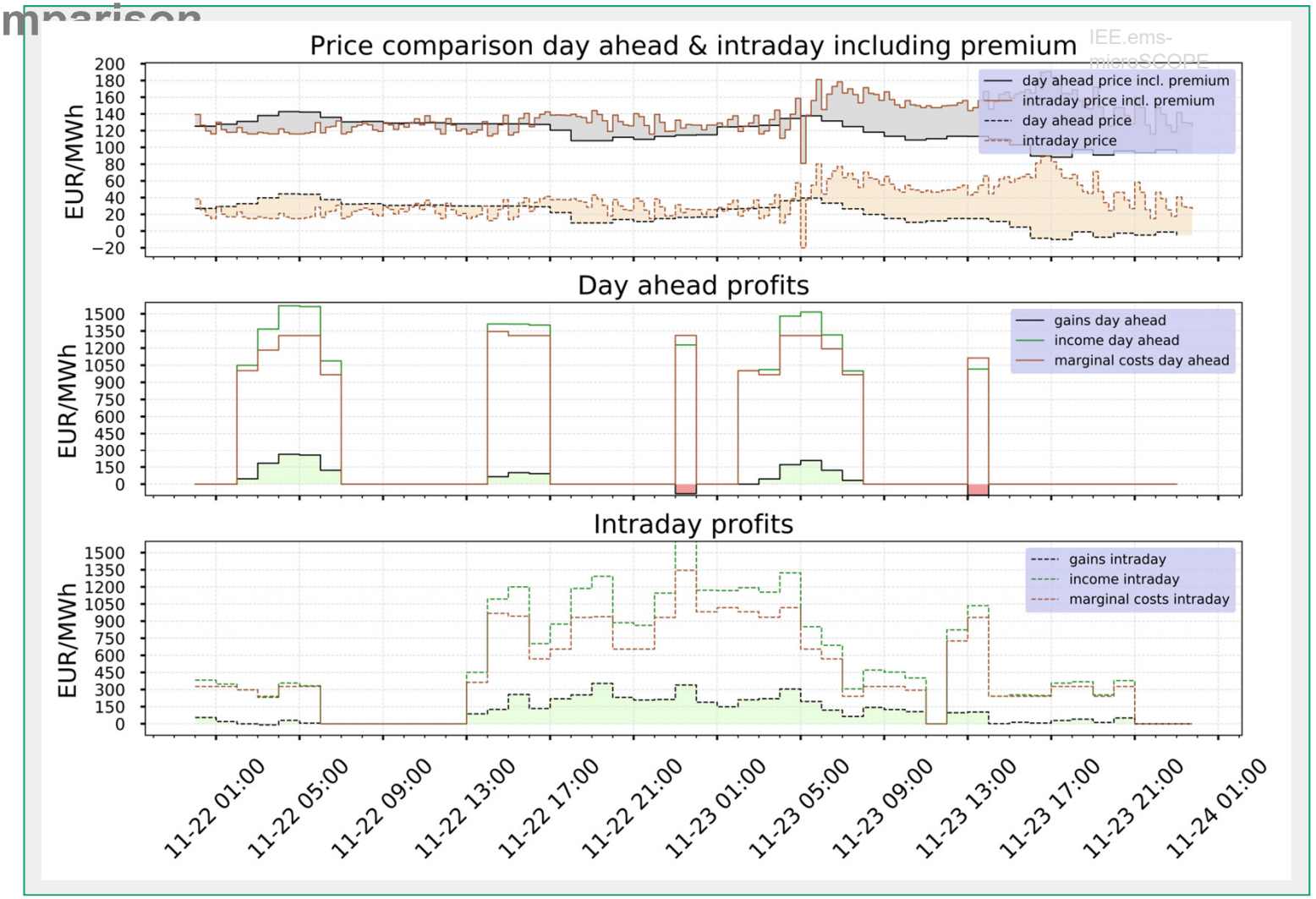
Part I – Markets Today

Unit Commitment Day Ahead and Intraday - Gain and Price Comparison



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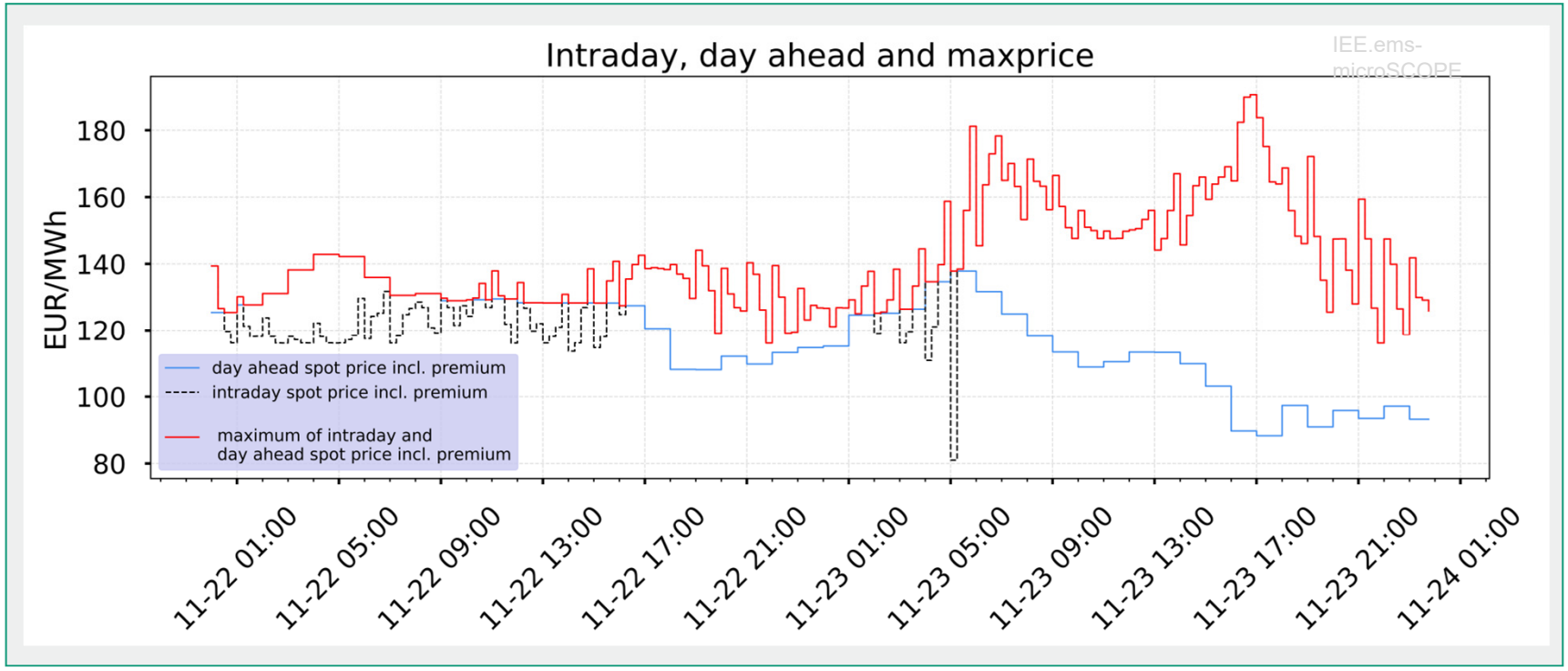
Part I – Markets Today

Introducing maxprice: Maximum of Day Ahead Price and Intraday Price (FC)



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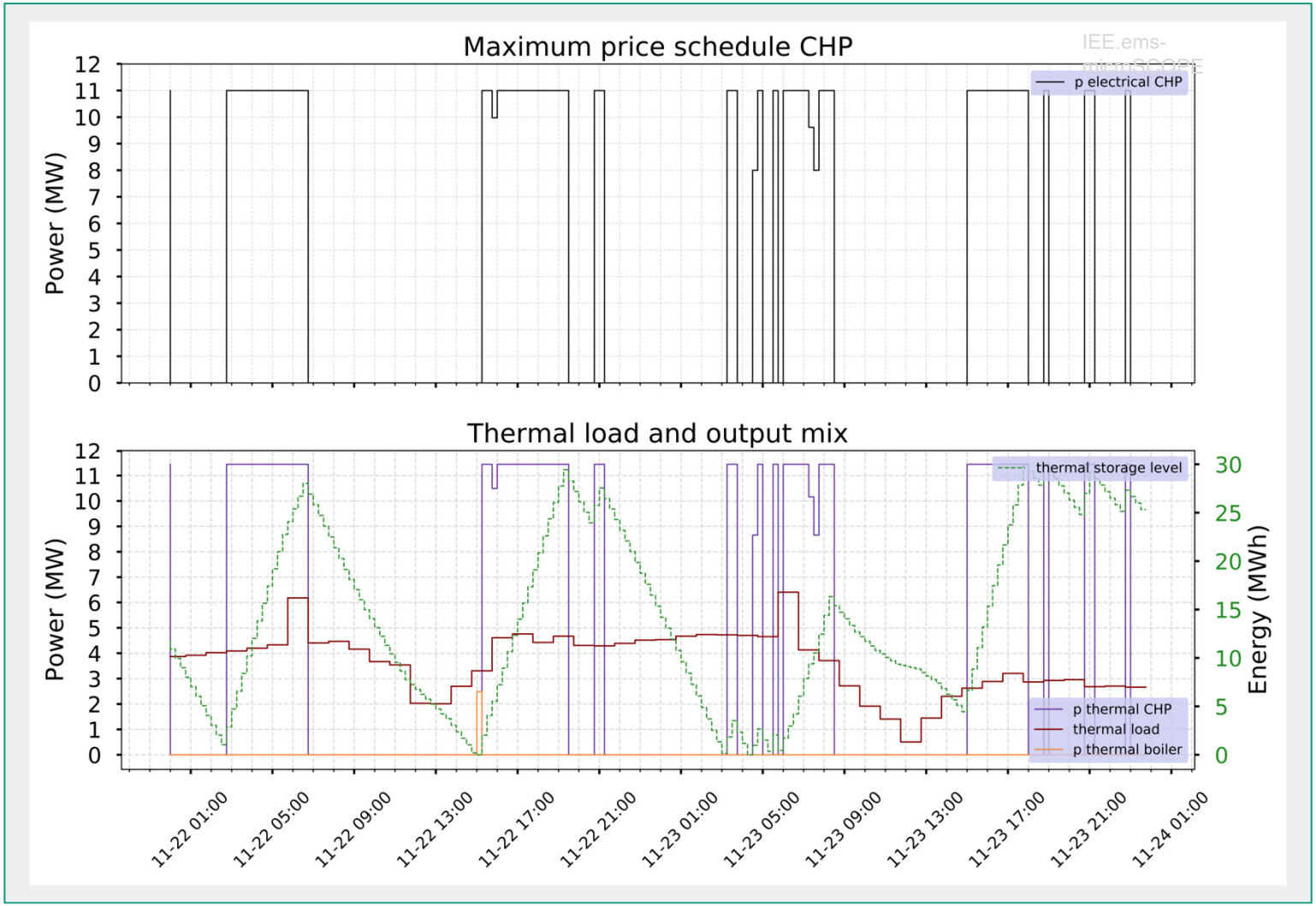
Part I – Markets Today

Unit Commitment Maxprice



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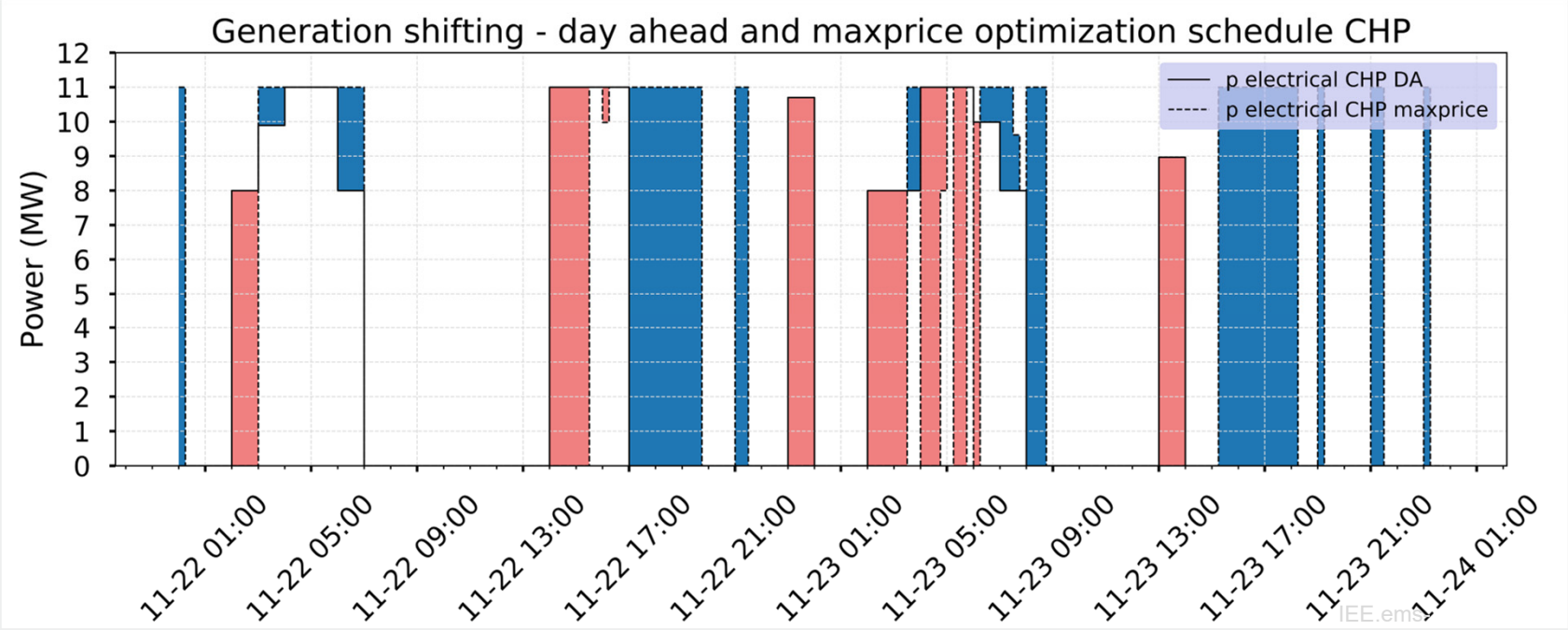
Part I – Markets Today

Trade at Intraday Market



	day ahead	intraday	maxprice
Gains EUR	1524	4724	5317

Added value through intraday trading: 3793 EUR

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Part II – Smart Markets

Part II – Smart Markets

Defining Smart Markets

"Smart Market is the area beyond the grid in which energy volumes or services derived from them are traded between different market participants on the basis of the available grid capacity."

– BNetzA 2011 (Federal Grid Agency Germany)

Part II – Smart Markets

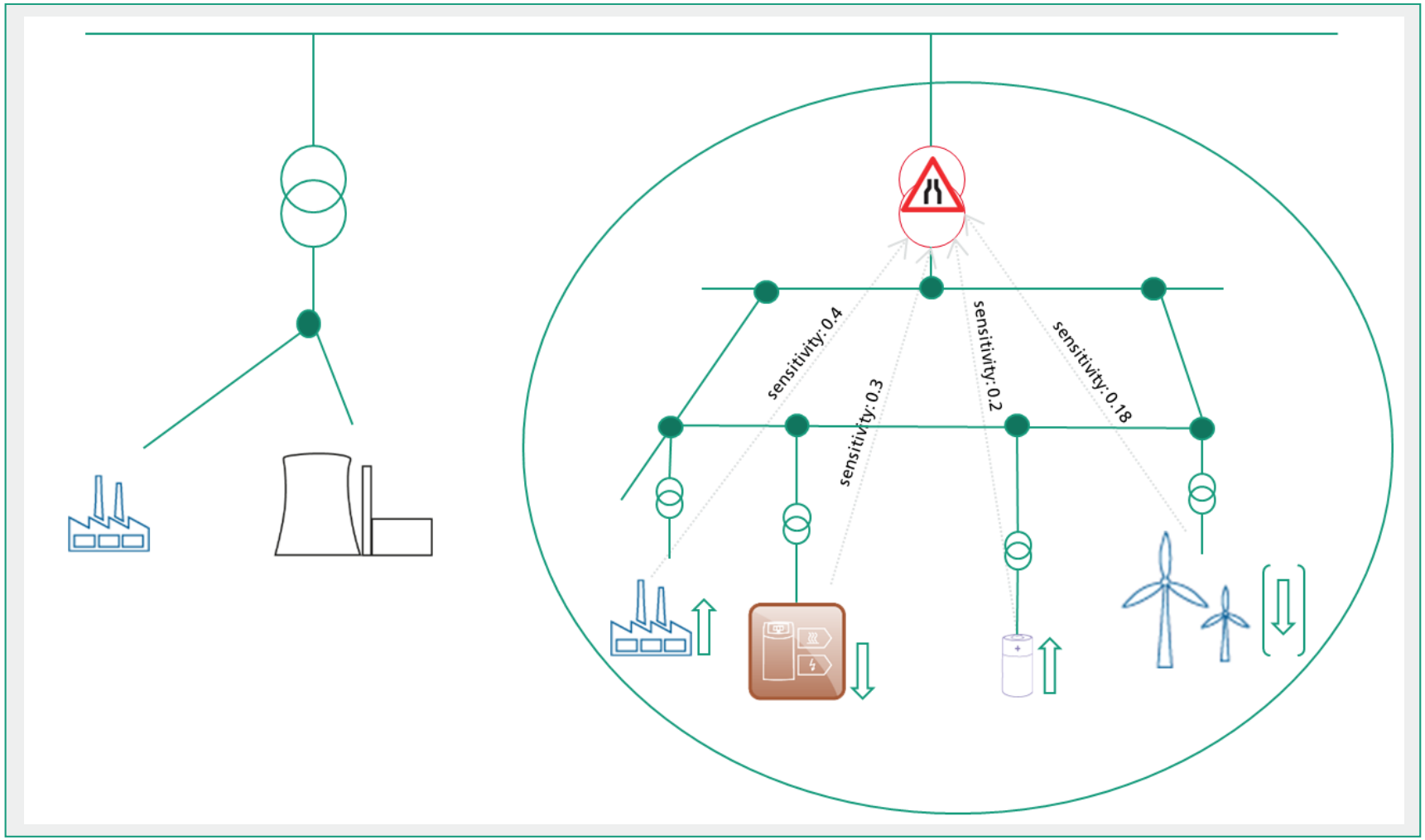
Defining Smart Markets

"[here,] smart markets are defined as a coordination mechanism that mediates between the market and the grid sphere […] smart markets are characterized by a temporal and spatial component, since they eliminate and avoid regional grid congestion."

– Agora 2017 (Fraunhofer IEE & Ecofys)

Part II – Smart Markets

Congestion Incident and Units Providing Flexibility



Part II – Smart Markets

Smart Market Concept Examples

- ENKO - „energy coordinated intelligently“
  - Day ahead auction
- C/Sells market platform
  - Day ahead auction
- Grid Integration market platform
  - Intraday auction with fixed lead time to forecasted congestion

Part II – Smart Markets

Example – Smart Market Concept ENKO

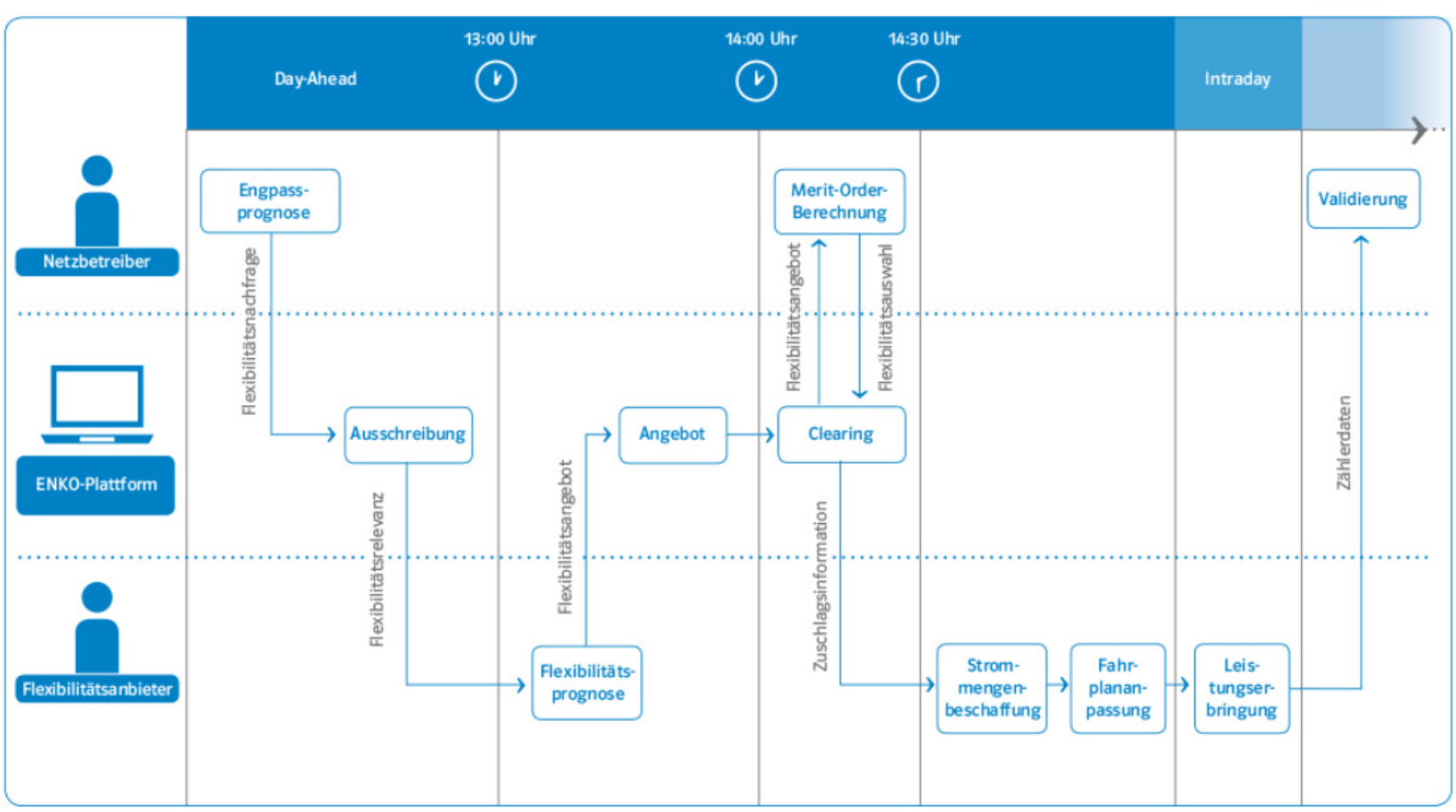
- Flexibility auction takes place between day ahead and intraday auctions

Market overview

Market type and time	FRR Auctions (aFRR, mFRR)	Day Ahead Auction EPEX Spot	Flexibility Auction ENKO	Intraday Auction EPEX Spot	Intraday Trading EPEX Spot	Intraday Trading XBID
	10.00 a.m	12.00 p.m.	2.30 p.m.	3.00 p.m.	Beginning at 3.00 / 4.00 p.m.	Beginning at 10 p.m.

Part II – Smart Markets

Example – Smart Market Concept ENKO



Source: Schleswig-Holstein Netz AG, Arge Netz GmbH

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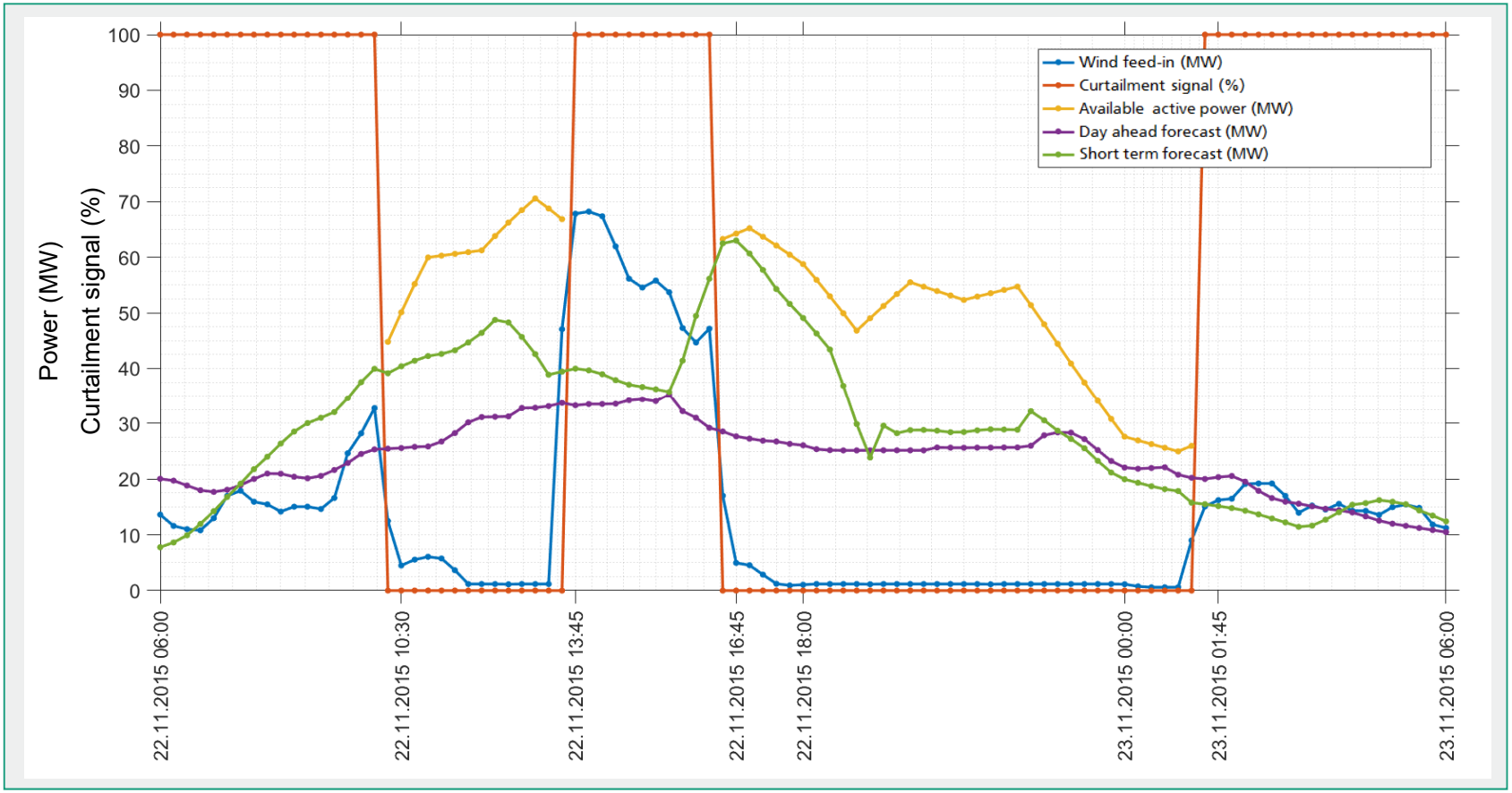
Part II – Smart Markets

Congestion Incident



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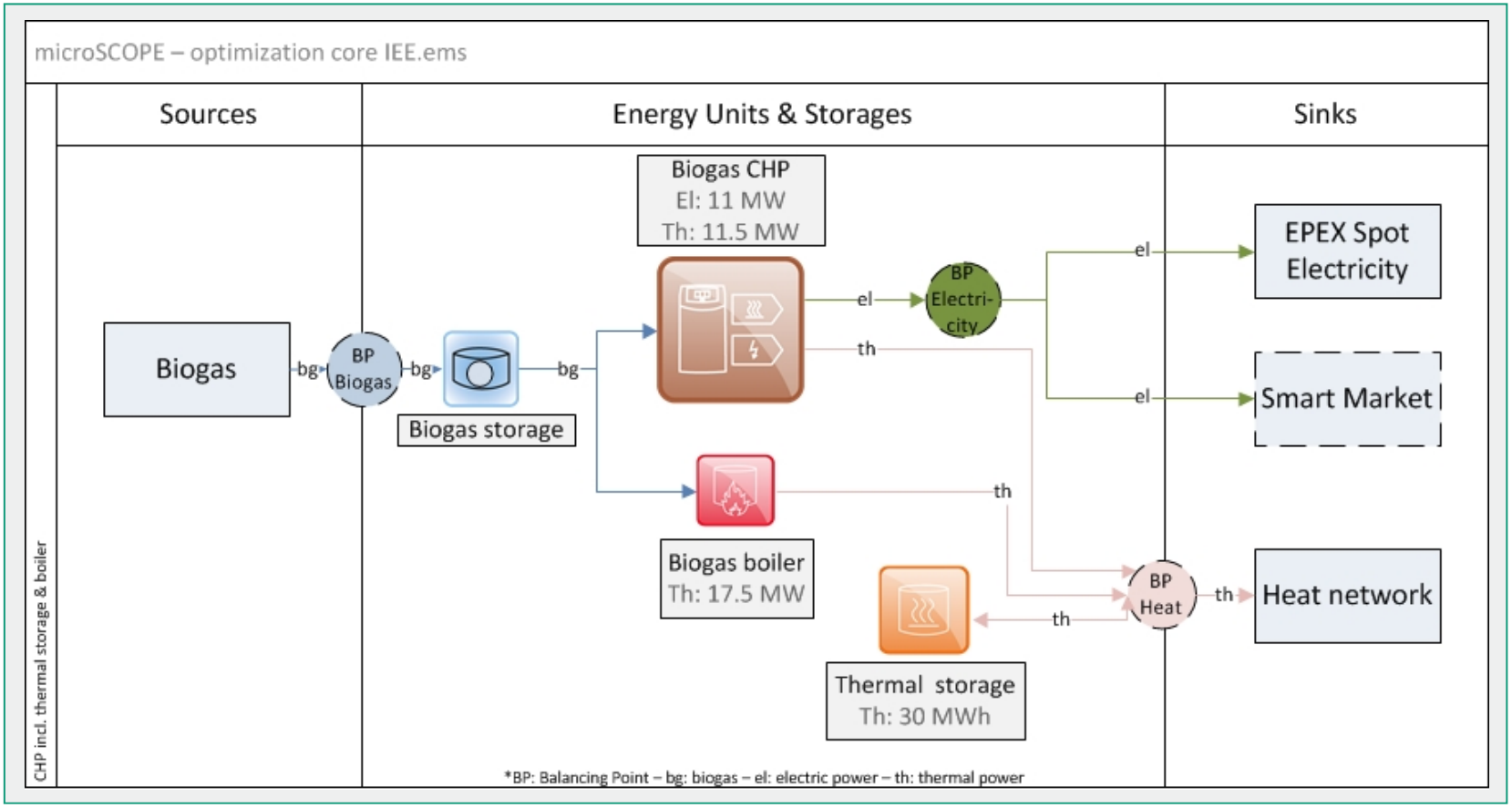
Part II – Smart Markets

Congestion Incident (Forecast)

- Congestion/curtailment incidents
  - 22.11.2015, 09.15 a.m. to 12.15 p.m.
  - 22.11.2015, 16.45 p.m. to midnight
- Flexibilities are tendered on the market platform for the indicated times

Part II – Smart Markets

CHP System for Unit Commitment Including Smart Market



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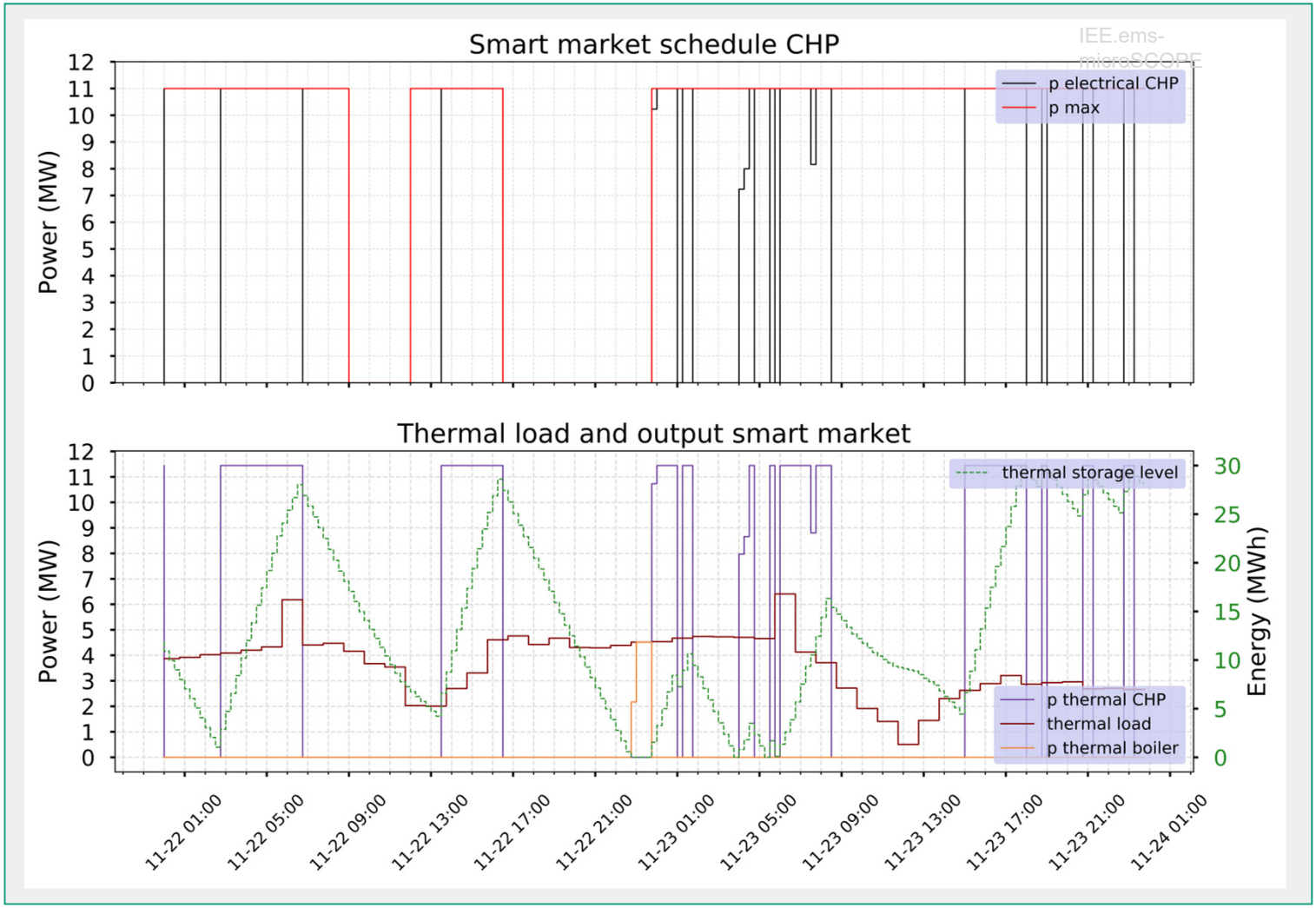
Part II – Smart Markets

Unit Commitment Including Flexibility Supply



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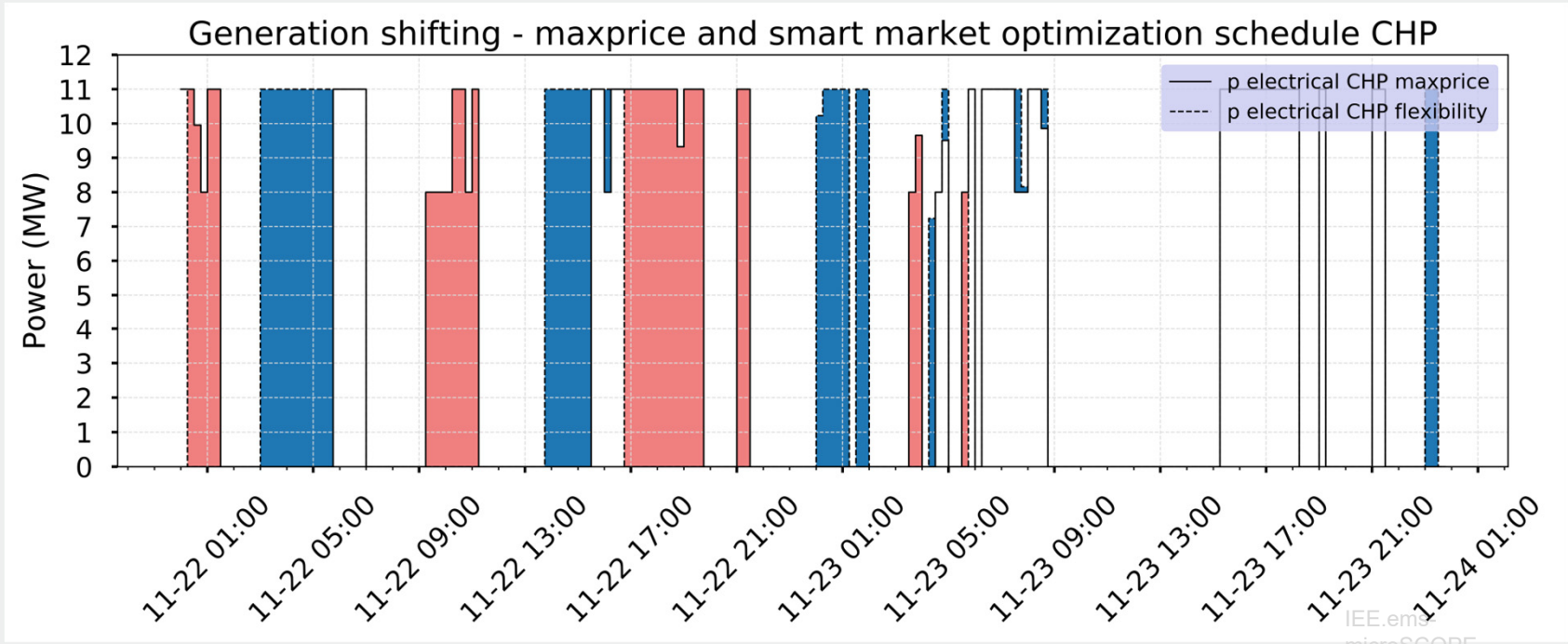
Part II – Smart Markets

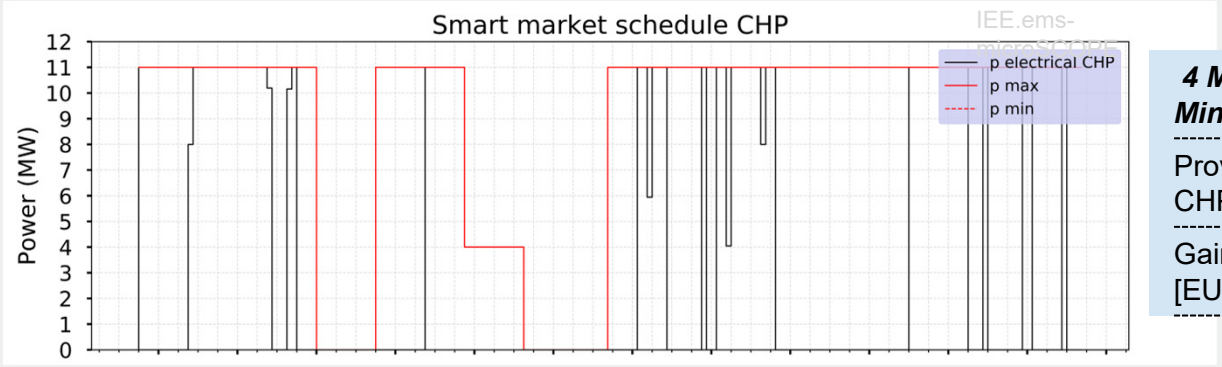
Generation Shifting



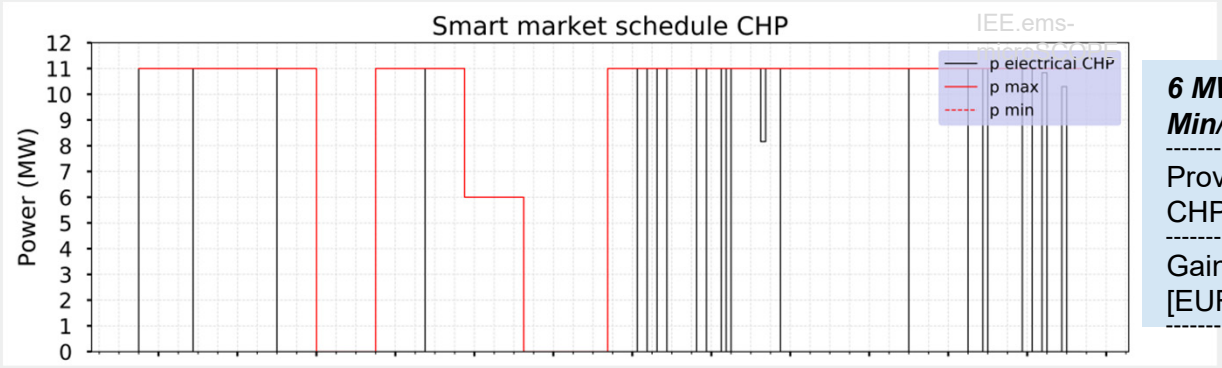
	maxprice	flexibility	Difference (abs.)
Flex provision CHP MWh	0	38.5	38.5
Gains [EUR]	5317	4841	476

Part II – Smart Markets

Unit Commitment Including Flexibility Supply



4 MW Min/Max	flexibility	Difference maxprice
Provision CHP MWh	28.5	28.5
Gains [EUR]	5022	295



6 MW Min/Max	flexibility	Difference maxprice
Provision CHP MWh	20.5	20.5
Gains [EUR]	5069	248

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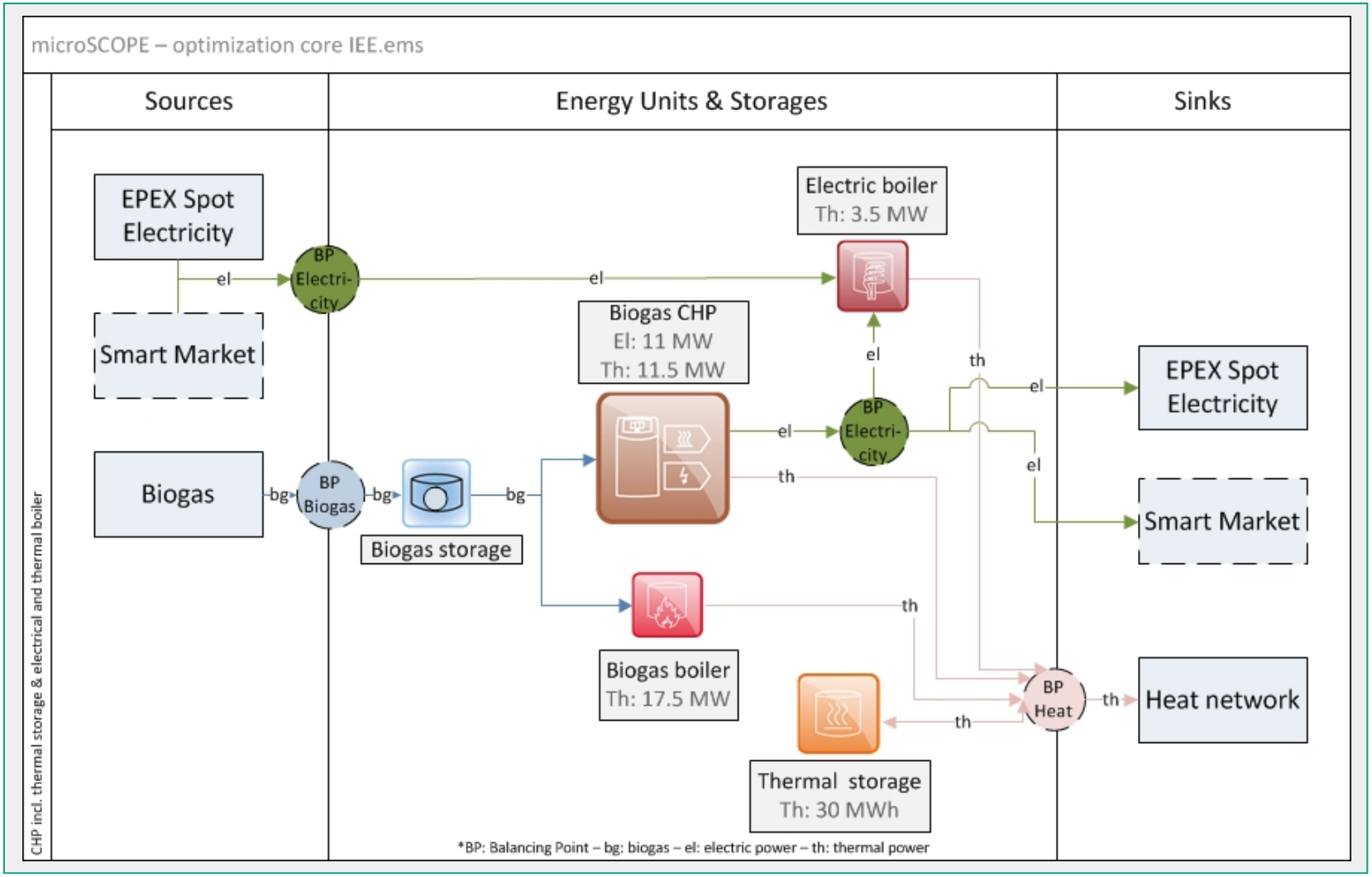
Part II – Markets Today

Developing Portfolio to Increase Flexibility Potential – P2H



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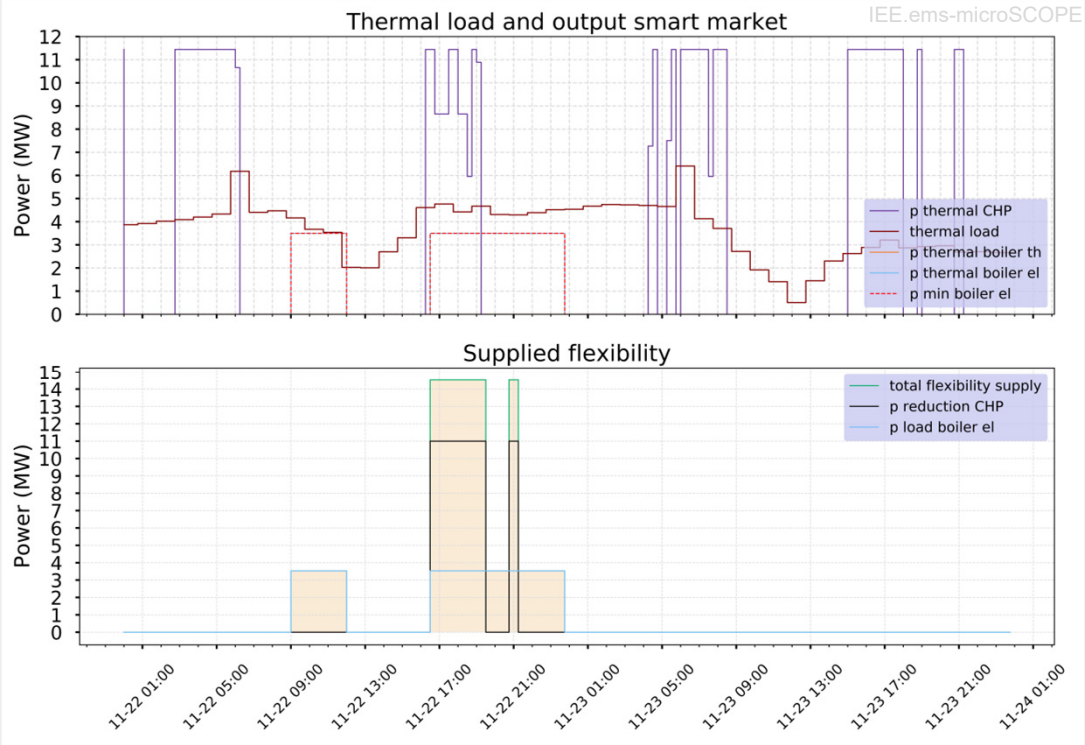
Part II – Smart Markets

Unit Commitment Including Flexibility Supply – P2H

- Providing further flexibility through electric boiler
  - Flexibility option 1: reducing CHP output
  - Flexibility option 2: using P2H to draw electric output of CHP
  - Flexibility option 3: using P2H to offer additional load flexibility
- Minimum price for P2H flexibility:
  - Flexibility option 2: fuel costs for electric output of CHP + missed market revenues → not economic
  - Flexibility option 3: electricity price + surcharges for load + CHP generation shifting costs

Part II – Smart Markets

Unit Commitment Including Flexibility Supply – P2H



	No supply	Scenario I	Scenario II
Flex provision CHP [MWh]	-	38.5	38.5
Flex provision boiler [MWh]	-	25	35.9
Total supply [MWh]	**-**	**63.5**	**74.4**
Gains [EUR] (incl. el. costs boiler)	5317	4318	3770

Part III

Flexibility Capacity of Energy Unit Portfolios Including Volatile Producers – Use Case FRR

Part III – Flexibility Capacity VPP

Background and Motivation

- With decreasing number of conventional plants new FRR providing units are required
- Current pilot phase for mFRR provision by wind farms (by German TSOs)
- Problem statement: high day ahead feed-in uncertainty of volatile producers leads to high risk in FRR provision
- Solution: using synergies in back-up security of FRR providing pool

Part III – Flexibility Capacity VPP

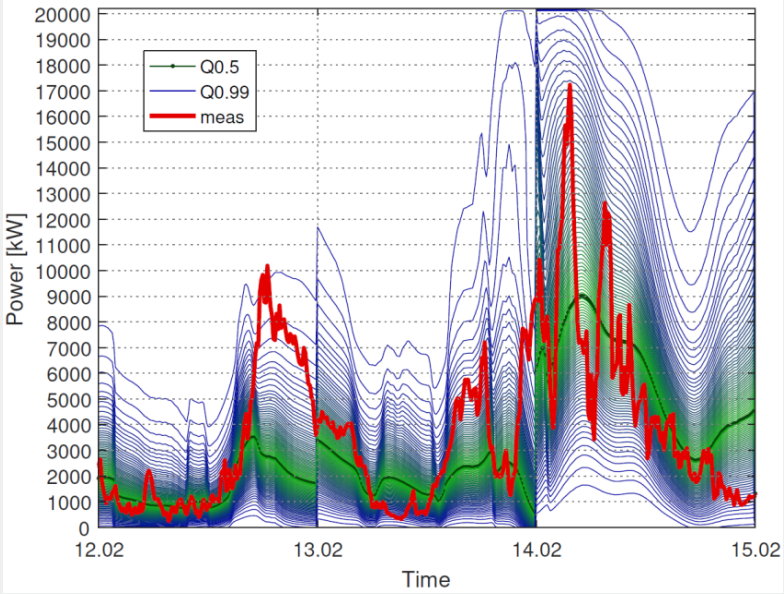
Approach – Mathematical Convolution of Input PDFs

- Input for FRR capacity dimensioning
- Applying a mathematical convolution on probability density functions

POWER PLANT SPECIFICATIONS

Power Plant	Prequalified cap [MW]	Forced outage [%]
1	95	2.249
2	95	0.375
3	70	1.195
4	41	2.249
5	30	0.415
6	20	1.195
7	13	1.195
8	12	0.415
9	9.4	0.375
10	3.5	0.583

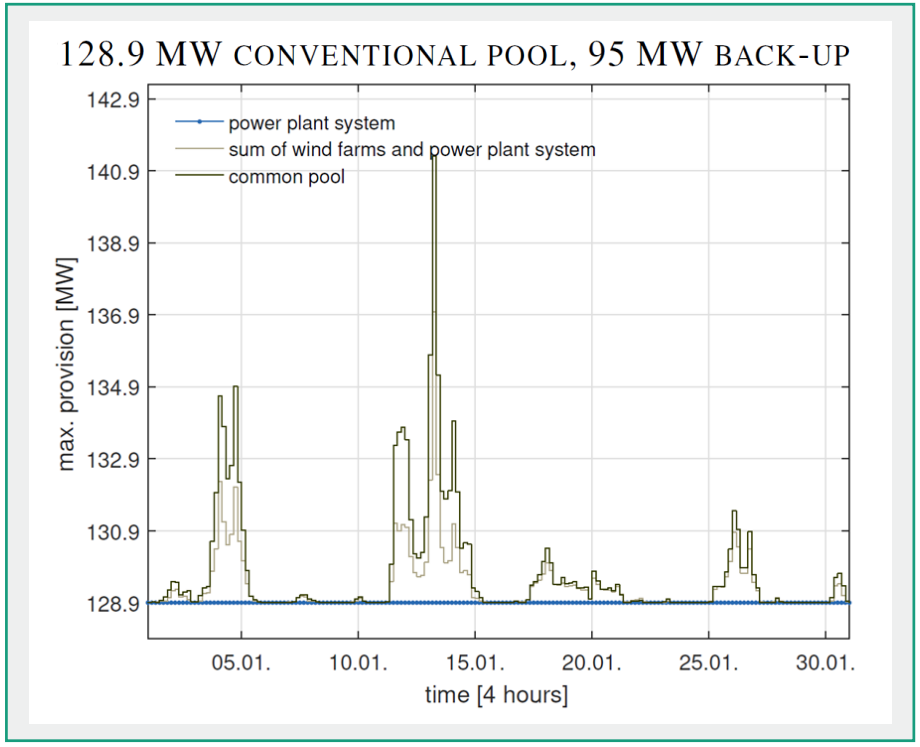
PROBABILISTIC FORECAST - 20 MW WIND FARM



Part III – Flexibility Capacity VPP

Results

- Result I: current (conventional) pool reliability: 99,859%
- Result II: holding the reliability (or grid security) constant:



Take away

- Regional smart market concepts are gaining in importance

- Including (current) baseload CHP units can access and provide flexibilities
- If CHP provides flexibility, missed spot market revenues define price
  - Marginal costs decrease with fuel costs
  - The maximum price for smart market flexibility are alternative curtailment costs (compare: Rosenberg problem in illiquid markets)
- Additional flexibilities can be accessed through different boiler types

- Energy unit portfolios (VPP) including volatile producers can increase their flexibility potential using pooling-synergies

More Information on FRR Pooling Concept

- Dreher, A., Jost, D., Otterson, S., Hochloff, P., *Pooled Frequency Restoration Reserve Provision by Wind Farms and Controllable Energy Units*, 15th International Conference on the European Energy Market (IEEE conference paper), 2018.

- Thank you for your attention.

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