Evaluating regulatory measures in the German energy transition:

A European multimodal market optimization approach including distributed flexibilities

Moritz Nobis, M.Sc.
Tom Kulms, M.Sc.

Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

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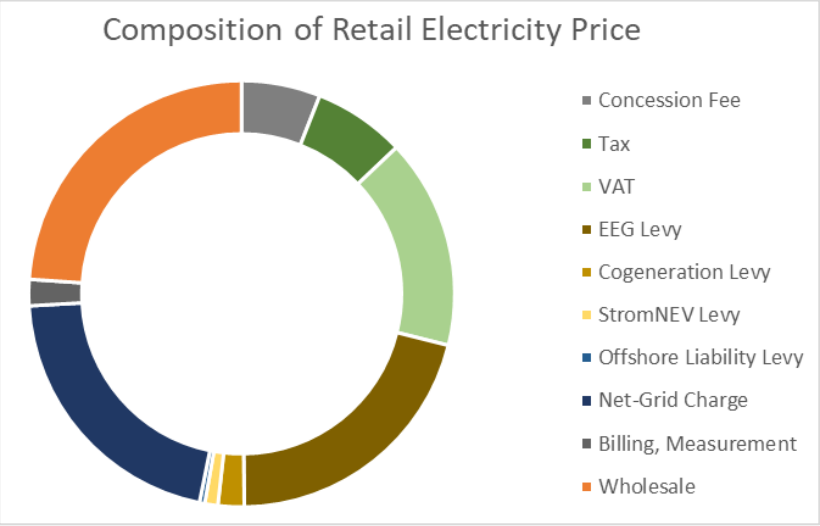
- Pan-European Marketsimulation
- Exemplary Results
- Conclusion and Outlook

Introduction
Motivation and Aim

- Climate obligations and decreasing ressources force us to
  - Include renewable energies into the power market
  - Electrify other sectors such as heat, transport,. …
- Large amounts of additional REN capacities have been installed in germany in the last years
- But…
  - Additionally, sector coupling is inhibited due to taxes and levies
  - Subsidies are decreasing and regulation pushes REN into direct market participation (using aggregators)



- How to adjust these issues though adapted taxes and levies?

→ Integration of decentral generation (DG) into a pan-European market simulation considering
  - → All techno-econmic constraints of hydrothermal power-plants
  - → Market coupling conecting markets within ENTSO-E
  - → DG have to perform as an individual acctor in the wholesale market
  - → Balacing of DG either on local or wholesale markets

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Pan-European Market Simulation

Overview on European Lagrangian Relaxation

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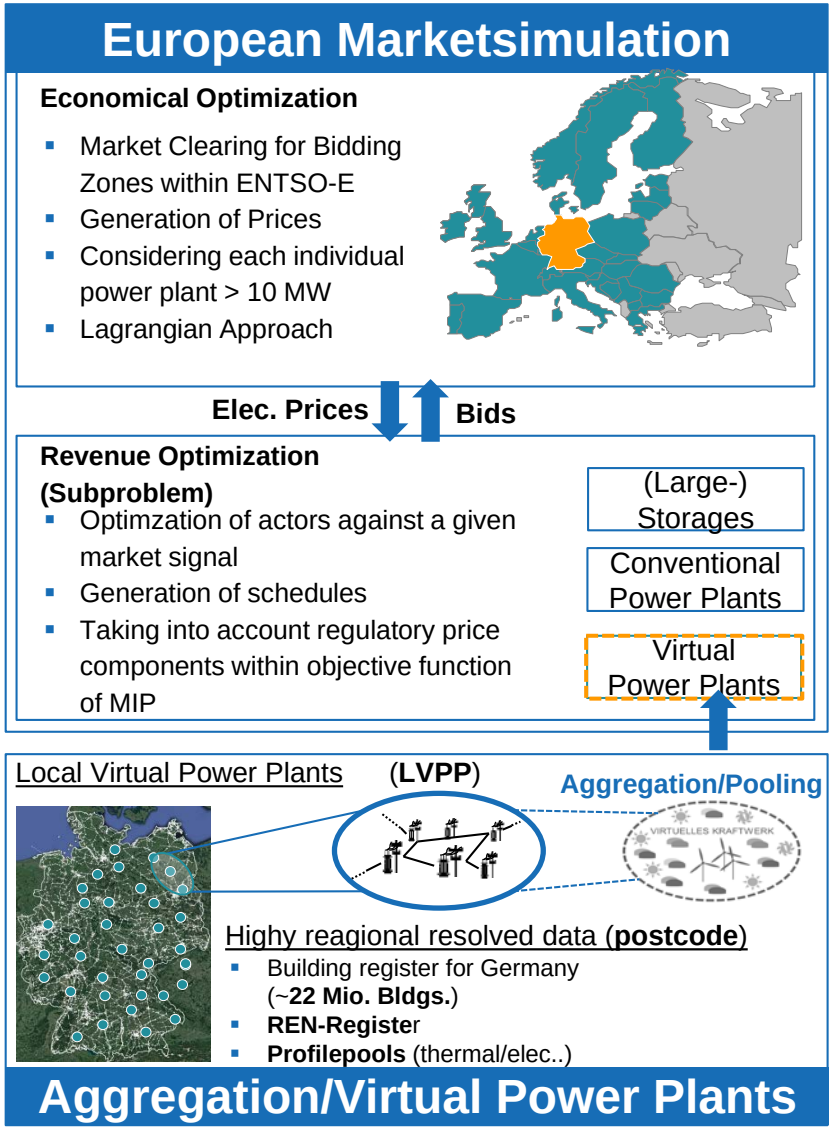
Scenario: Local Virtual Power Plants within Market Simulation

- Optimzation of the locally defined supply task through aggregators/LVPP
- ➢ Taking into account/varying regulatory price components
- ➢ Analysis of economic feedbacks

Data basis for the scenario local virtual power plants (LVPP):

- Modelling of LVPP covering Germany
  - ➢ Comprehensive data source (Demand, technologies, time series)
  - ➢ Aggregation the highly resolved data onto „Cell-Level“ → Performing an aggregated unit commitment
- Matching of **LVPP** to German HV-Grid (approx. 4300 substations)
  → topological power plants / „**cells**“
- Potential to consider all installed (decentralized) flexibility into a pan-European market simulation



Pan-European Market Simulation

Overview on European Lagrangian Relaxation

IFHT - REG & RES

IFHT – European Lagrangian Relaxation

Single PP-Optim.

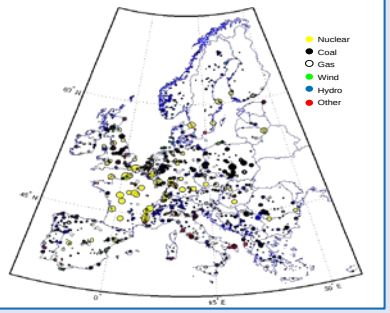
- Aim: Maximizing the revenue
- MIP Approach for thermal PP
- DP-Approach for (pump) storages
- LP approach for REN
- Decomposition of load coverage constraint

Market Clearing

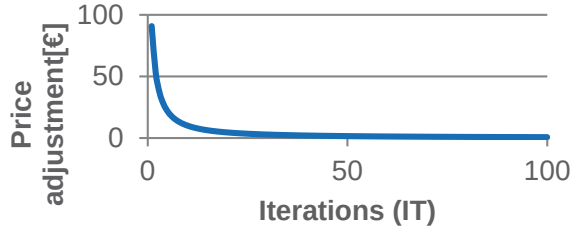
Welfare optimal coupling of markets using EUPHEMIA

Dispatch

Cost-optimal portfolio-/country dispatch of power plants



Λ-adjustment

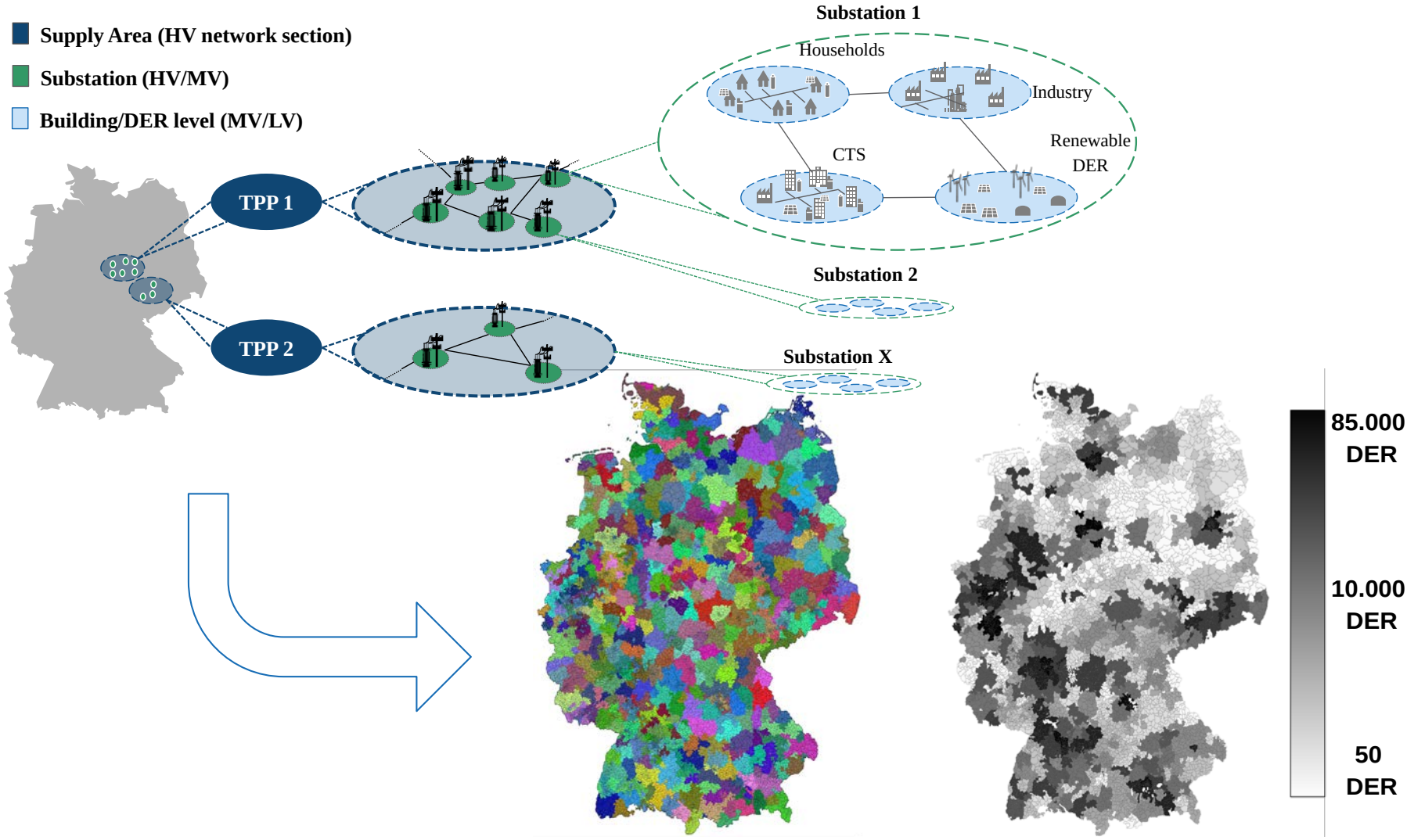


Iterative convergence process

IFHT - POS & RED

Integration of DG into the EULR

DG aggregated on hv-node and then optimized within EULR



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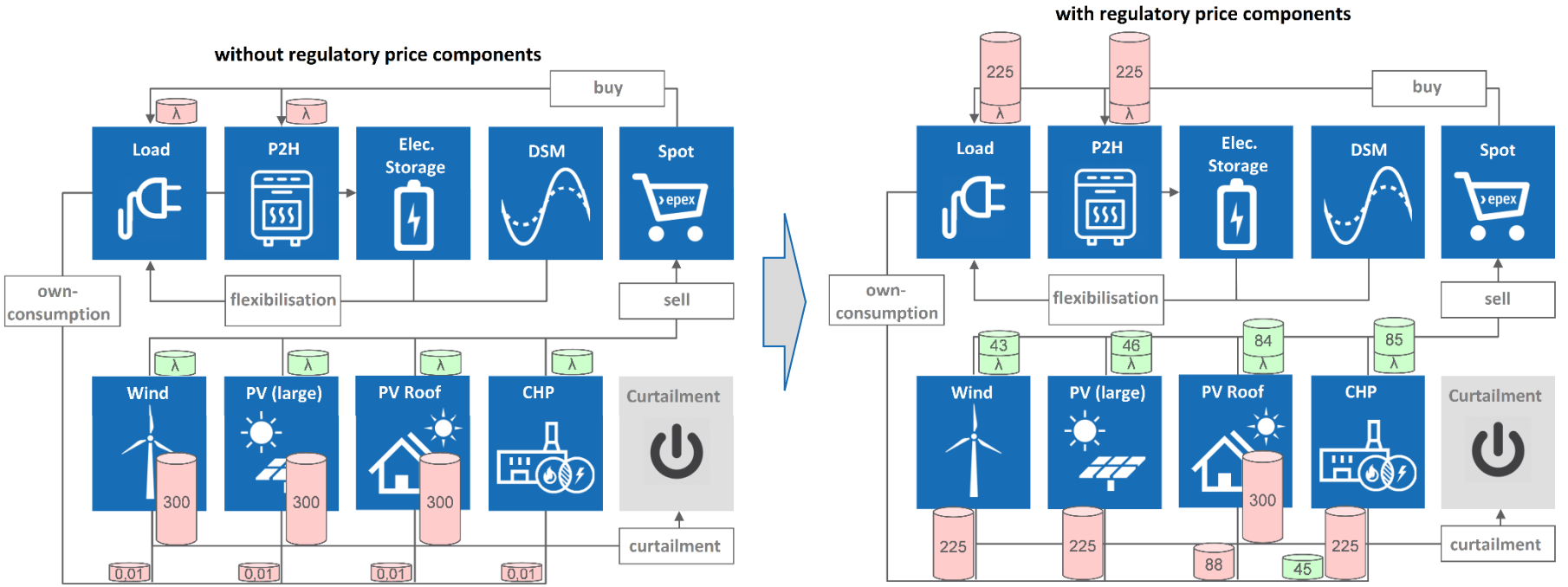
Exemplary Results

Test Case: Implementation of status quo-regulation

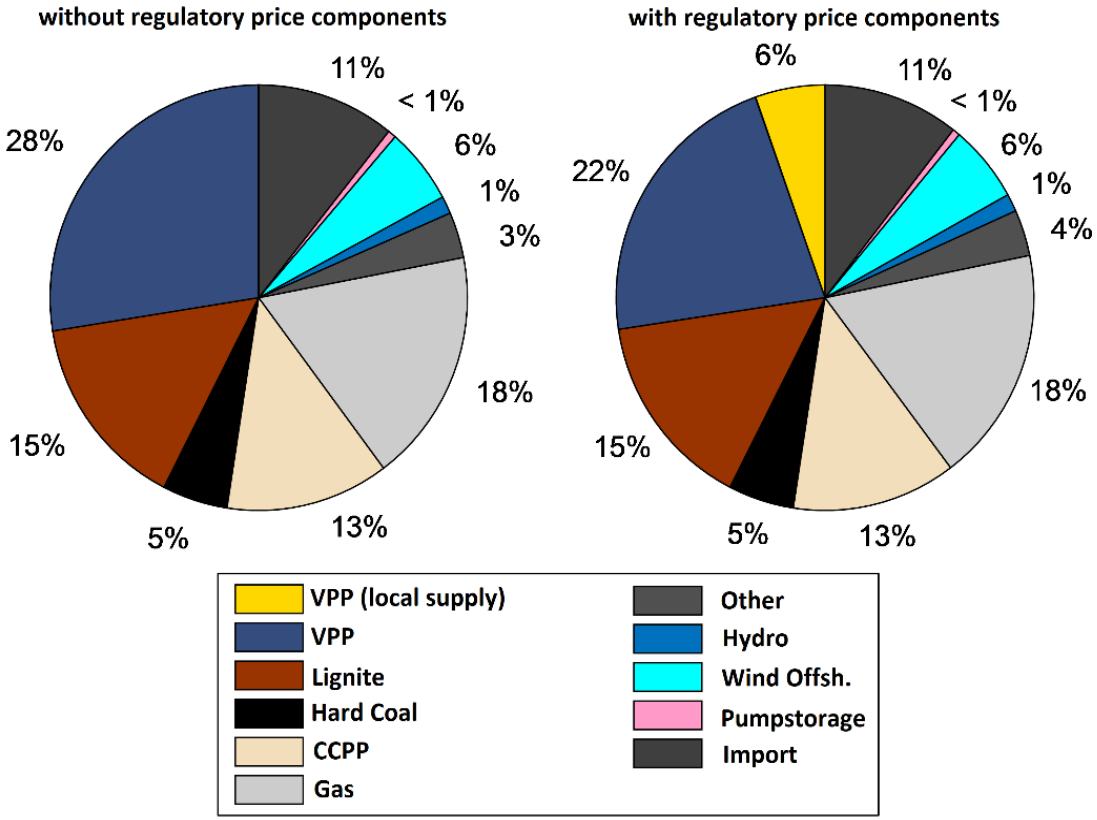


- Consumers are subject to wholesale prices and REN receive wholesale prices
- Curtailment of REN is penlaized
- Inifitisemal price-markup to avoid solver indiferrence for own-consumption

- Price markups for end-consumption (direct consumption of PV-Roof is only subject to the EEG-levy)
- REN receive either market premia or fixed feed-in tarrifs (+ „6 hours rule“)
- CHP receive a cogeneration bonus

Exemplary Results

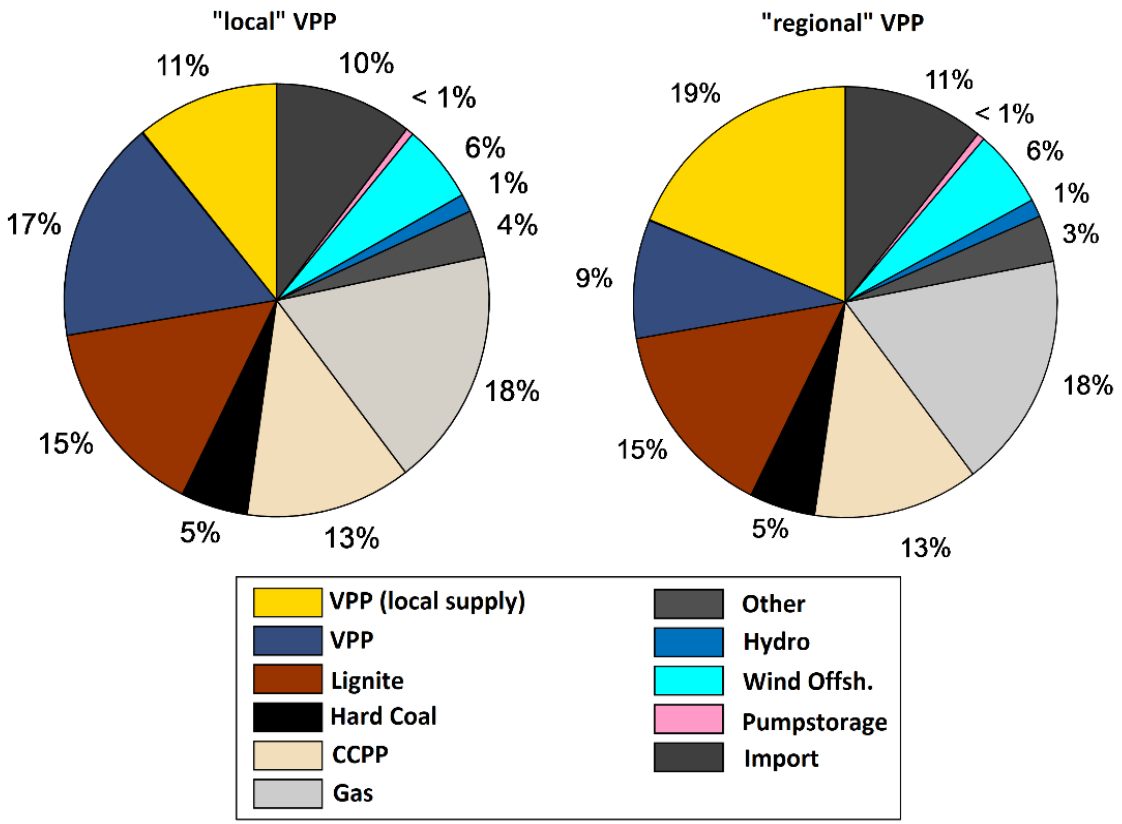
Test Case: Implementation of status quo-regulation



- Scenario for 2030
  (GDP and TYNDP)
- Less negative prices
  - W/O regulation: -109 €/MWh
  - With reg.: -27 €/MWh
- Significant reduction of P2H
  - W/O regulation: 15.0 TWh
  - With reg.: 9.7 TWh
- Pumpstorages reduce dispatch by 0.4 TWh (due to price markups for pumping)

Exemplary Results

Test Case: Support of self-consumption

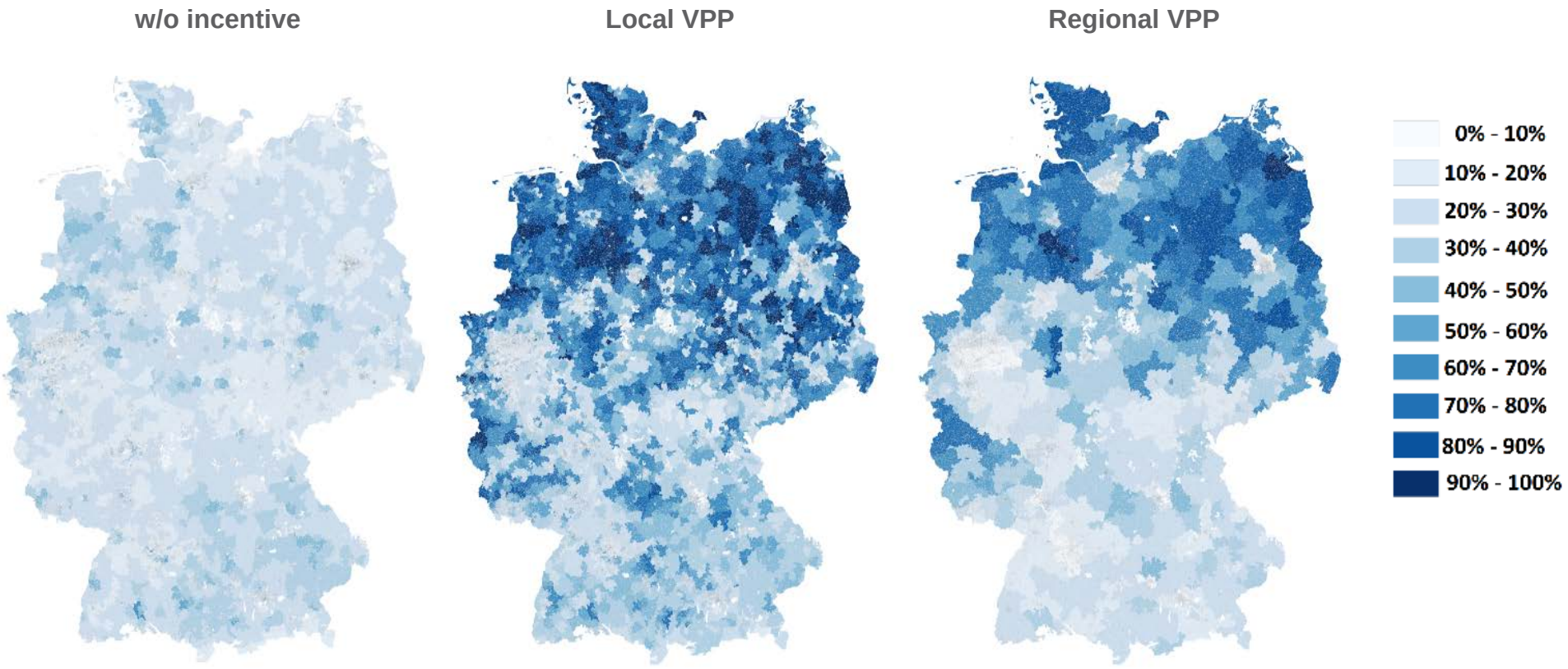


Remaining costs	Diminishing costs
• Production costs	• Grid fee
• VAT	• Grid related levies
• EEG-levy	• Electricity tax
	• Concession fee

- Local supply in total
  (no incentive → local; regional)
  37 TWh → 75 TWh; 111 TWh
- Local supply by technologies
  - PV: 37 TWh → 42 TWh; 42 TWh
  - Wind: 0 TWh → 23 TWh; 59 TWh
  - CHP: 0.05 TWh → 10 TWh; 10 TWh

Exemplary Results

Test Case: Support of self-consumption



Supply of demand by local technologies relative to the total demand of the VPP

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Conclusion

- Integration of +4,000 (L)VPP into a pan-European Marketsimulation achieved
- Fundamental models usually exclude regulatory price components → distorted unit commitment
- The remission of costs related to transport of electricity significantly enhances local demand coverage

Outlook

- Further sensitivity analysis regarding
  - Derive „regulatory costs“ for the further integration of sector coupling
  - Incentives for local load supply
- Derive implications for transport grid through
  - power flow and
  - redispatch simulations