EXPECTED IMPACTS ON THE PAN-EUROPEAN DAY AHEAD POWER MARKET IN 2040 DUE TO LARGE-SCALE OFFSHORE WIND FARMS

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MOTIVATION AND INTRODUCTION

- The EU set high targets for renewable energy expansion
- Already today overproduction of renewables and grid congestion appear frequently
- Aim
  - Integrate renewables (offshore wind) of 2040 into market models and analyze impacts of energy system change
  - Assess impact on market pricing and transmission
  - Analyze regional disparities

EU OFFSHORE EXPANSION TARGETS

TEN-E Priority Offshore Grid Corridors	Countries involved
1. NSOG	BE, DK, FR, DE, IE, LU, NL, SE
2. BEMIP offshore	DK, EE, FI, DE, LT, LV, PL, SE
3. Atlantic offshore grid	FR, IE, PT, ES
4. South & West offshore Grid	FR, GR, IT, MT, PT, ES
5. South & East offshore Grid	BG, CY, HR, GR, IT, RO, SI

Source: ENTSO-E. Ten-year network development plan (TYNDP), 2025. Accessed: 2025-07-15

METHODOLOGY – APPROACH AND ASSUMPTIONS

- Scenario-based simulation using historical data and climate models
- Introduction of 12 Offshore Bidding Zones
- Major additional inputs:
  - ENTSO-E's TYNDP 2024 National Trends+ and Distributed Energy scenarios for onshore wind, PV, hydro and demand development
  - SSP2-4.5 and SSP5-8.5 climate model plus offshore expansion plans
- Historical market data of 2024 was extended per hour with renewable generation projection for 2040
- Assumption of grid transmission capacity growth at the same rate as demand
- In total four scenarios

CONCEPT OF THE MARKET COUPLING SIMULATIONS

- Usage of real market/network data and EUPHEMIA algorithm
- Aim of algorithm: maximize social economic welfare
- Inputs:
  - Bids from market participants
  - Transmission capacities
  - Network constraints
- Daily auction for the subsequent day

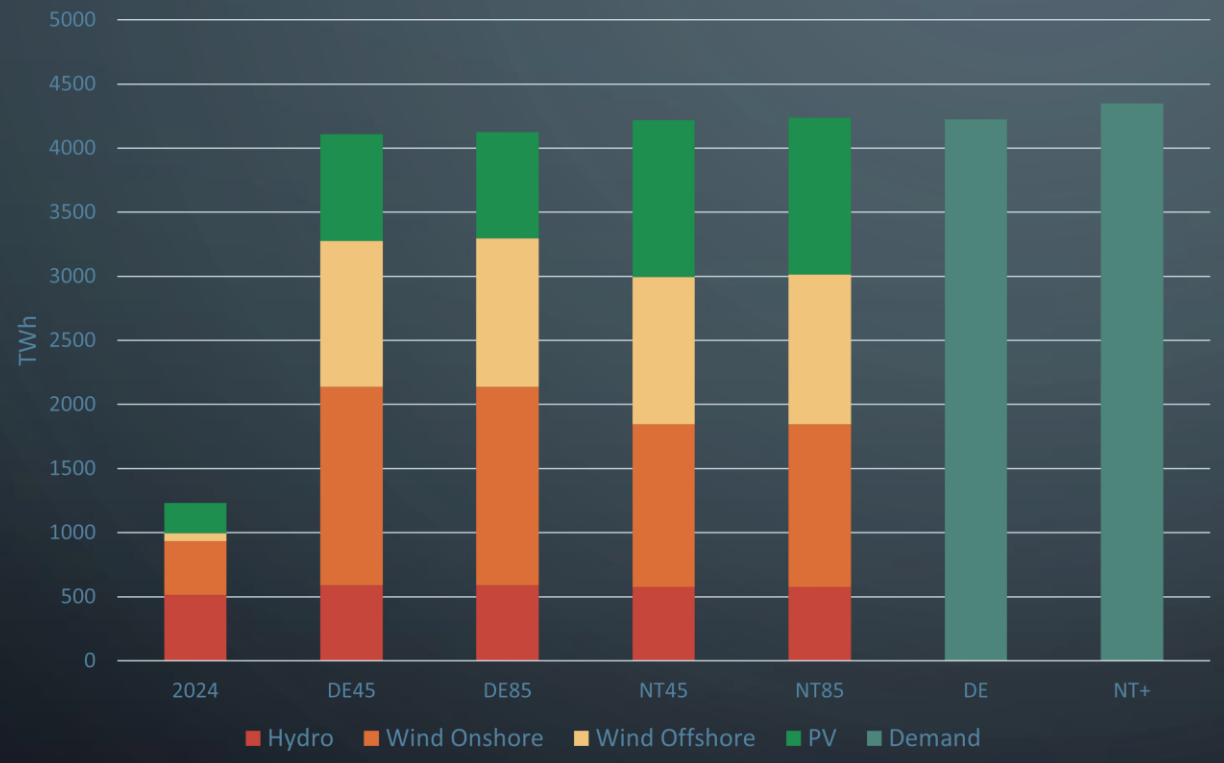
REALIZATION OF THE SCENARIOS

- Creation of topologies
- Inclusion of the new grid lines' capacities
- (Challenging) data collection
- Accumulation of the generation input data
- Creation of multiple OBKs
- Creation of the batches covering 2040 considering the new topology, additional supply, demand, and capacities
- Several limitations had to be accepted

TOPOLOGICAL CHANGES

- Introduction of Offshore Bidding Zones and respective grid capacities
- Connected to more than one Bidding Zone
- Has no demand thus prices are set by bordering Bidding Zones

RENEWABLE GENERATION VS. DEMAND



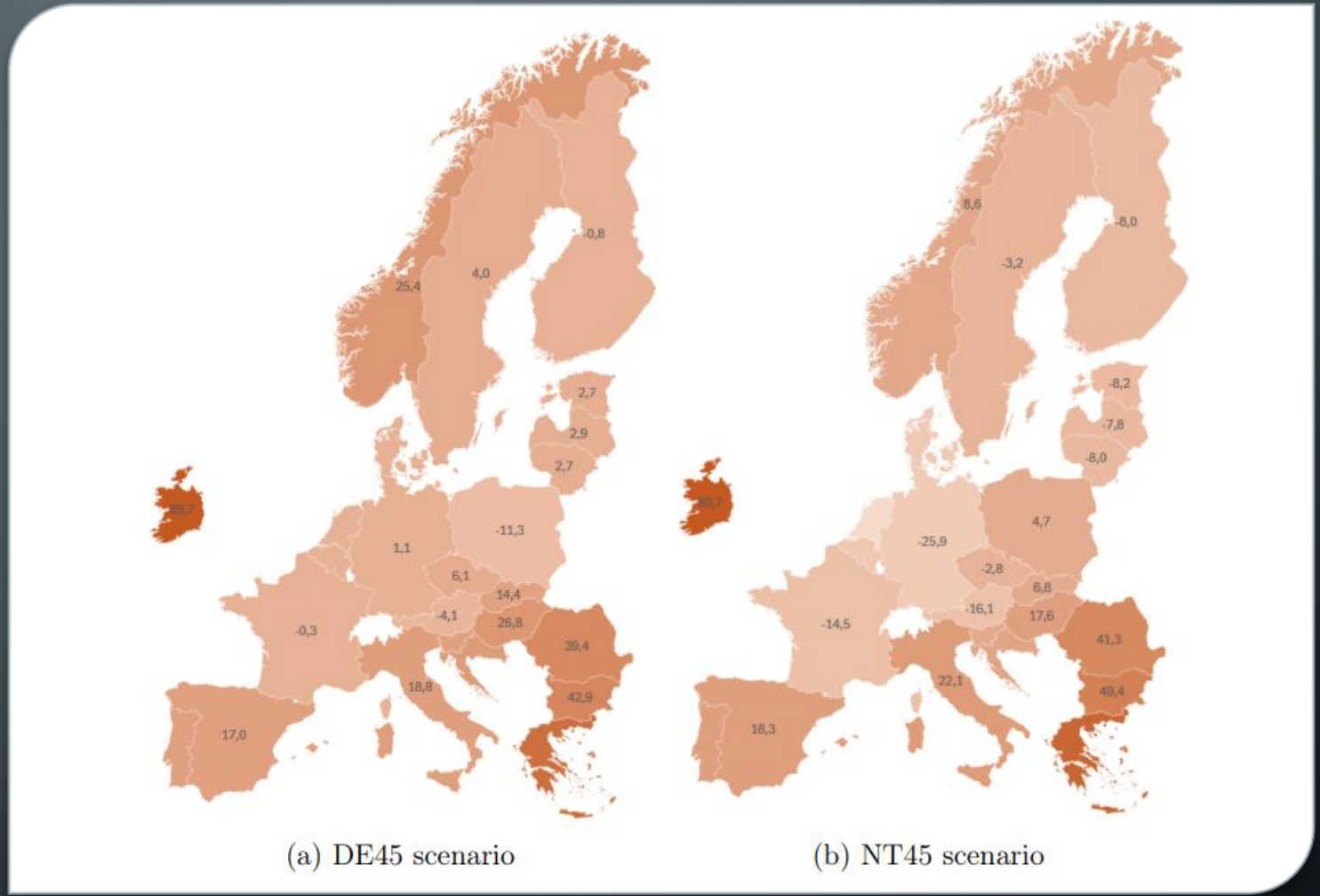
Comparison of the total generation of hydro, wind and PV in the EU plus Norway for the four scenarios and the year 2024

Planned tenfold increase of installed offshore wind capacities to 260 GW over the whole EU plus Norway, thereof 65% in the North Sea

RESULTS – GENERAL OBSERVATIONS

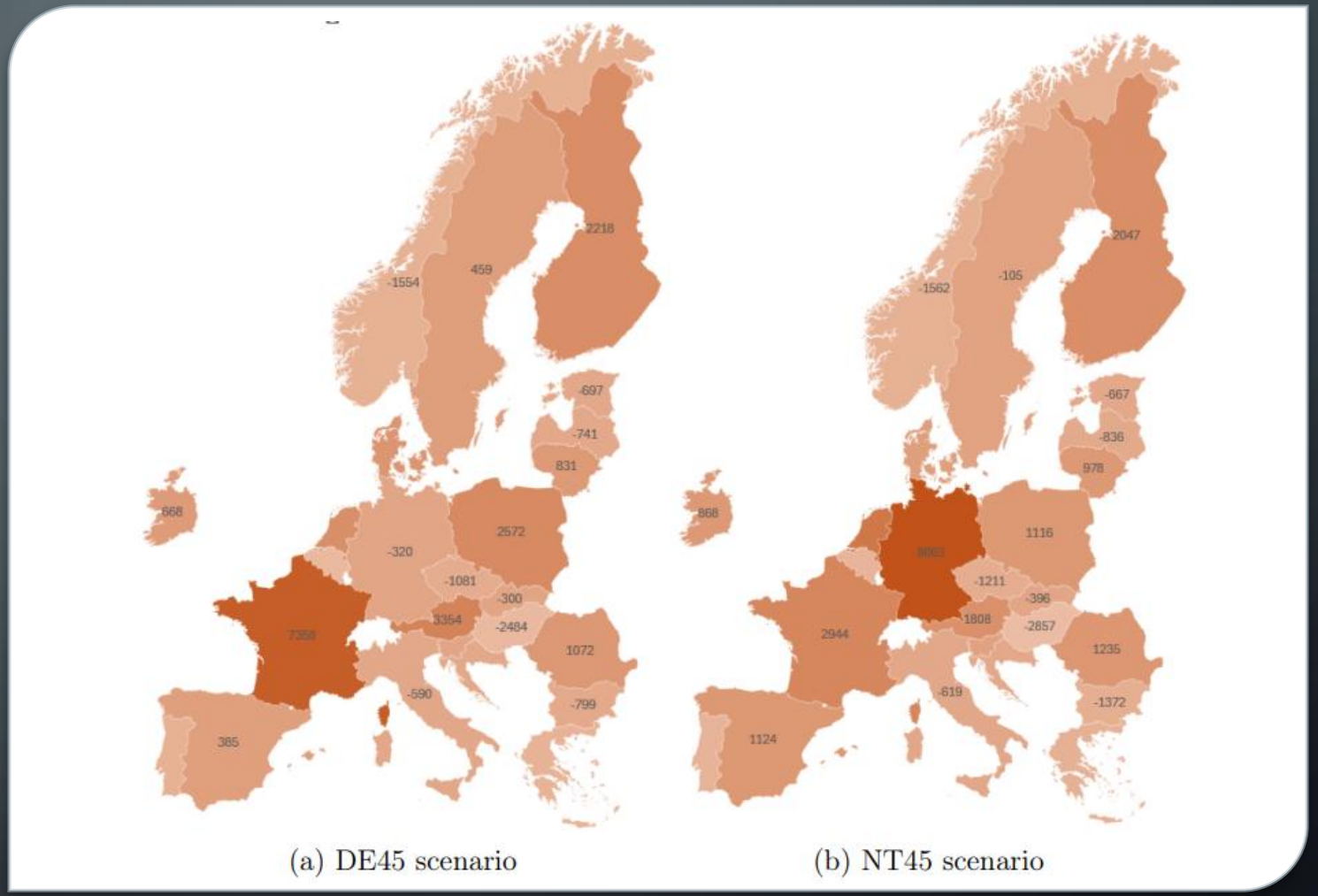
- Focus on Consumer and Producer Surplus (CS/PS), Net Position (NP), and Market Clearing Price (MCP)
- Central European countries that border the North Sea have comparably low prices
- The further away countries are from the North Sea, the higher the prices
- Negative prices occur frequently but little extreme prices
- Importing/exporting role of several countries changes between scenarios

RESULTS – MEAN PRICES



(a) DE45 scenario (b) NT45 scenario

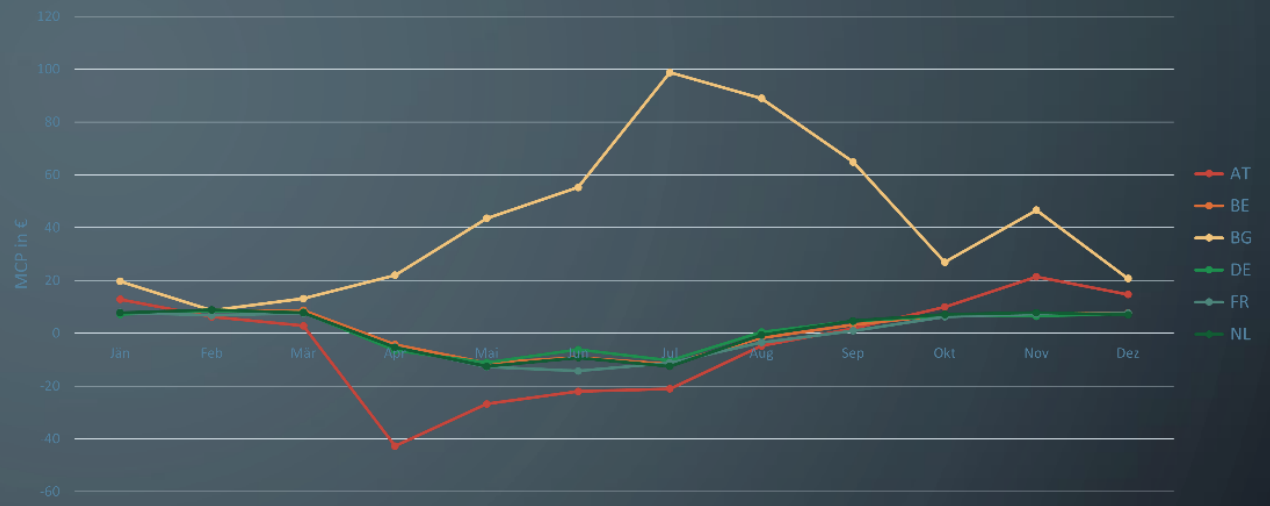
RESULTS – MEAN NET POSITIONS



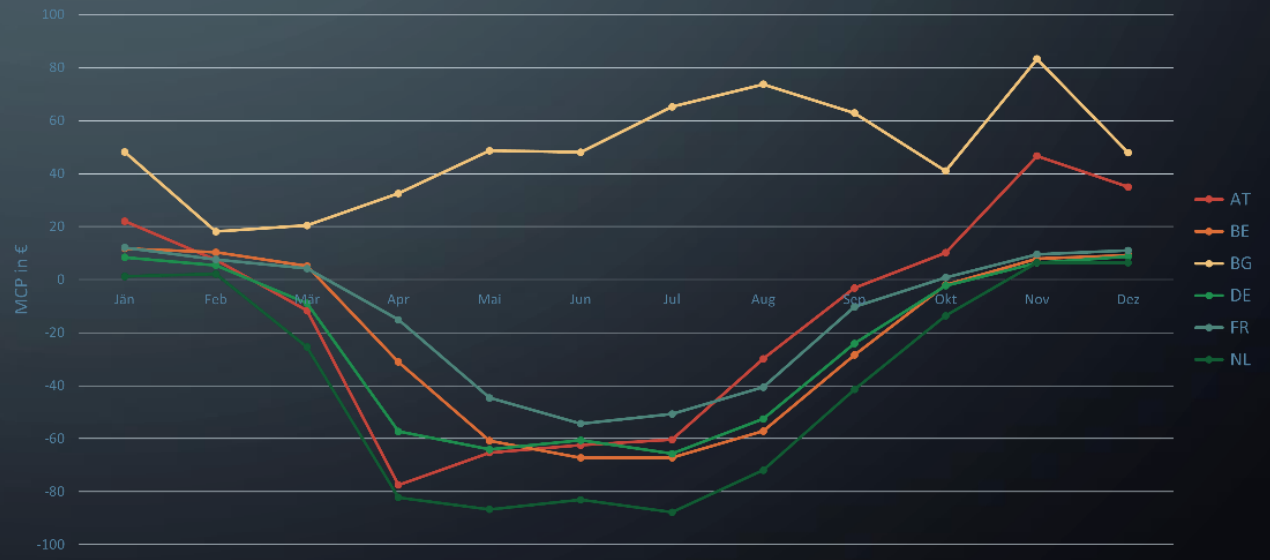
(a) DE45 scenario (b) NT45 scenario

SEASONAL PATTERNS

- More pronounced negative prices in summer and for NT45
- Offshore wind has peak production in winter months
- Negative prices are mainly triggered by excess of PV production



Average monthly MCP for selected countries according to DE45 scenario



Average monthly MCP for selected countries according to NT45 scenario

COMPARISON WITH 2024

- Historical vs. simulated results
- For all countries, projected prices in 2040 are significantly reduced compared to 2024
- For many countries (e.g., Germany) typical import or export behaviors change

	MCP [€]			NP [MW]		
Country	**DE45**	**NT45**	**Hist.**	**DE45**	**NT45**	**Hist.**
Austria	-4.11	-16.11	81,54	3 354	1 808	606
Belgium	0.87	-22.86	70.32	-2 487	-2 020	-1 777
Bulgaria	42.85	49.41	102.55	-799	-1 372	-221
Germany	1.14	-25.94	78.51	-320	8 663	-2 718
France	-0.31	-14.49	58.02	7 358	2 944	6 072
Netherlands	0.78	-40.17	77.29	2 111	4 575	360

Mean values for selected countries according to simulations and historical results

CONSEQUENCES AND ROLE OF STORAGE

- Constantly low, or even negative prices, lead to unprofitable power plants, as the CAPEX cannot be recouped on the market
- As a result, investments in renewable energies will be withdrawn unless countermeasures are taken
- Could accelerate the shutdown of conventional power plants due to unprofitability
- Introduction of large-scale (long-term) storage essential
- Price variations are an incentive for storage
- Incentivize hybrid power plants

CONCLUSIONS

- Market dynamics and regional price formation will significantly change
- The choice of climate model does not lead to any major differences
- Prices are reduced everywhere - revenues of asset owners must be ensured
- Remote countries cannot fully profit from current plans
- Grid enforcement is essential
- Storage, flexibility measures, and hedging possibilities are required
- A coordinated transition at the European level results in more sustainable prices compared to national pathways
- Possible model extensions: integration of flexible demand and storage, regulatory considerations

CONTACT

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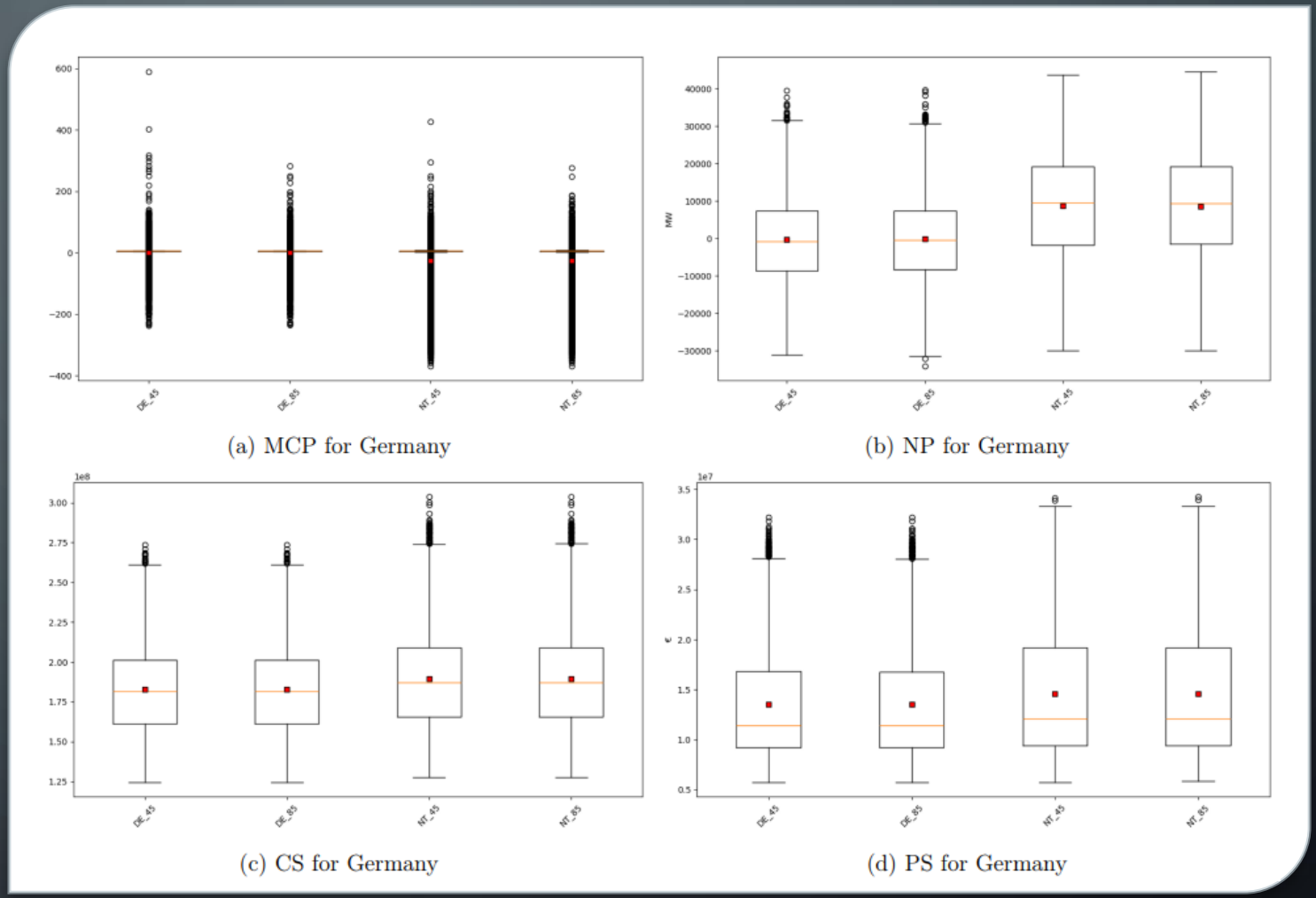
DETAILED COUNTRY ANALYSIS FOR GERMANY



(a) MCP for Germany

(b) NP for Germany

(c) CS for Germany

(d) PS for Germany