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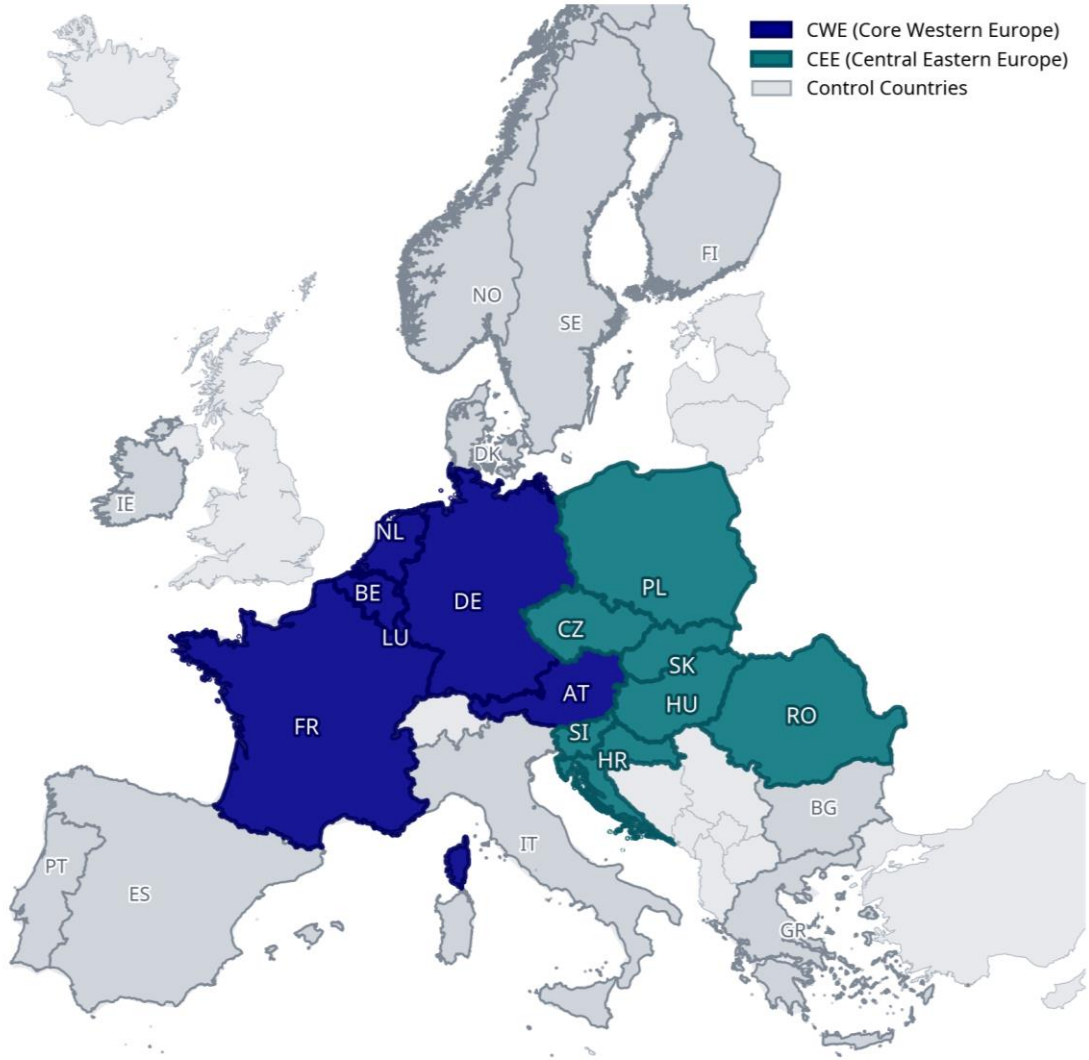
Price Effects of Flow-Based Market Coupling Extension

ENERDAY 2026, 27.03.2026 TU Dresden

How did the 2022 FBMC expansion affect Prices?

- 2015: Flow-Based Market Coupling (FBMC) goes live in **Central Western Europe (CWE)**
- 2022: FBMC is **extended to the full Core region** (CWE + CEE) on **8 June 2022**, covering 13 countries (JAO: Launch of Flow-Based Market Coupling in the Core region)
- The FBMC-CORE go-live in June 2022 coincides with the **European energy crisis** (high gas and power prices, 2021–2023).



Treatment Groups in FBMC-Expansion Impact Model (based on JAO)

To answer this, we use a Crisis-Controlled DiD Model

- **Model Equation** (Roth et al., 2023)

$$\begin{aligned}\text{Price}_{it} = {} & \beta_1 \cdot \text{ResLoad}_{i,t} + \beta_2 \cdot \text{NetPos}_{i,t} + \beta_3 \cdot \text{Gas}_{i,t} \\ & + \varphi_{CWE} \cdot (\text{Crisis}_t \times D_{CWE}) + \varphi_{CEE} \cdot (\text{Crisis}_t \times D_{CEE}) \\ & + \delta_{CWE} \cdot (\text{Post}_t \times D_{CWE}) + \delta_{CEE} \cdot (\text{Post}_t \times D_{CEE}) \\ & + \alpha_i + \gamma_t + \varepsilon_{i,t}\end{aligned}$$

Interaction Terms

- **φ:** how much MORE countries' prices increased during the energy crisis compared to control countries
- **δ:** the FBMC effect on countries AFTER removing the crisis confound

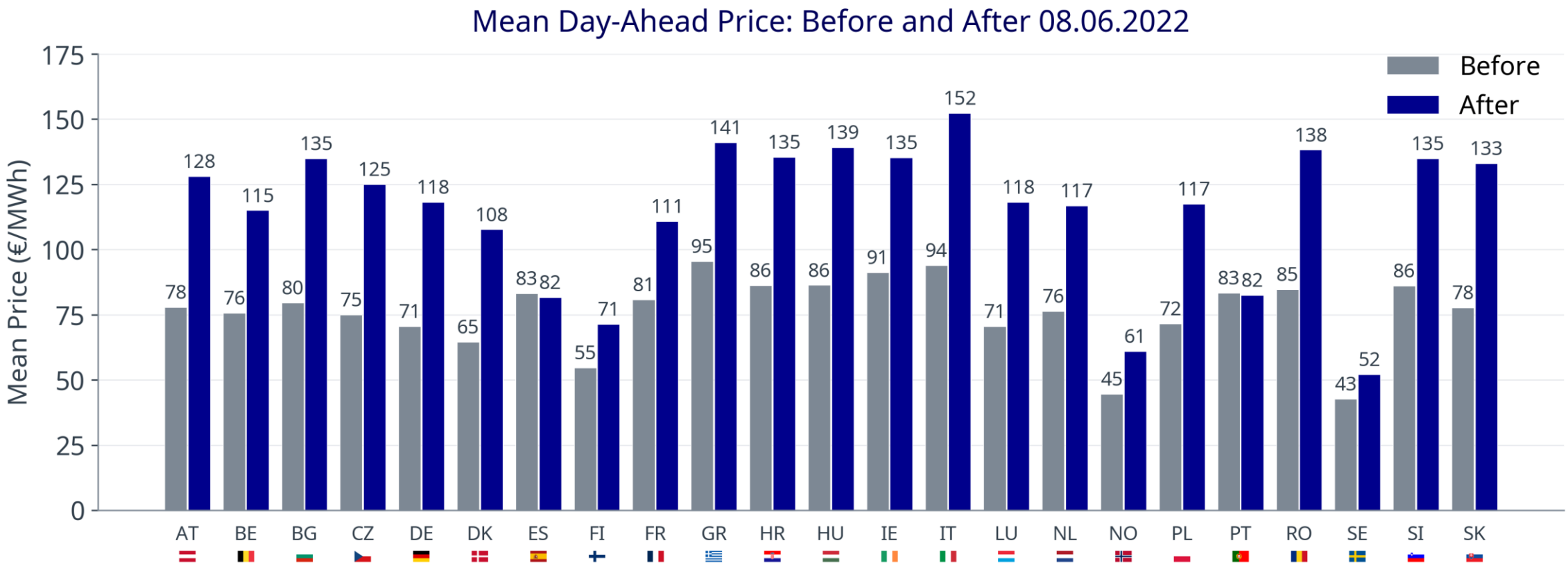
Fixed Effects & Inference

- α_i — Country FE (absorb time-invariant country differences)
- γ_t — Date FE (absorb common daily shocks)
- $\varepsilon_{i,t}$ — Clustered standard errors at country level (23 clusters)
- Time-varying controls: Residual load (β_1), Net position (β_2), Gas price (β_3)

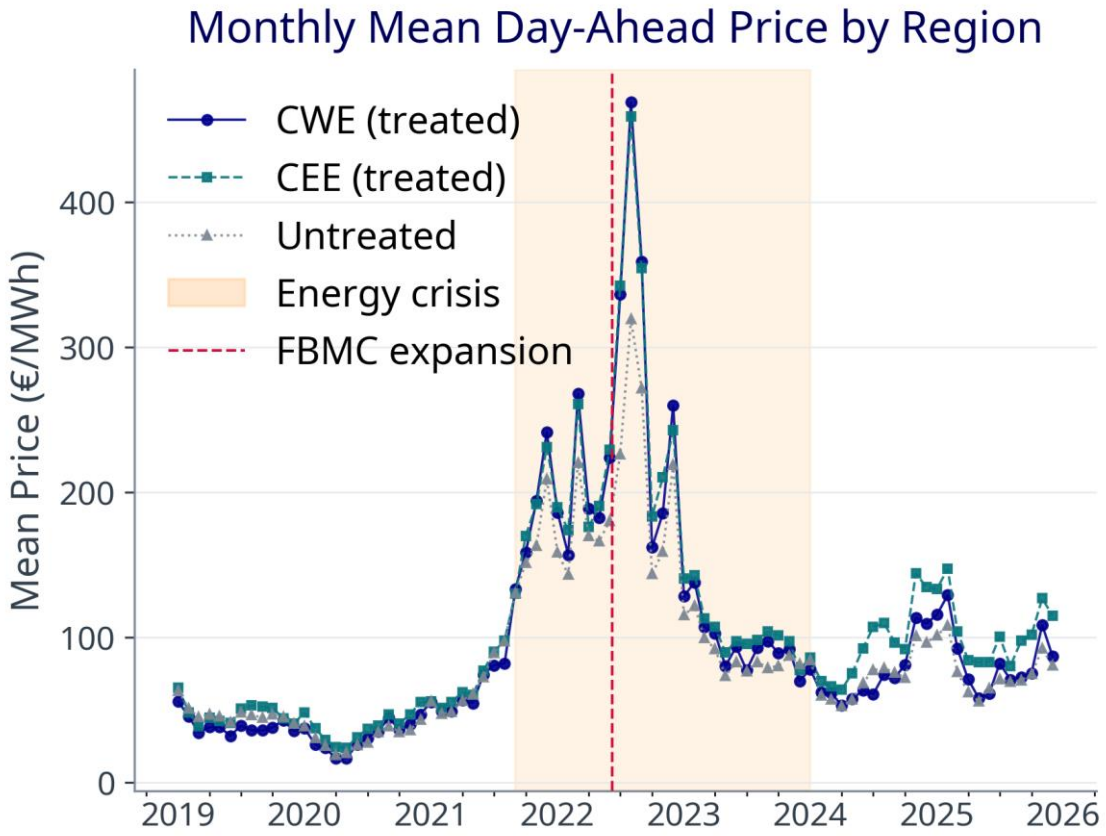
The Model is validated with 5 Diagnostic Tests

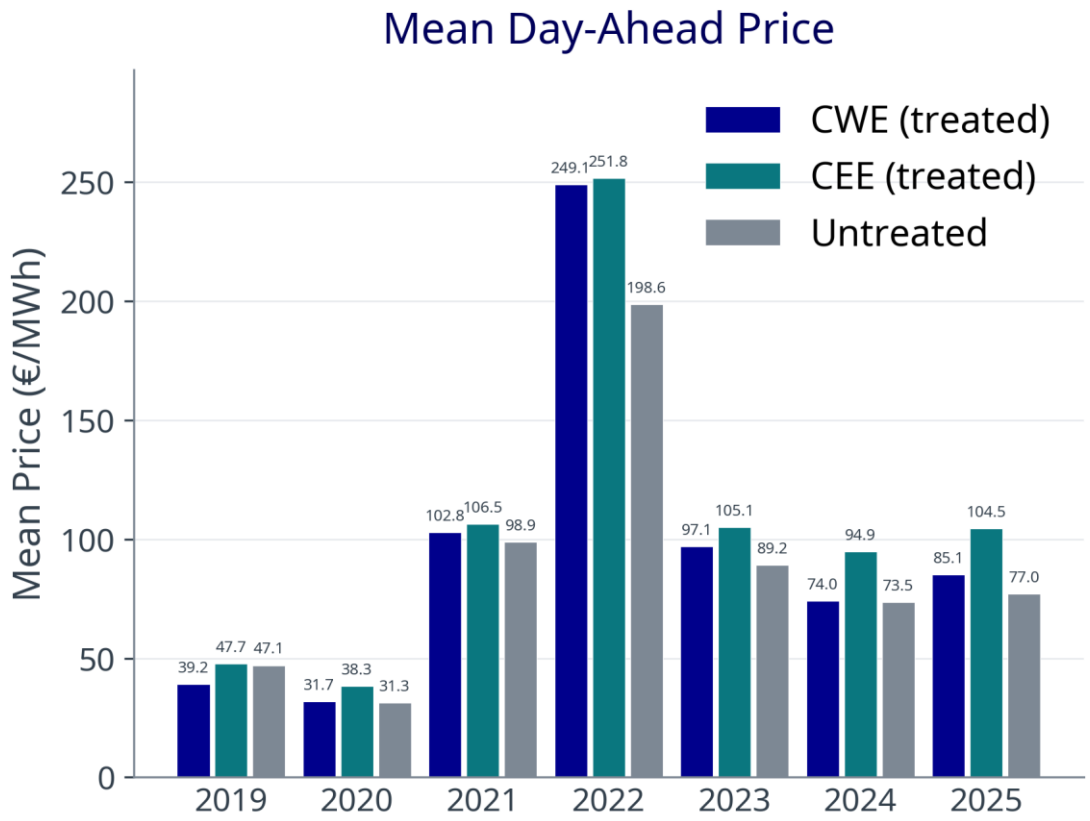
Event Study / Parallel Trends	Treatment and control groups followed similar price paths before FBMC. Pre-treatment coefficients are insignificant, supporting the parallel trends assumption required for valid DiD ✓
Placebo Treatment Dates	Fake FBMC dates (2021, 2023) to detect spurious effects. Both produce insignificant coefficients → the effect is unique to the actual reform. ✓
Log Specification	Re-estimates in logarithms to check sensitivity to functional form and outliers. CEE remains significant across all specifications ✓
Heterogeneous Treatment	Tests whether Country-level effects like high RES or structural net exports change the effect. Interactions are insignificant and base coefficients stable ✓
HonestDiD Sensitivity	Quantifies tolerable parallel trends violations. CEE survives up to 2x worst pre-trend deviation ✓

FBMC Expansion takes place during energy crisis

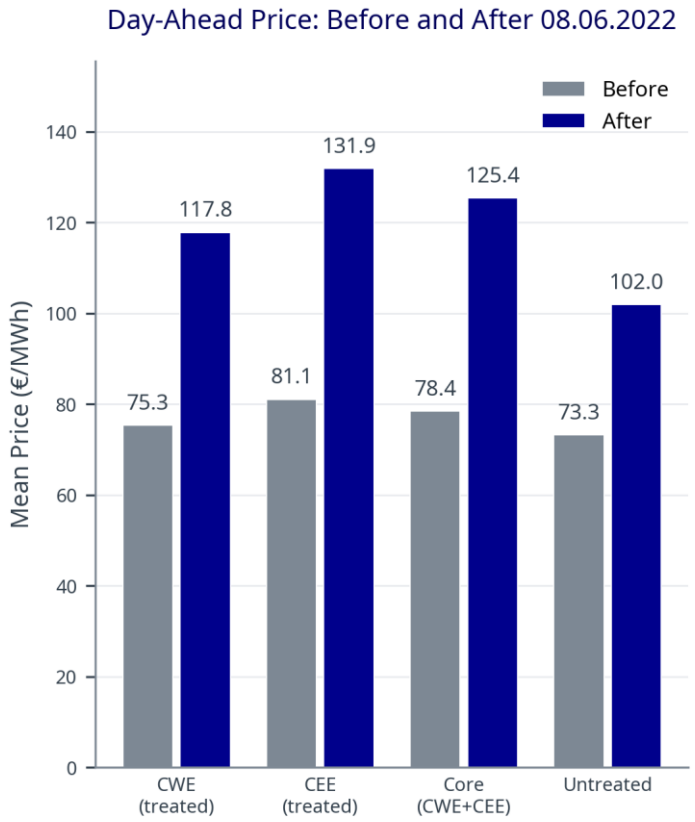


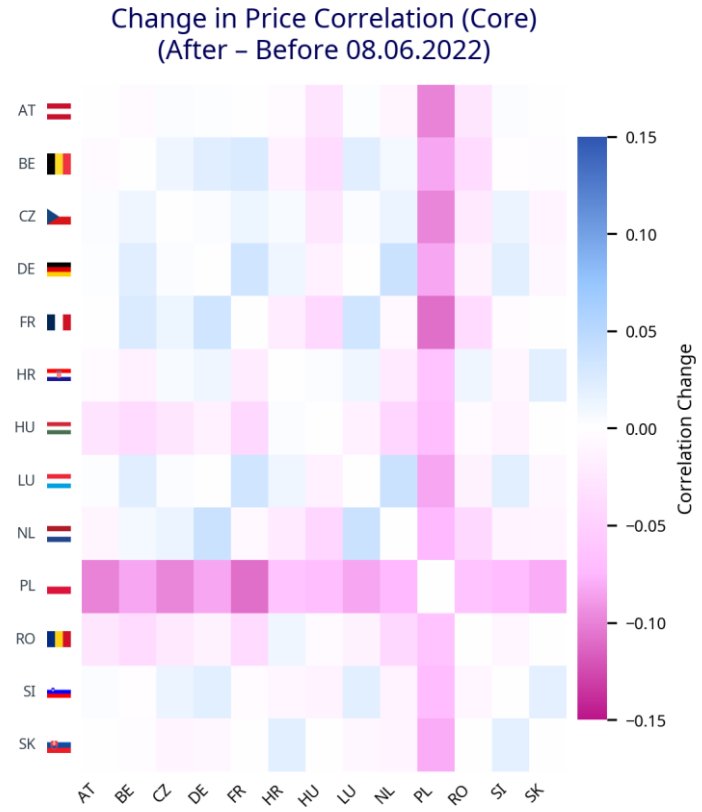
Parallel trends confirm that no differential pre-trends existed before FBMC-extension

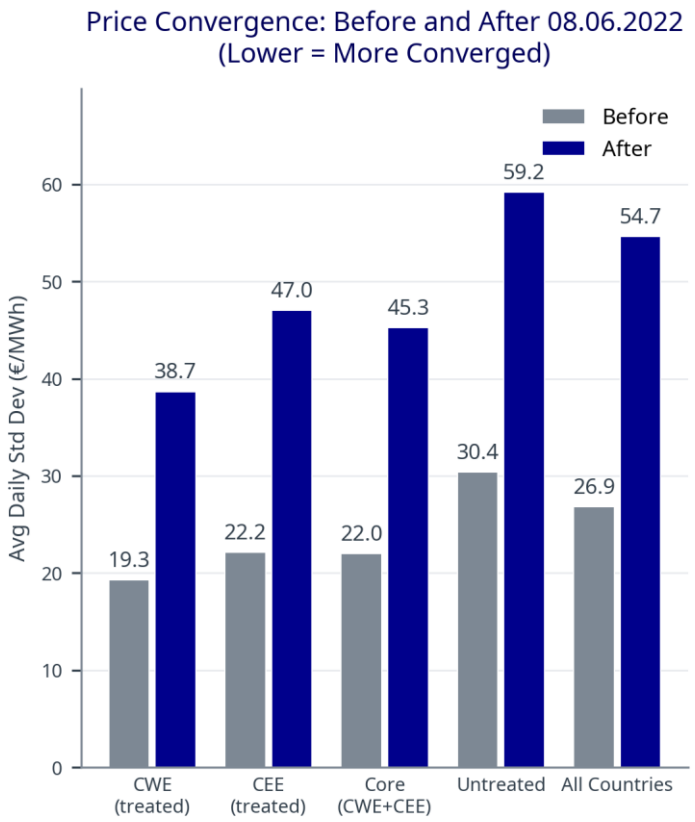




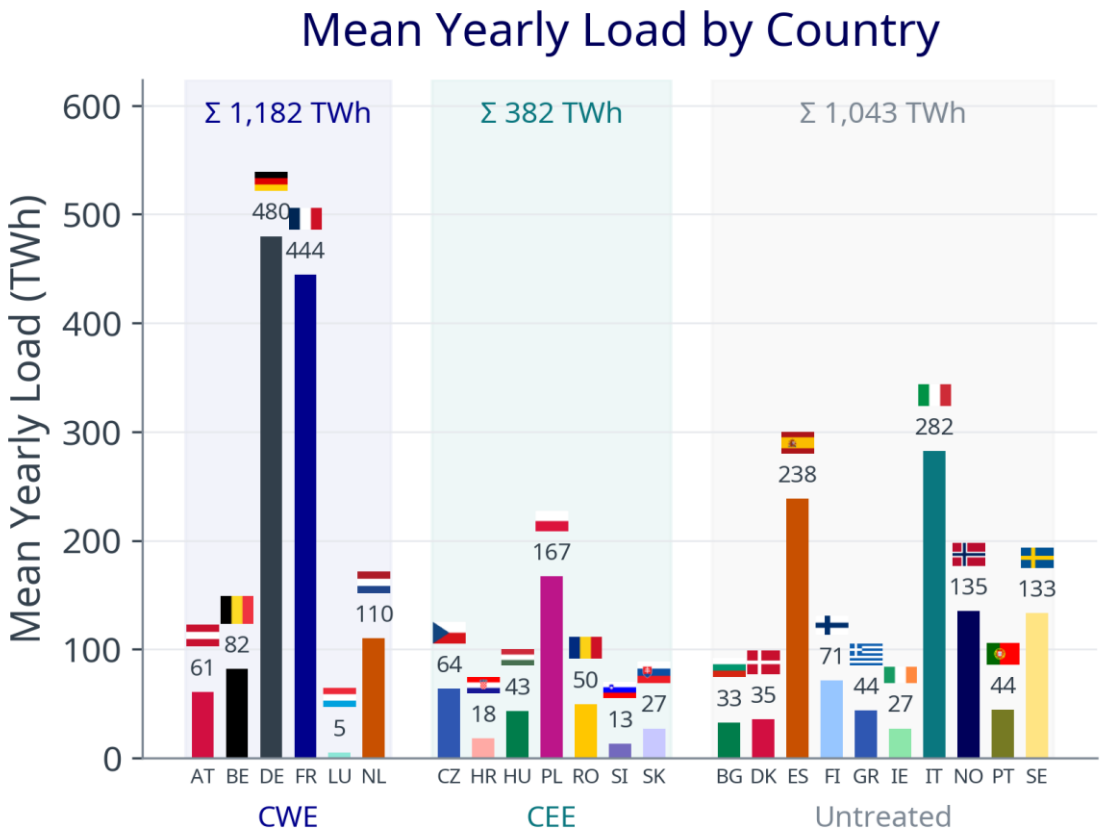
Lower price convergence signals complicate the impact assessment of the FBMC-expansion







The model isolates the effect by controlling for market fundamentals — starting with residual load



Residual load (β_1) : **load** – generation of RES

Research Design

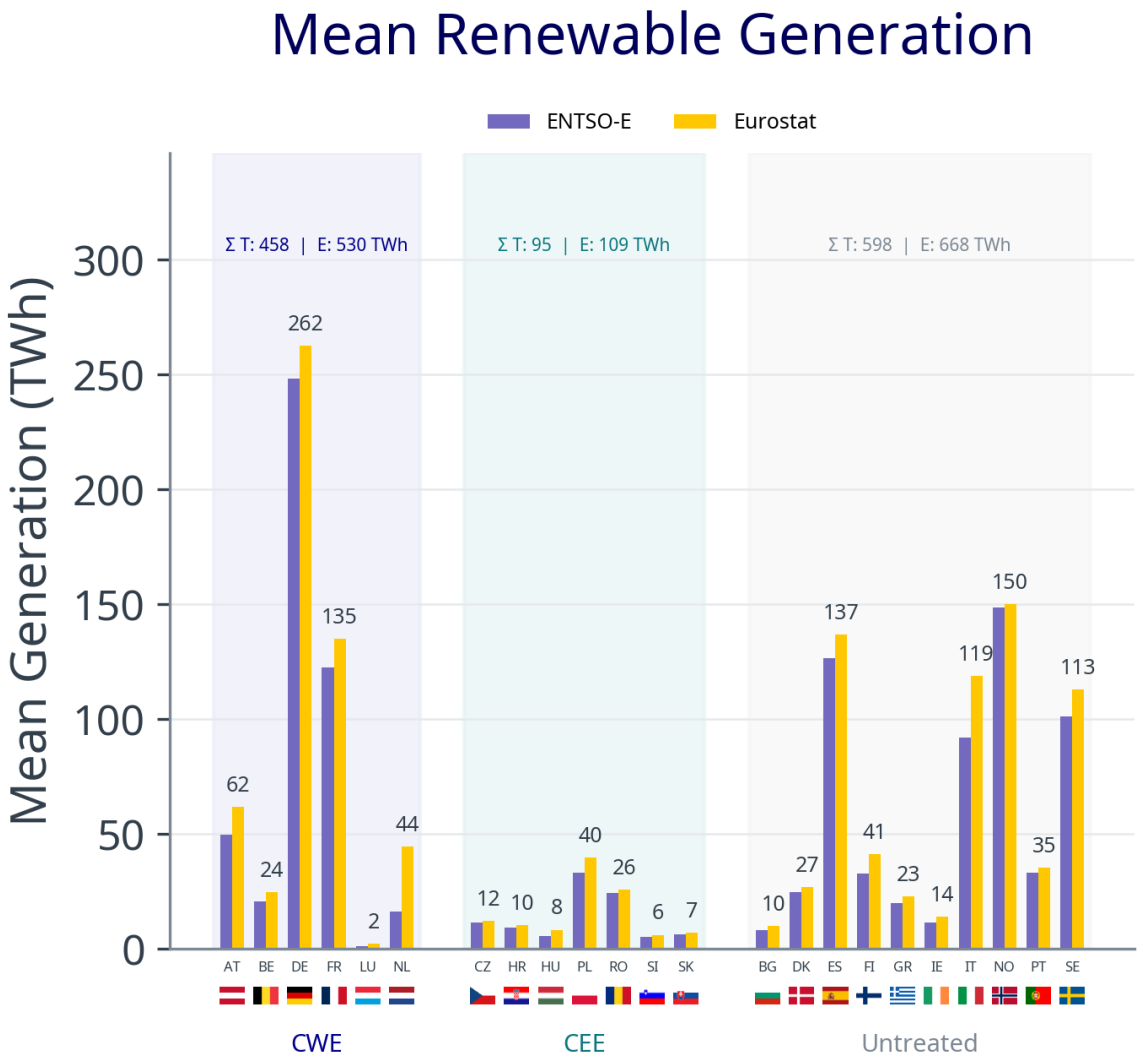
- 23 countries, daily data (Jan 2019 – Dec 2025)
- Treatment: FBMC expansion to CORE ,
- CWE (6): **AT, BE, DE, FR, LU, NL**
- CEE (7): **CZ, HR, HU, PL, RO, SI, SK**
- Control (10): **BG, DK, ES, FI, GR, IE, IT, NO, PT, SE**

- CORE largest load area in the sample

Calculated as total load minus variable renewable generation

Residual load (β_1) : load – **generation of RES**

- Residual load is the main price-driving variable in European electricity markets
- Despite having the highest absolute electricity demand, the CORE region has *lower* RES penetration than the control group — residual load dynamics differ structurally across treatment and control
- Eurostat systematically overestimates RES

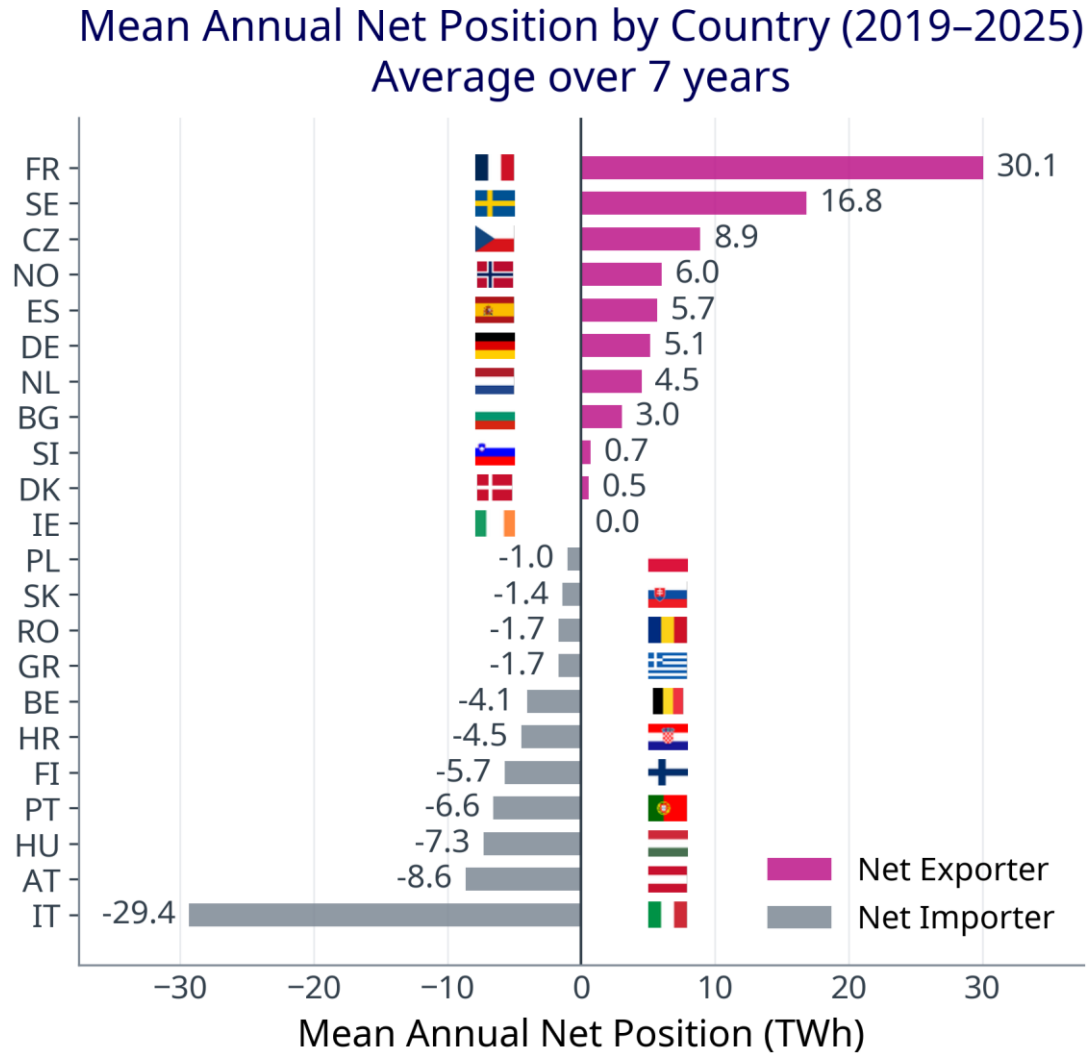


Comparison of ENTSO-E with Eurostat Renewable Generation Data

Net Positions absorb Cross-Border demand effects

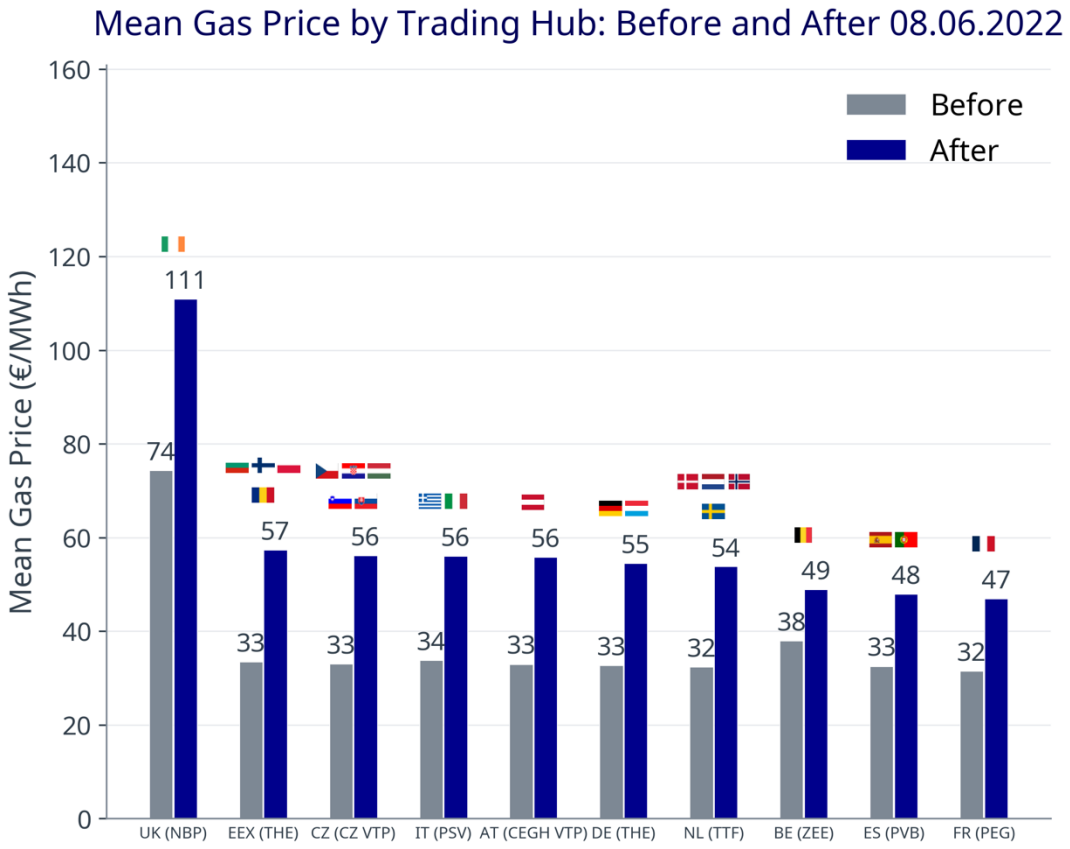
Net position (β_2)

- A country's daily net scheduled commercial exchanges — positive = net exporter, negative = net importer
- FBMC directly reshapes cross-border capacity allocation; without this control, trade-pattern shifts at go-live would bleed into δ_{CWE} and δ_{CEE}



Net positions calculated based on the commercial scheduled exchanges

And gas prices capture the energy crisis variation



Gas price (β_3)

- Proxy for expensive fossil-fuel marginal cost
- Absorbs the bulk of the 2021–2023 energy-crisis price spike, preventing crisis-driven volatility from inflating the treatment coefficients
- Each country is mapped to its nearest liquid gas trading hub, for IE there is most probably an error in data after 2023

The Baseline Model Shows Significant Effects for CEE Region

- **No significant CWE impact**: Legacy flow-based countries were unaffected by the expansion.
- **Significant CEE price increase**: CEE countries experienced a price increase after FBMC integration (p = 0.006)
- **Crisis confounding controlled**: The energy crisis asymmetrically raised CWE

Variable	Coefficient	SE	p-value	95 % CI
Treatment effects				
FBMC × CWE (δ_1)	**+10,32**	6,58	0,1321	[-2.58, +23.22]
FBMC × CEE (δ_2)	**+17,38**	5,70	0,0061	[+6.21, +28.55]**
Controls				
Energy crisis × CWE	+30,41	8,96	0,0027	[+12.85, +47.97]**
Energy crisis × CEE	+16,18	11,14	0,1610	[-5.65, +38.01]
Gas price (€/MWh)	+0,46	0,23	0,0527	[+0.01, +0.91]†
Residual load (GW)	+1,43	0,51	0,0100	[+0.43, +2.43]*
Net position (GW)	-2,10	0,83	0,0164	[-3.73, -0.47]*
Model diagnostics				
Fixed effects	**Country + Date**			
Clustering	**Country (23)**			
Observations	**56,148**			
Countries	**23**			
R^2	**0.866**			
R^2 (within)	**0.113**			
Dep. var. mean	**96.07**			
Dep. var. SD	**84.21**			

*** p < 0.001, ** p < 0.01, * p < 0.05, † p < 0.10.
SE clustered at country level (23 clusters)

Does the CEE effect survive without crisis years? Yes

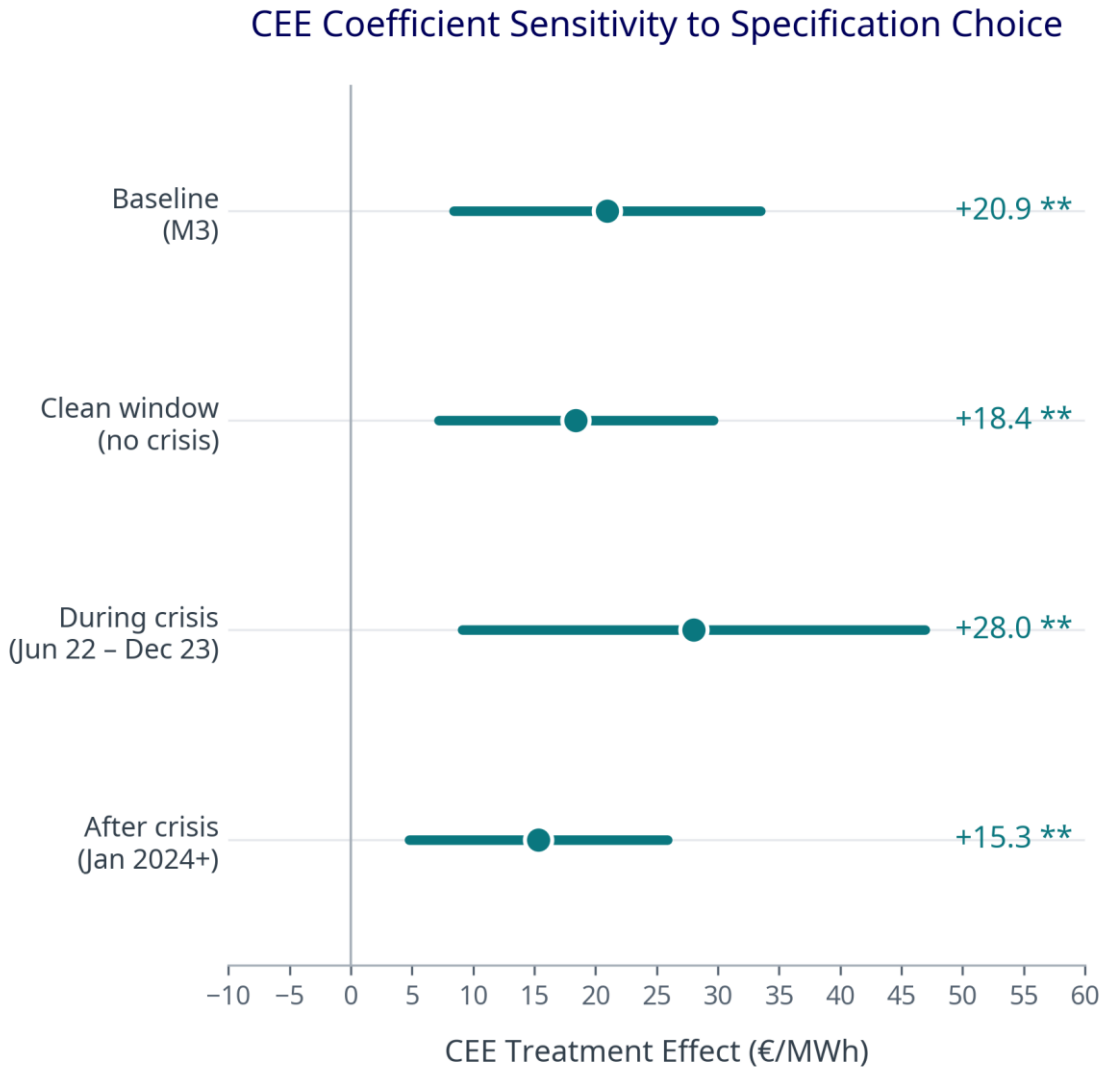
Variable	Coefficient	SE	p-value	95 % CI
Treatment effects (FBMC)				
FBMC × CWE (δ_1)	**+7,20**	6,96	0,3126	[-6.44, +20.84]
FBMC × CEE (δ_2)	**+18,38**	5,73	0,0043	[+7.15, +29.61]**
Controls				
Gas price (€/MWh)	+0,40	0,08	0,0001	[+0.24, +0.56]***
Residual load (GW)	+1,30	0,45	0,0090	[+0.42, +2.18]**
Net position (GW)	-1,30	0,34	0,0010	[-1.97, -0.63]**
Model diagnostics				
Fixed effects	**Country + Date**			
Clustering	**Country (23)**			
Observations	**40,094**			
Countries	**23**			
R^2	**0.836**			
R^2 (within)	**0.115**			
Sample window	**2019–21 vs 2024–25**			
Dep. var. mean	**69.71**			
Dep. var. SD	**49.49**			

*** p < 0.001, ** p < 0.01, * p < 0.05, † p < 0.10.
SE clustered at country level (23 clusters)

- Clean window (2019–21 vs. 2024–25): crisis years dropped entirely
- CEE: +18.38 EUR/MWh — significant and larger than baseline
- The CEE price increase seems to be a *structural consequence* of FBMC integration, not an artifact of the 2021–23 energy crisis
- CWE: +7.20 EUR/MWh (p = 0.313) — still insignificant → no hidden CWE effect

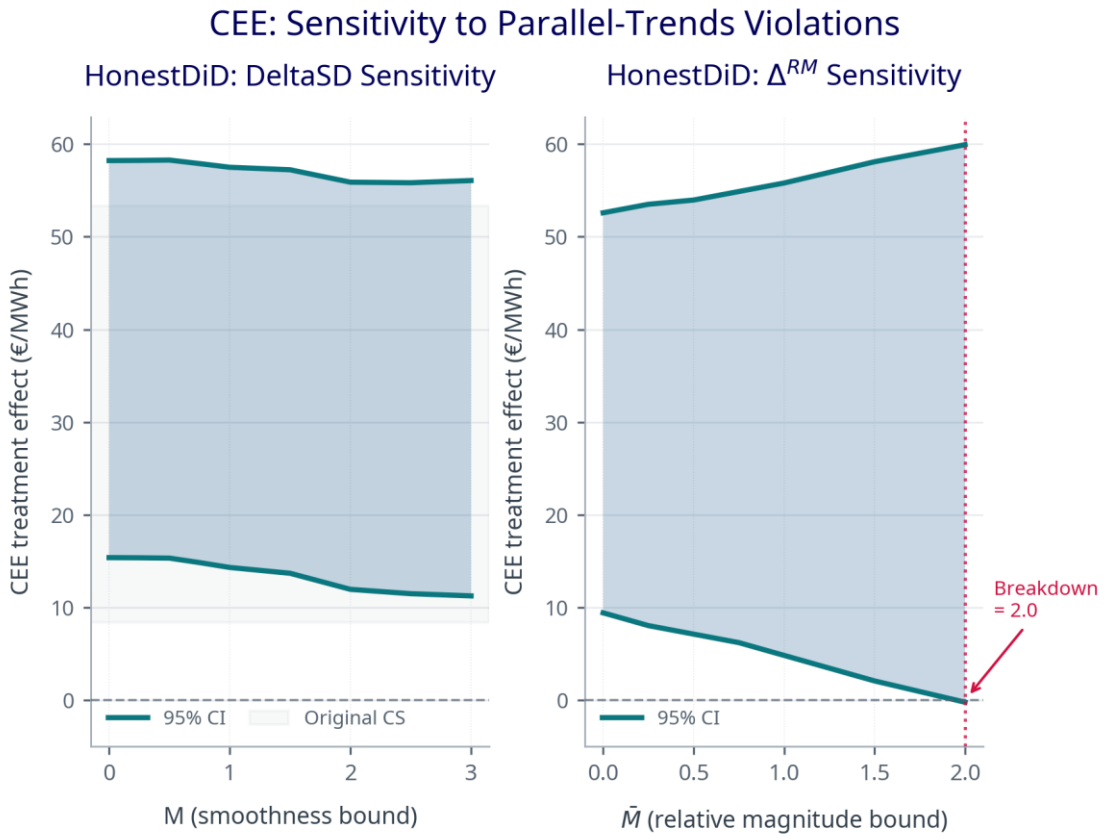
CEE effect survives crisis and post-crisis windows

- But FBMC launched mid-crisis — is the effect crisis-dependent?
- We split the treatment into two distinct time windows
- CEE effect larger, amplified by crisis volatility, but it persists when crisis fades — not an artifact
- All four confidence intervals exclude zero → robust across regimes



Temporal Decomposition Test

HonestDiD confirms the robustness of the CEE result



- **The assumption** DiD assumes treated and control countries would have followed the *same* price trend without FBMC
- **The problem** Pre-treatment coefficients are close to zero — not *exactly* zero
- HonestDiD asks: *what if those small deviations continued post-treatment?* (Rambachan, A., & Roth, J.)
  - Re-computes confidence intervals under increasingly pessimistic assumptions

CEE's effect is robust — but why? We need to dig deeper

Interpretation

- FBMC optimizes total CORE welfare, not individual zone prices
  - CWE economies much larger and better interconnected.
  - CEE bears adjustment cost for system-wide efficiency gains
  - Counterintuitive flows

Next Steps

- Country-by-Year Fixed Effects: absorb country-specific annual policy shock
- Account for national energy policies, market reforms and particularities
  - e.g., Poland imposes individual constraints on the flow-based domain
  - Re-estimate excluding Poland or treating it as separate treatment

References

JAO: Explanation of the difference between the flow-based plain and flow-based intuitive market coupling approach Version, date and status. (2020). From https://www.jao.eu/sites/default/files/2021-05/CWE%20FB%20plain%20Explanatory%20Material_v1.0.pdf

JAO: Launch of Flow-Based Market Coupling in the Core region enhances energy transition Flow-Based Market Coupling mechanism optimises day-ahead European electricity market for 13 countries. Retrieved March 25, 2026 from https://www.jao.eu/core-fb-da-mc

Roth, J., Sant'Anna, P. H. C., Bilinski, A., & Poe, J. (2023). What's trending in difference-in-differences? A synthesis of the recent econometrics literature. *Journal of Econometrics*, *235*(2), 2218–2244. https://doi.org/10.1016/J.JECONOM.2023.03.008

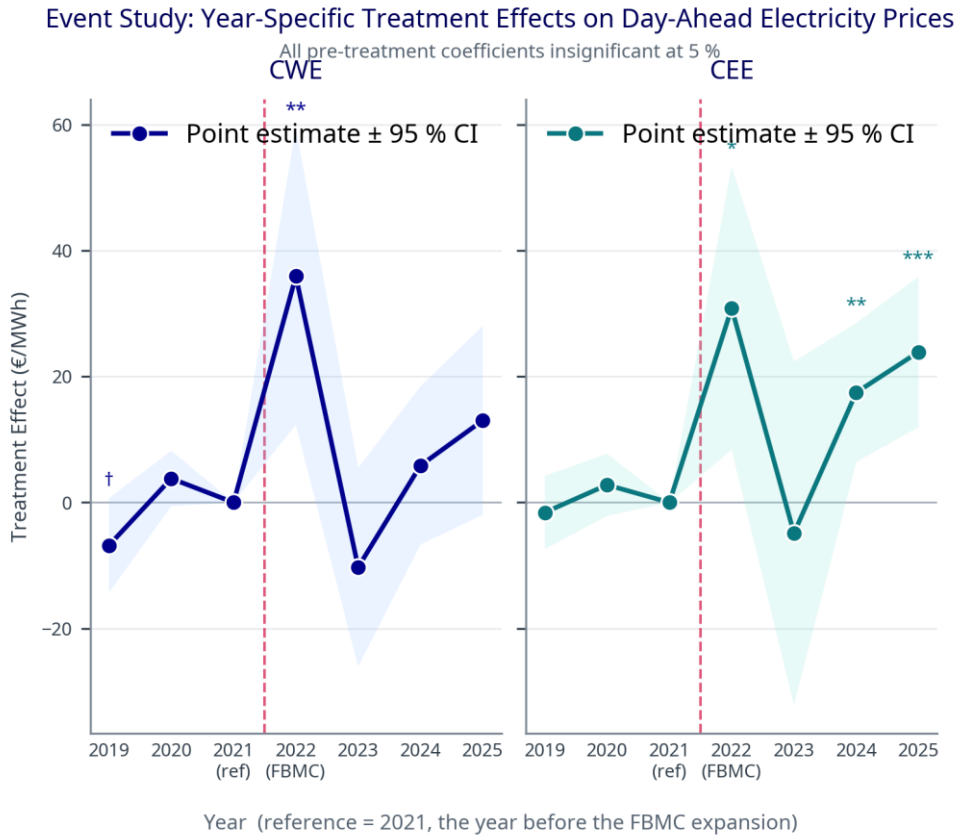
Rambachan, A., & Roth, J. (2023). A More Credible Approach to Parallel Trends. *Review of Economic Studies*, *90*, 2555–2591. https://doi.org/10.1093/restud/rdad018

Backup

Event Study / Parallel Trends, necessary for any DiD

All pre-treatment coefficients (2019, 2020) are statistically insignificant at 5% for both CWE and CEE — no differential pre-trends before FBMC.

The treatment effect appears precisely at year 0 (2022), ruling out anticipation or pre-existing divergence.



CEE Treatment Effect — Level vs. Log Specification

Variable	M3 Level	M3 Log	p-value (Log)
Controls			
Gas price	0.4077	—	
	(0.2536)		
Residual load	0.0015**	—	
	(0.0005)		
Net position	−0.0021†	—	
	(0.0011)		
Treatment Effects (CEE)			
FBMC × CEE (treat_post:cee_treated)	20.9435**	0.2501*	0.0148
	(6.4011)	(0.0942)	
FBMC × CWE (treat_post:cwe_treated)	16.7214*	0.2469*	0.0329
	(7.5230)	(0.1081)	
Goodness of Fit			
N	56,148	55,993	
R^2	0.8619	0.7684	
R^2 Within	0.0836	0.0765	
Rows dropped (price ≤ 0)	—	185	

Note: Log coefficient of 0.25 ≈ 25% price increase attributable to FBMC coupling for CEE countries. Level coefficient of €20.94 confirms the magnitude. Both significant at 5% level with clustered SE.
† p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

CEE Placebo Treatment Tests — Falsification Check

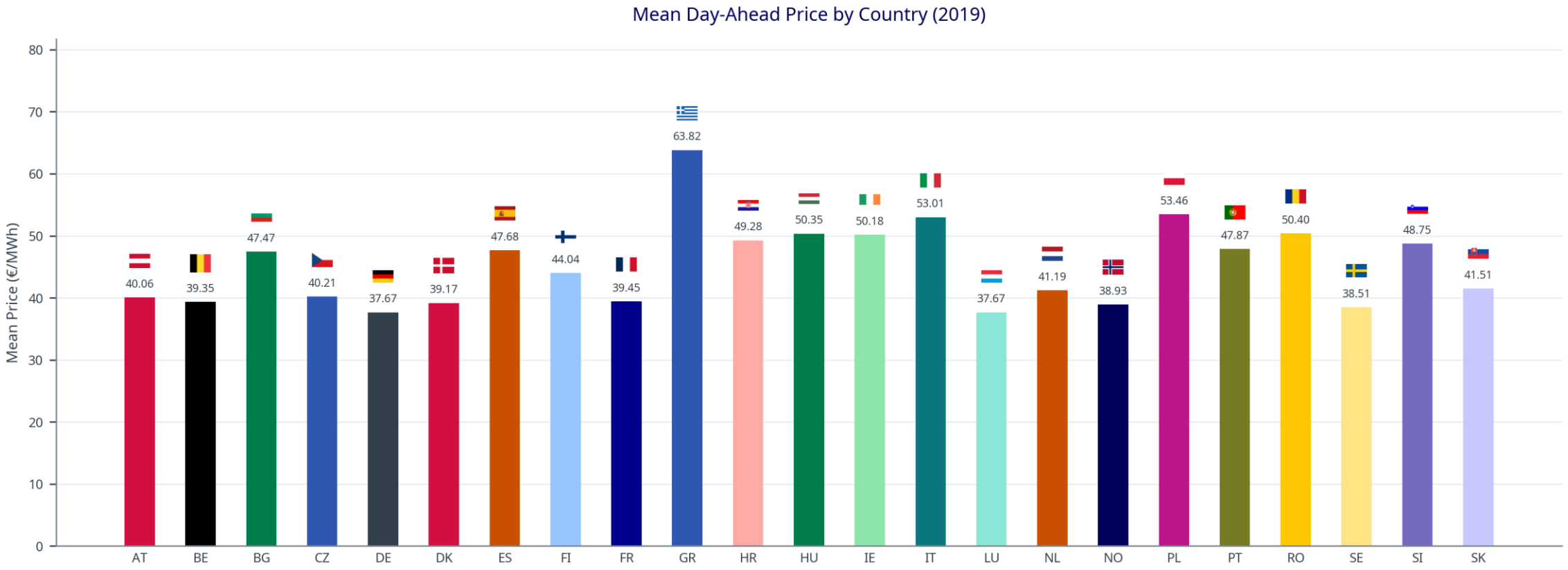
Variable	PL 2019 (no crisis ctrl)	PL 2019 (+ crisis ctrl)	PL 2021 (no crisis ctrl)	PL 2021 (+ crisis ctrl)	Pre-crisis PL 2020
CEE Placebo Treatment					
Placebo FBMC × CEE (tpp:cee)	21.3340**		23.6205*		
	(7.0654)		(9.5857)		
Placebo Controls					
Placebo FBMC × CEE (tpp_cee)		5.5644***		−1.0816	3.2731
		(1.3899)		(4.5118)	(2.0306)
Crisis × CEE		24.0705*		24.9842**	
		(9.3132)		(6.5712)	
COVID × CEE		−0.1372		2.1025	
		(2.1374)		(1.9743)	
Summary (from grand table)					
Placebo 2019 + crisis ctrl		5.56 (p = 0.0006)			
Placebo 2021 + crisis ctrl				−1.08 (p = 0.8129)	
Pre-crisis PL 2020					3.27 (p = 0.1219)
Goodness of Fit					
N	56,148	56,148	56,148	56,148	21,423
R^2	0.8595	0.8638	0.8630	0.8638	0.8418
R^2 Within	0.0683	0.0967	0.0909	0.0965	0.1497

Note: Placebo tests shift the treatment date to check for pre-existing effects. A valid placebo should show no significant effect (p > 0.10). PL 2019/2021 without crisis controls show significance — once crisis/COVID controls are added, PL 2021 becomes insignificant (p = 0.81), confirming the crisis drives the pre-2022 'effect'. PL 2020 is also insignificant for CEE (p = 0.12).
† p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

CEE Heterogeneous Treatment Effects

Variable	M3 Baseline	× RES Share	× Net Exporter
Controls			
Gas price	0.4077	0.4025	0.4043
	(0.2536)	(0.2542)	(0.2541)
Residual load	0.0015**	0.0015**	0.0014*
	(0.0005)	(0.0005)	(0.0005)
Net position	−0.0021†	−0.0020†	−0.0022†
	(0.0011)	(0.0011)	(0.0011)
CEE Treatment Effects			
FBMC × CEE	20.9435**	21.8659**	21.7393**
	(6.4011)	(6.4982)	(6.4529)
FBMC × CEE × High RES		−2.1548	
		(2.0632)	
FBMC × CEE × Net Exporter			−2.7483
			(1.6468)
CWE Treatment Effects (reference)			
FBMC × CWE	16.7214*	14.2450†	23.0170**
	(7.5230)	(7.5356)	(6.3807)
FBMC × CWE × High RES		6.3387	
		(3.6944)	
FBMC × CWE × Net Exporter			−7.9744*
			(3.2487)
Goodness of Fit			
N	56,148	56,148	56,148
R^2	0.8619	0.8620	0.8620
R^2 Within	0.0836	0.0842	0.0843

Note: Heterogeneous effects test whether the FBMC treatment varies by country RES share or net-exporter status. CEE interactions are small and insignificant, suggesting a homogeneous treatment effect across CEE countries. For CWE, net-exporter status significantly reduces the coupling effect (−7.97*, $p < 0.05$).
† $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$


Mean Day-Ahead Price by Country (2019)
Mean Price (€/MWh)
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10
20
30
40
50
60
70
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40.06
39.35
47.47
40.21
37.67
39.17
47.68
44.04
39.45
63.82
49.28
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50.18
53.01
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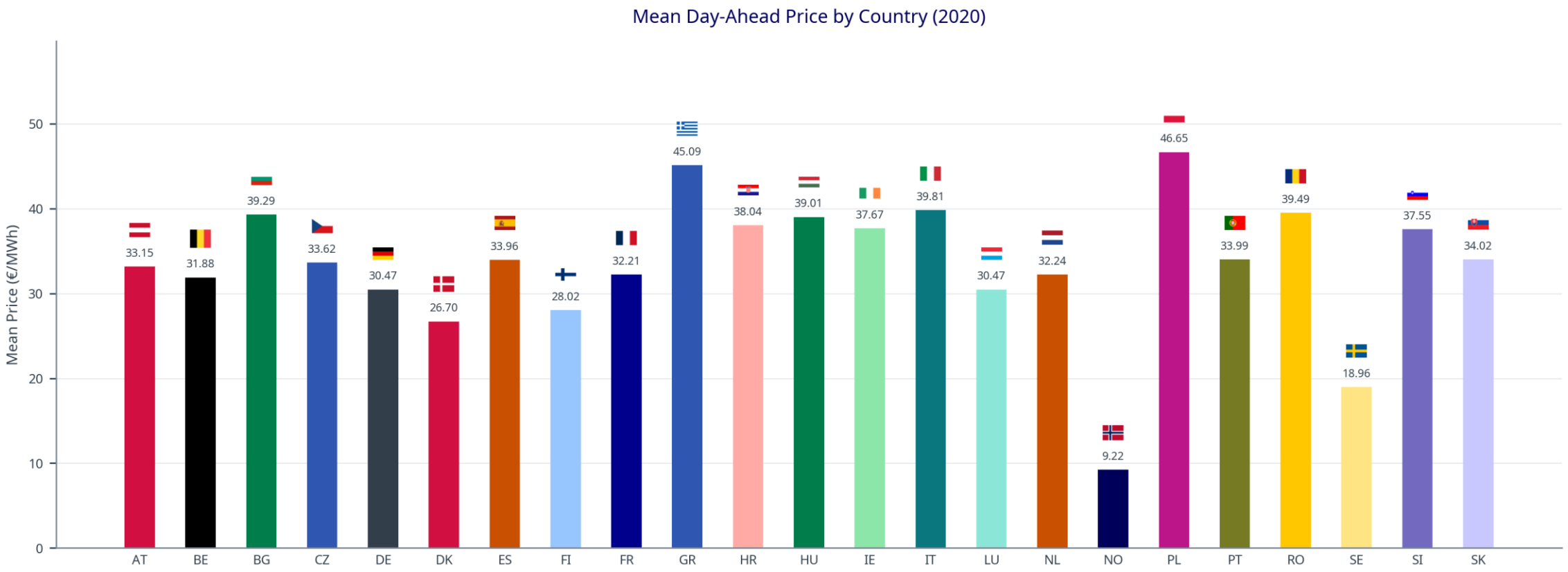
Mean Day-Ahead Price by Country (2020)
Mean Price (€/MWh)
0
10
20
30
40
50
33.15
31.88
39.29
33.62
30.47
26.70
33.96
28.02
32.21
45.09
38.04
39.01
37.67
39.81
30.47
32.24
9.22
46.65
33.99
39.49
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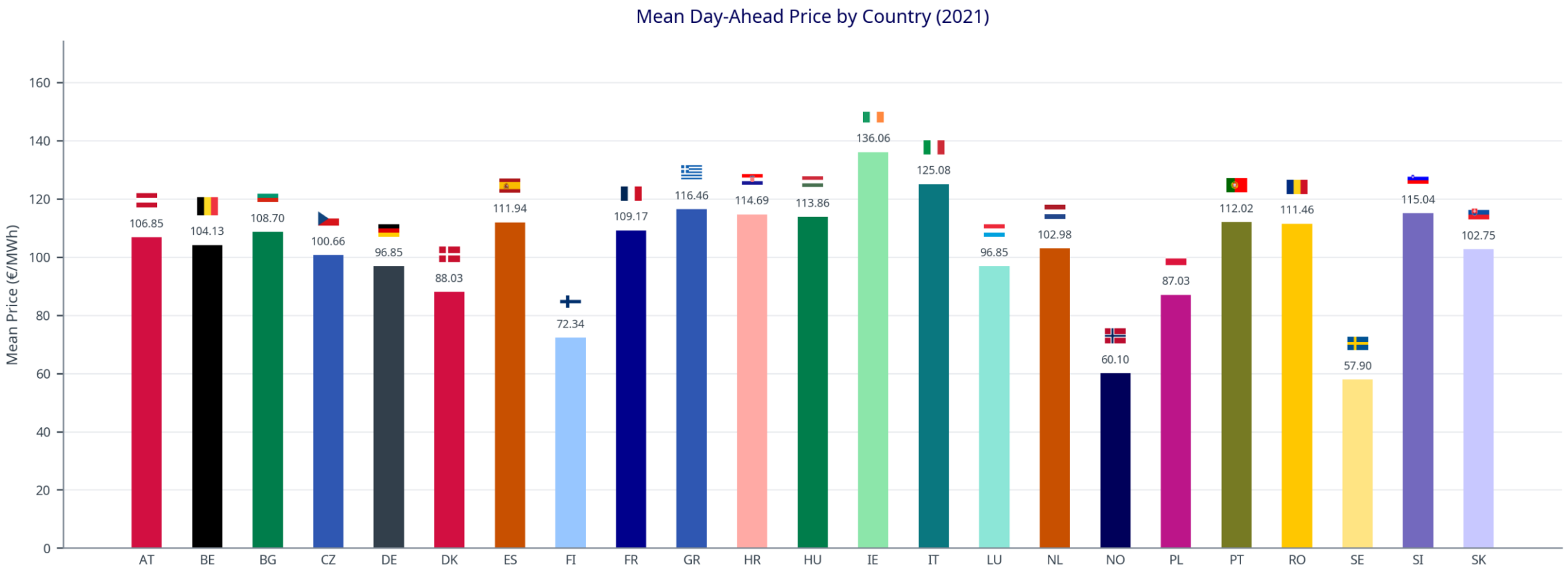
Mean Day-Ahead Price by Country (2021)
Mean Price (€/MWh)
0
20
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60
80
100
120
140
160
106.85
104.13
108.70
100.66
96.85
88.03
111.94
72.34
109.17
116.46
114.69
113.86
136.06
125.08
96.85
102.98
60.10
87.03
112.02
111.46
57.90
115.04
102.75
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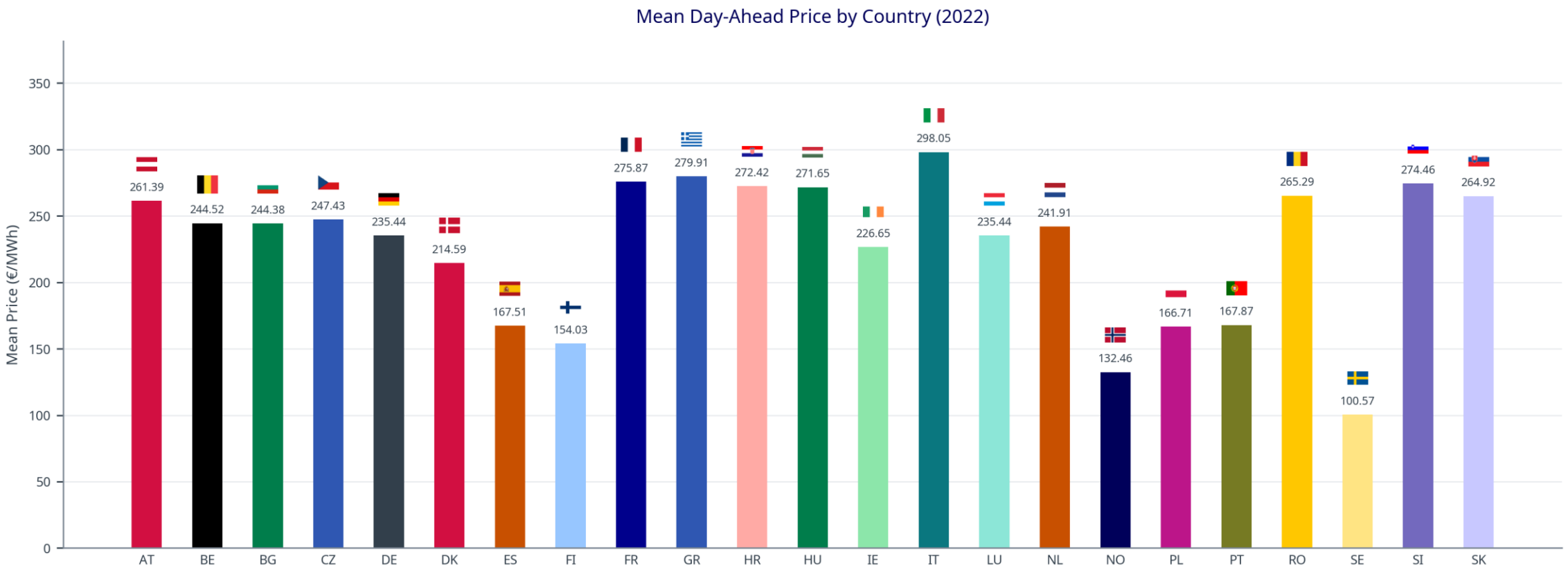
Mean Day-Ahead Price by Country (2022)
Mean Price (€/MWh)
0
50
100
150
200
250
300
350
261.39
244.52
244.38
247.43
235.44
214.59
167.51
154.03
275.87
279.91
272.42
271.65
226.65
298.05
235.44
241.91
132.46
166.71
167.87
265.29
100.57
274.46
264.92
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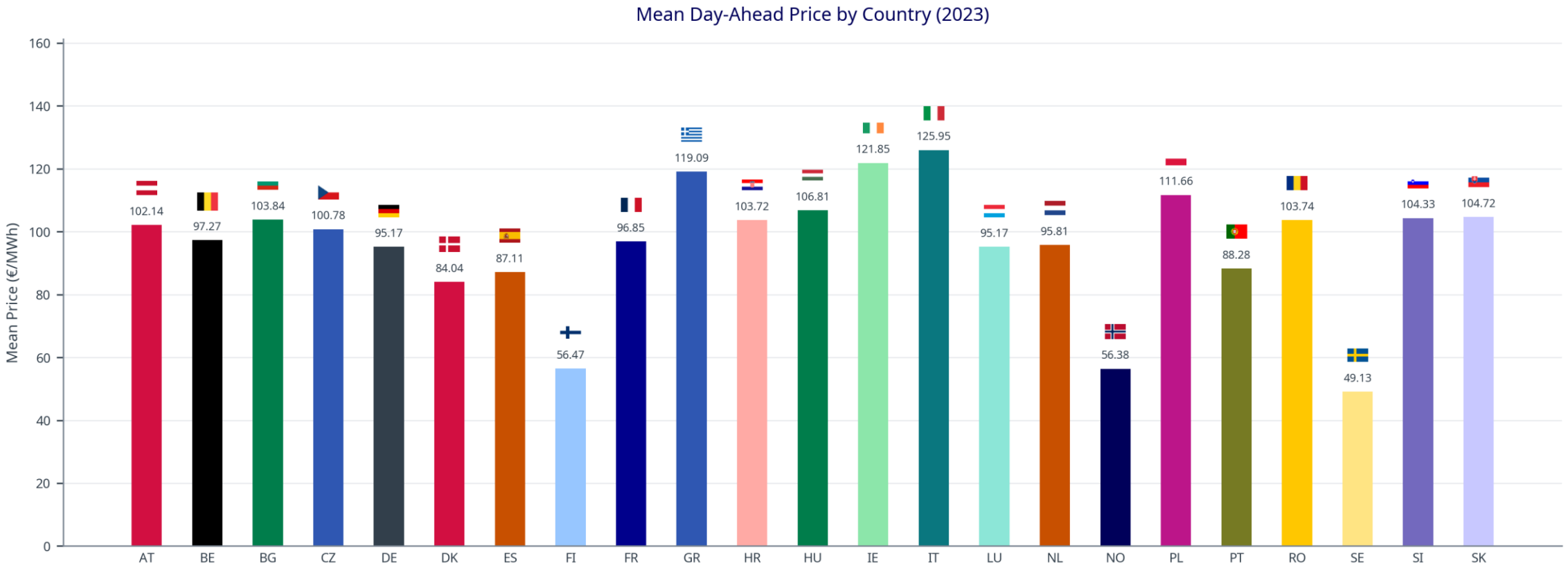
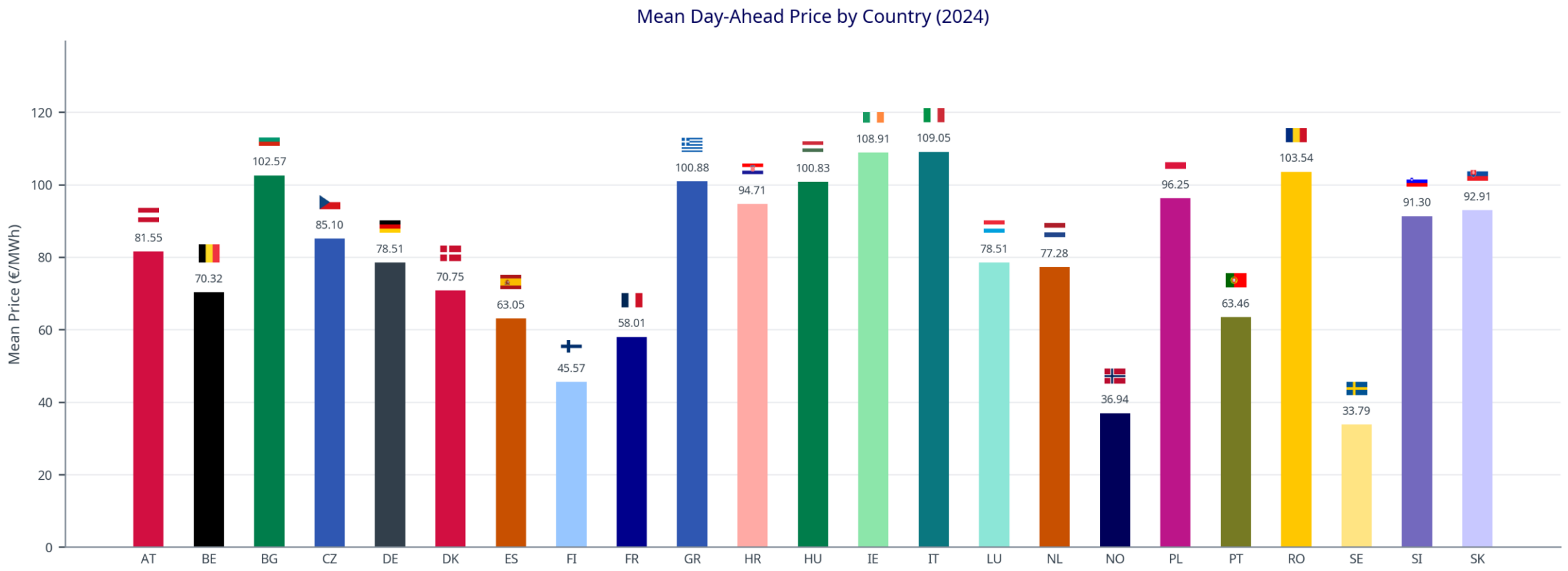

Mean Day-Ahead Price by Country (2023)
Mean Price (€/MWh)
0
20
40
60
80
100
120
140
160
AT 102.14
BE 97.27
BG 103.84
CZ 100.78
DE 95.17
DK 84.04
ES 87.11
FI 56.47
FR 96.85
GR 119.09
HR 103.72
HU 106.81
IE 121.85
IT 125.95
LU 95.17
NL 95.81
NO 56.38
PL 111.66
PT 88.28
RO 103.74
SE 49.13
SI 104.33
SK 104.72


Mean Day-Ahead Price by Country (2024)
Mean Price (€/MWh)
0
20
40
60
80
100
120
81.55
70.32
102.57
85.10
78.51
70.75
63.05
45.57
58.01
100.88
94.71
100.83
108.91
109.05
78.51
77.28
36.94
96.25
63.46
103.54
33.79
91.30
92.91
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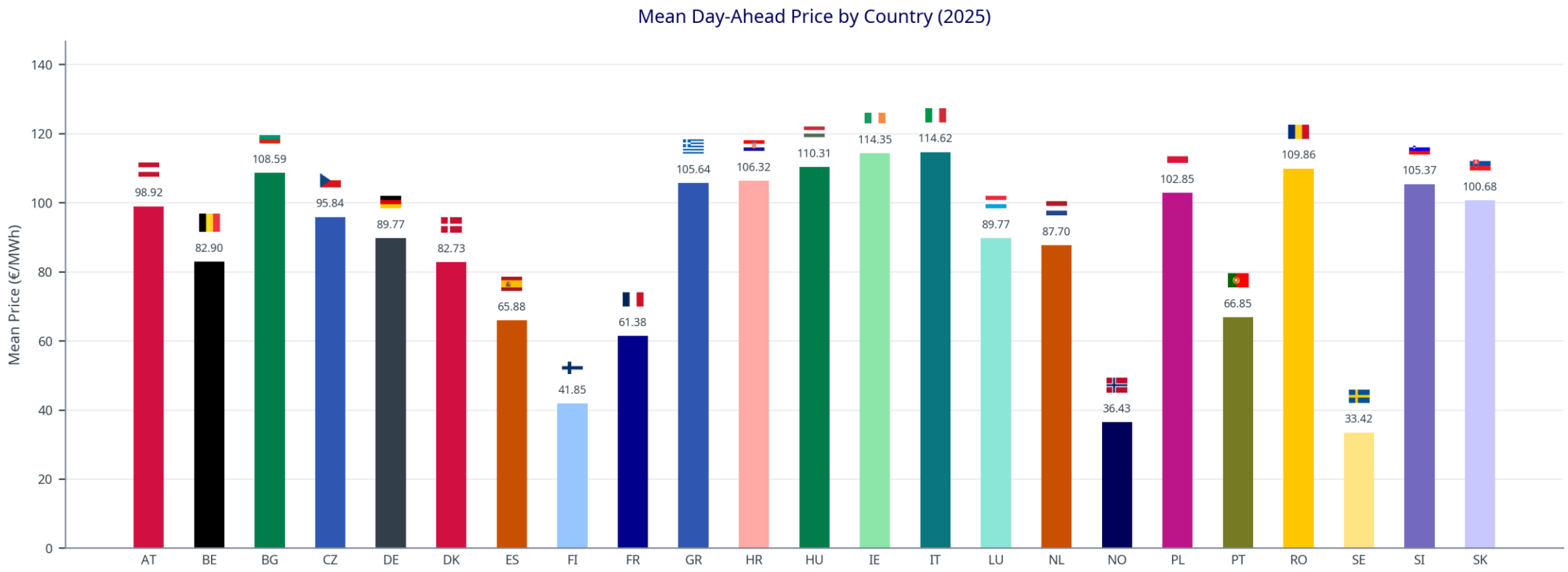
Mean Day-Ahead Price by Country (2025)
Mean Price (€/MWh)
0
20
40
60
80
100
120
140
98.92
82.90
108.59
95.84
89.77
82.73
65.88
41.85
61.38
105.64
106.32
110.31
114.35
114.62
89.77
87.70
36.43
102.85
66.85
109.86
33.42
105.37
100.68
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