A Restructured Moroccan Electricity Market and its Interaction with the Iberian Power Market

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Context and motivations

- Morocco is well ahead of the majority of African countries regarding the unbundling of its power sector and private sector's participation. Further liberalization efforts are ongoing;
- Morocco and Spain have been interconnected since 1997. In 2006, the first expansion of the interconnection's capacity was commissioned;
- Memorandum of Understanding signed in 2019 for the establishment of a third interconnection line between Spain and Morocco, to be commissioned in 2026; An interconnection between Morocco and Portugal is under study, to be commissioned by 2030.
- The first and unique existing grid interconnection between the African and the European continents.

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Objectives

- Analysing how a potential deregulated Moroccan electricity market and the Iberian power market would interact under market coupling and various scenarios of interconnection capacity: Isolated, current capacity and unlimited capacity.
  - Prices and their behaviour;
  - Congestion and congestion rents;
  - Overall social welfare.

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The Moroccan market

- Current state:
  - Structured as a single buyer market. The public utility (ONEE) plays a major role in all the sector's activities;
  - Allows for private sector participation in generation and distribution since 1993 and 1997, respectively.
- Simulated state:
  - The Moroccan market is designed similarly to European power markets, meaning that it operates on hourly basis as a uniform price auction;
  - The market design was chosen based on Morocco's current and future planned grid interconnections and the stated objectives of the country's national energy strategy.

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The Iberian market

- Established in July 2007, it unified the Portuguese and the Spanish electricity markets;
- MIBEL is a deregulated market that operates as a uniform price auction, structured on hourly basis.
- Due to its geographic conditions, the Iberian peninsula is an electricity island. It is solely interconnected to two other systems, Morocco and France, with a very low interconnection ratio: 3.4%.

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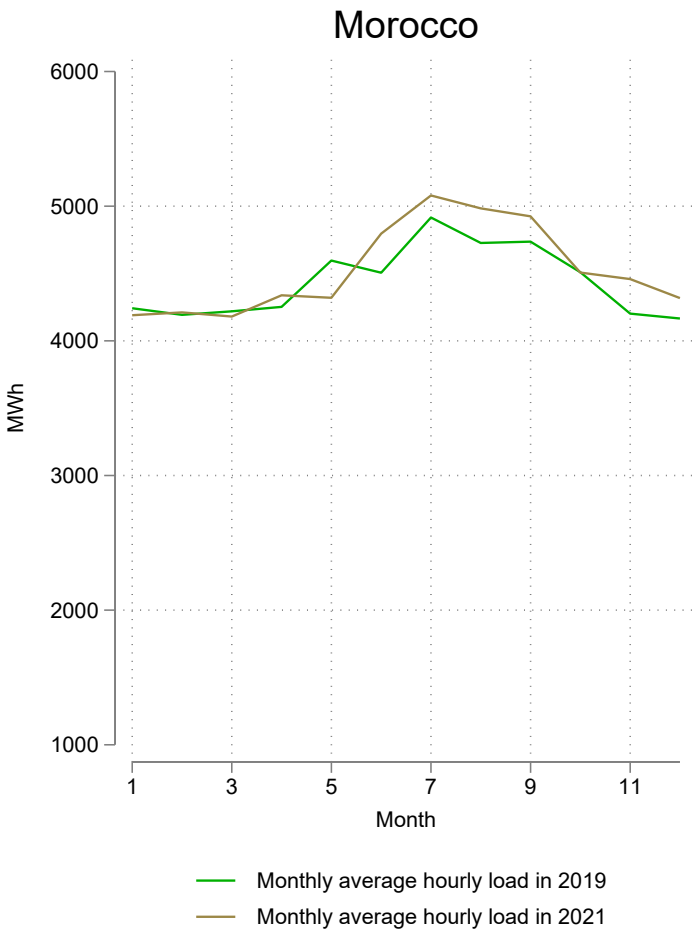
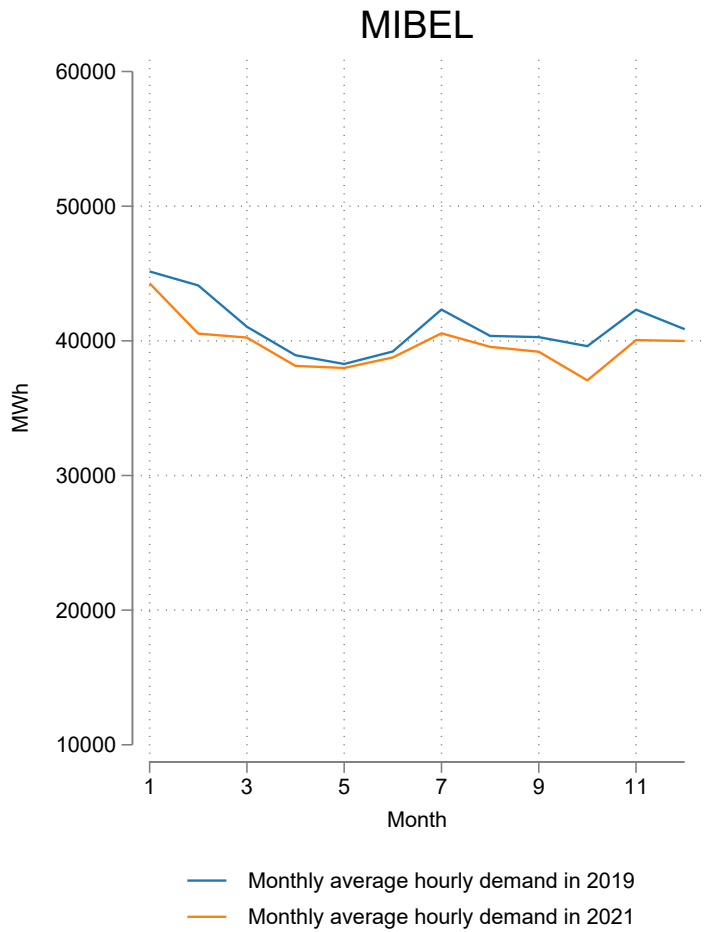
Monthly demand profiles





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Supply profiles: Installed Capacity

Technology	MIBEL (in MW)				Morocco (in MW)			
	2019	%	2021	%	2019	%	2021	%
Solar PV	9,395.00	7.53%	16,227.00	12.78%	175.00	1.64%	321.00	2.93%
Solar thermal	2,304.00	1.85%	2,304.00	1.81%	510.00	4.78%	510.00	4.65%
Wind	30,573.00	24.49%	33,140.00	26.09%	1,220.00	11.43%	1,466.00	13.37%
Regular hydropower	21,601.00	**17.31%**	21,610.00	**17.01%**	1,257.00	11.77%	1,306.00	11.91%
Pumped storage	6,027.00	4.83%	6,036.00	4.75%	464.00	4.35%	464.00	4.23%
Nuclear	7,117.00	5.70%	7,117.00	5.60%	0.00	0.00%	0.00	0.00%
Coal	10,971.00	8.79%	3,523.00	2.77%	4,092.00	**38.33%**	4,092.00	**37.31%**
Combined cycle	28,391.00	**22.75%**	28,391.00	**22.35%**	870.00	8.15%	870.00 *	7.93%
Other technologies	8,436.00	6.76%	8,670.00	6.83%	2,089.00	19.57%	1,939.00	17.68%
Total	124,815.00		127,018.00		10,677.00		10,968.00	

Source: Yearly reports of ONEE, the High Commission of Planing of Morocco, REE and REN.

* It should be noted that in the wake of the loss of natural gas supply from Algeria, resulting from the expiration of the Maghreb Europe gas pipeline contract, Moroccan combined cycle units were taken out of service at the end of October.

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Simulation of the market coupling of the Moroccan and the Iberian markets

- We simulate the day-ahead market coupling for the years 2019 and 2021;
- Cross border electricity trade is enabled by grid interconnections;
- The capacity of the interconnection determines how much electricity can be exchanged in each direction;
- The allocation of the interconnection's capacity in electricity markets is usually done through explicit or implicit auctions;
- Market coupling is an implicit allocation mechanism for the interconnection capacity.

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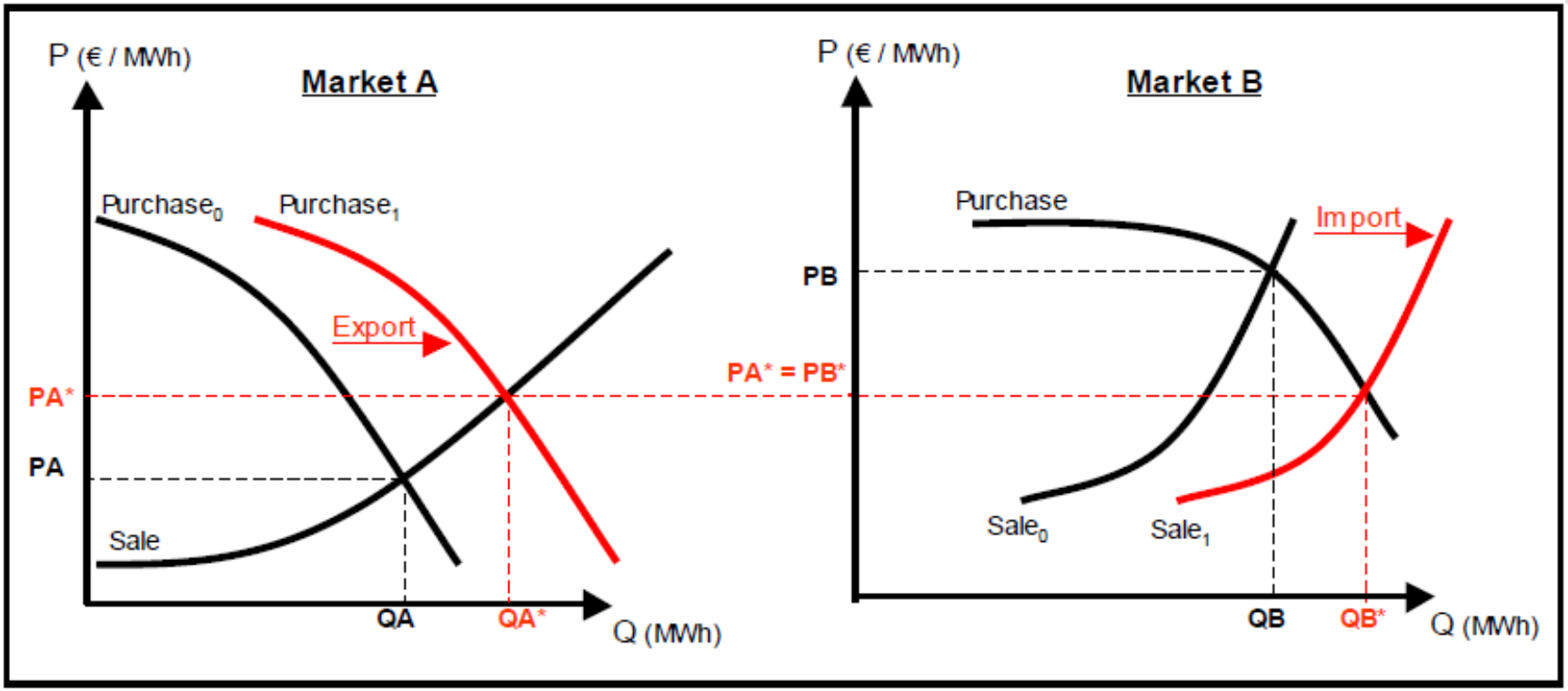
Market coupling (Source: EPEX)



- PA and PB are respectively the prices in the exporting and the importing markets, when they are isolated.
- When the markets are coupled and assuming sufficient interconnection capacity, the prices converge to a unique price PA* = PB*.

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Market coupling

- In market coupling, the markets are jointly cleared. Transfer capacity and energy are simultaneously allocated across the markets.
- Our simulation is based on a "Net Export Curves" (NEC) methodology.
- Market clearing occurs at the volume of exchange where the respective markets' willingness to export and to import electricity are equal.
- When the interconnection capacity is sufficient, prices in both markets converge to a unique price and we have a single market. Alternatively, congestion occurs, prices converge partially and congestion rents arise.

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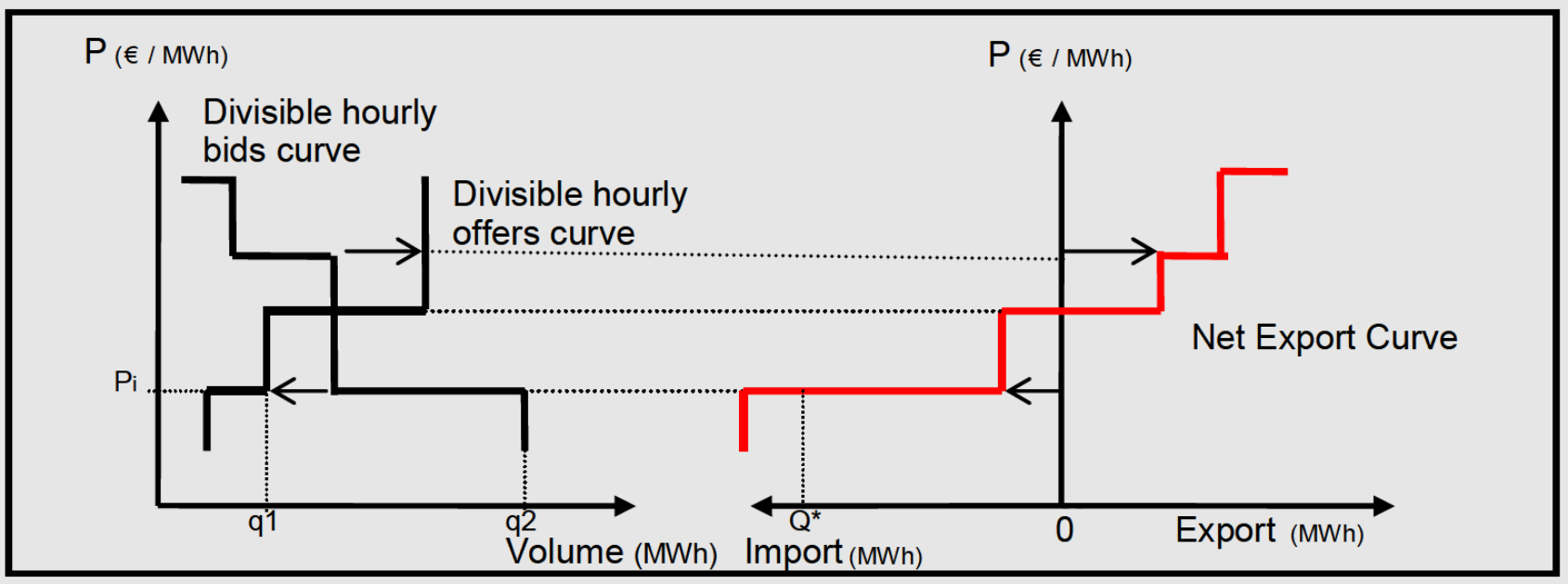
Construction of Net Export Curves (Source: EPEX)



– At every price level P_i, the NEC is defined as the willingness to export (positive NEC) or import (negative NEC), and computed as the difference between the aggregate supply and aggregate demand. In the above figure NEC $= Q* = q1 - q2$.

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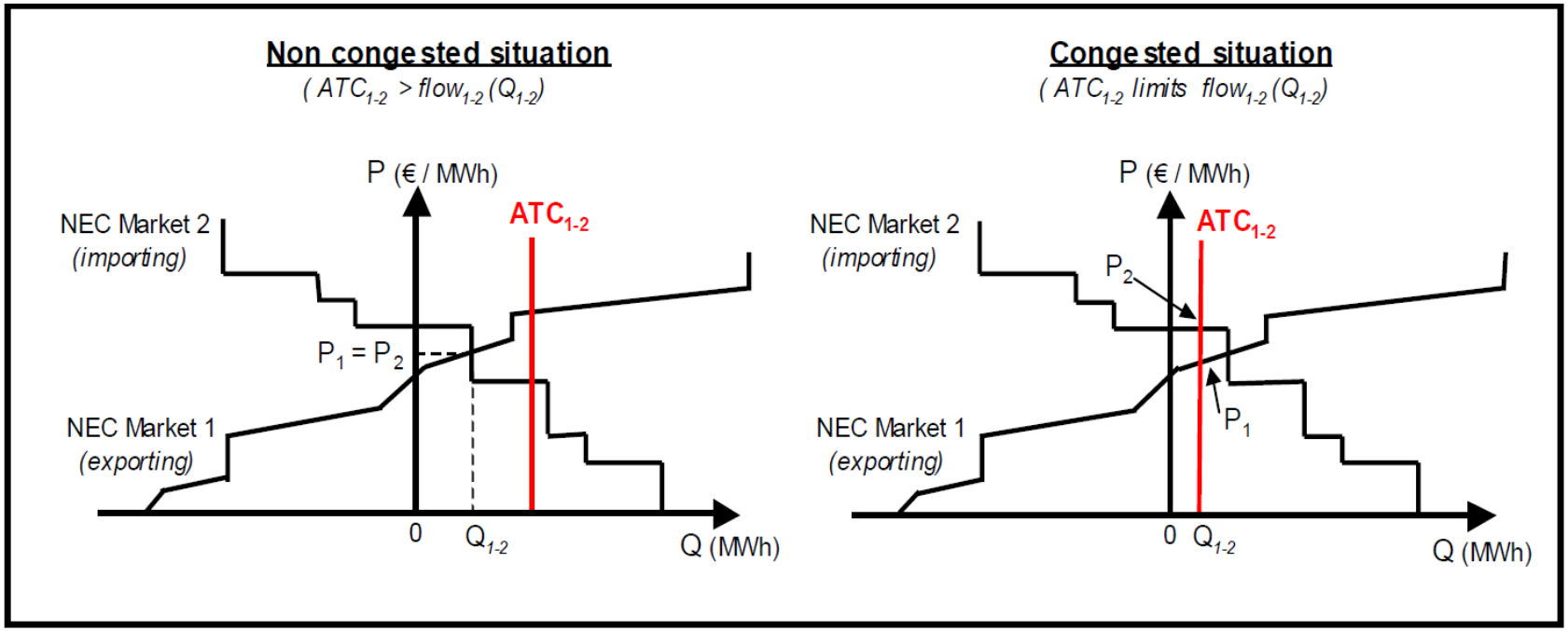
Illustration of NEC clearing (Source: EPEX)



- $ATC_{1\text{-}2}$ and $Q_{1\text{-}2}$ are respectively the Available Transfer Capacity and the volume flowing from market 1 (exporter) to market 2 (importer).
- P_1 and P_2 are respectively the clearing prices in markets 1 and 2.

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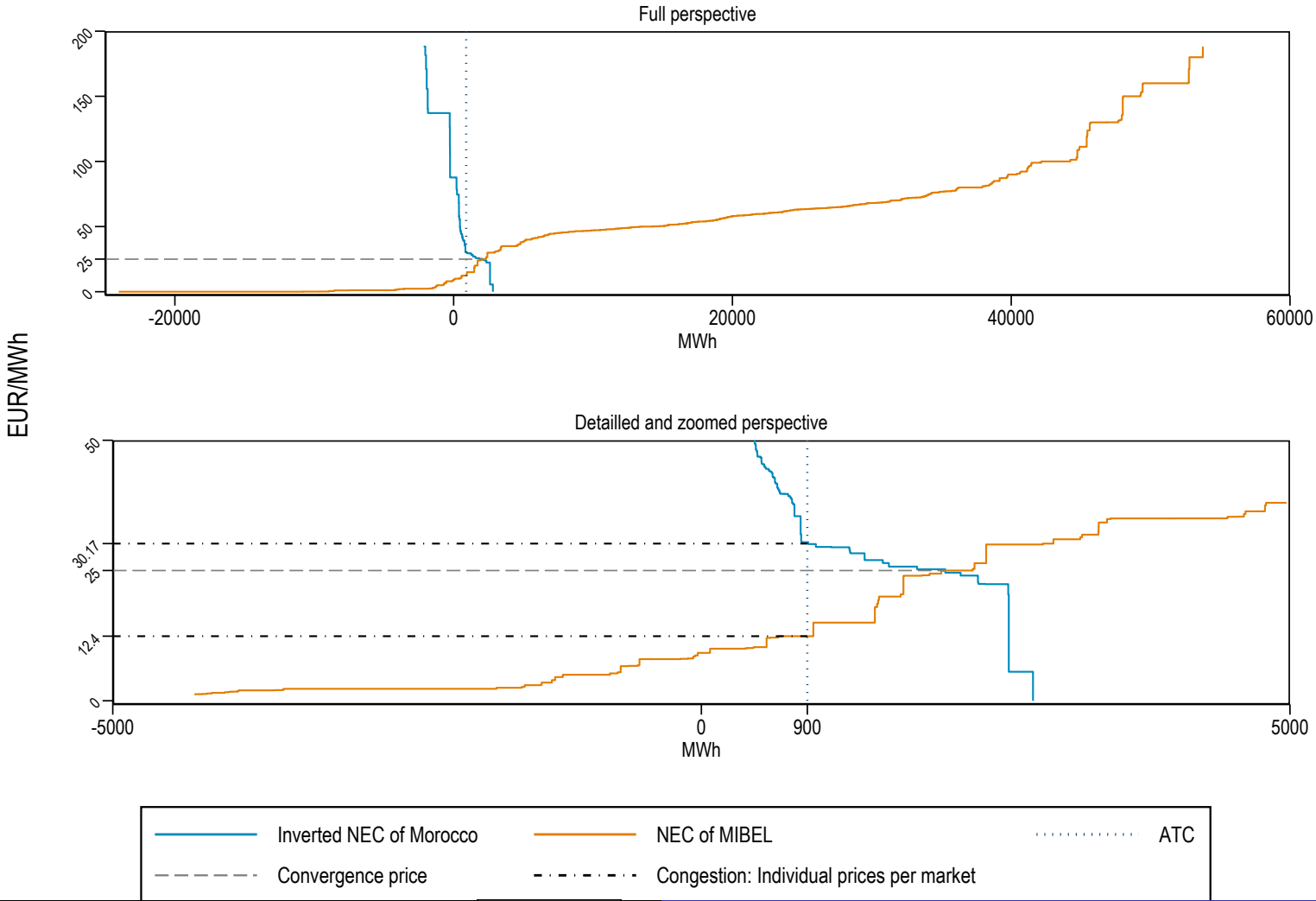
Results: Representative market coupling: 9 p.m, 01/02/2019.



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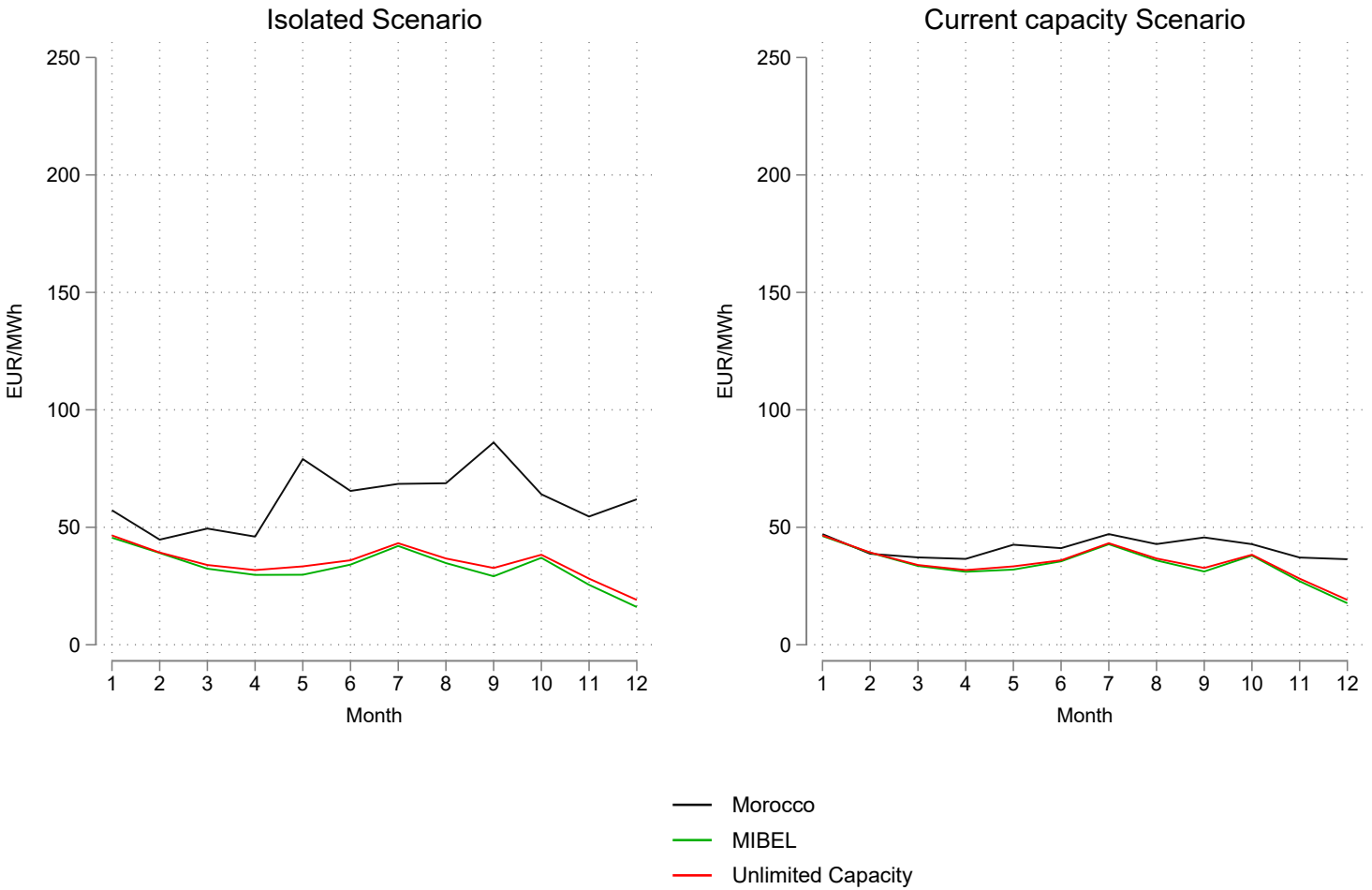
Average monthly market clearing prices in 2019



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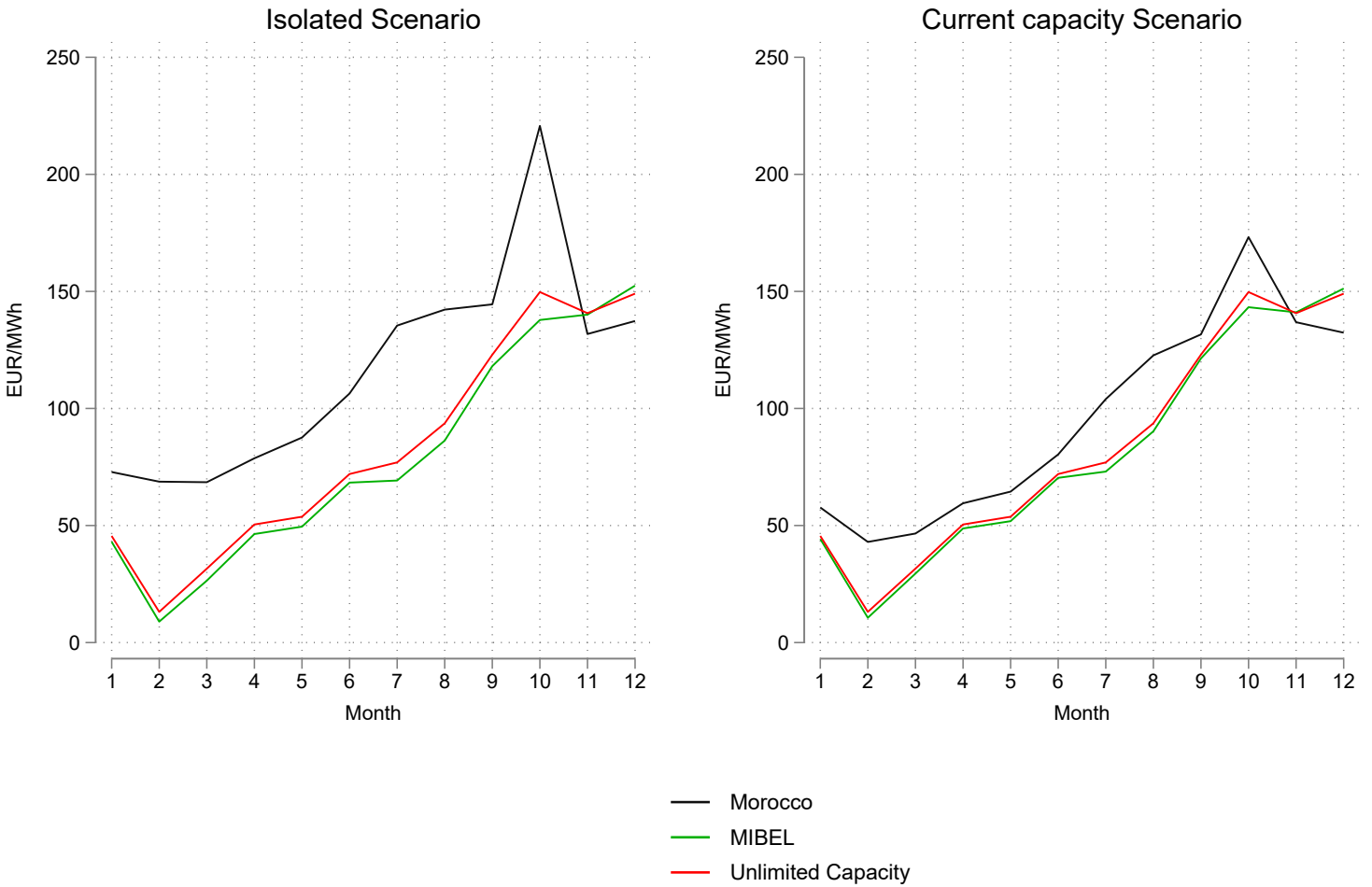
Average monthly market clearing prices in 2021



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Average annual prices in EUR per MWh by scenario, market and year

Year	2019		2021	
Scenario \ Market	Morocco	MIBEL	Morocco	MIBEL
Isolated	62.30	32.93	116.61	79.31
Current capacity	41.30	34.17	96.42	81.73
Unlimited capacity	34.92		83.73	

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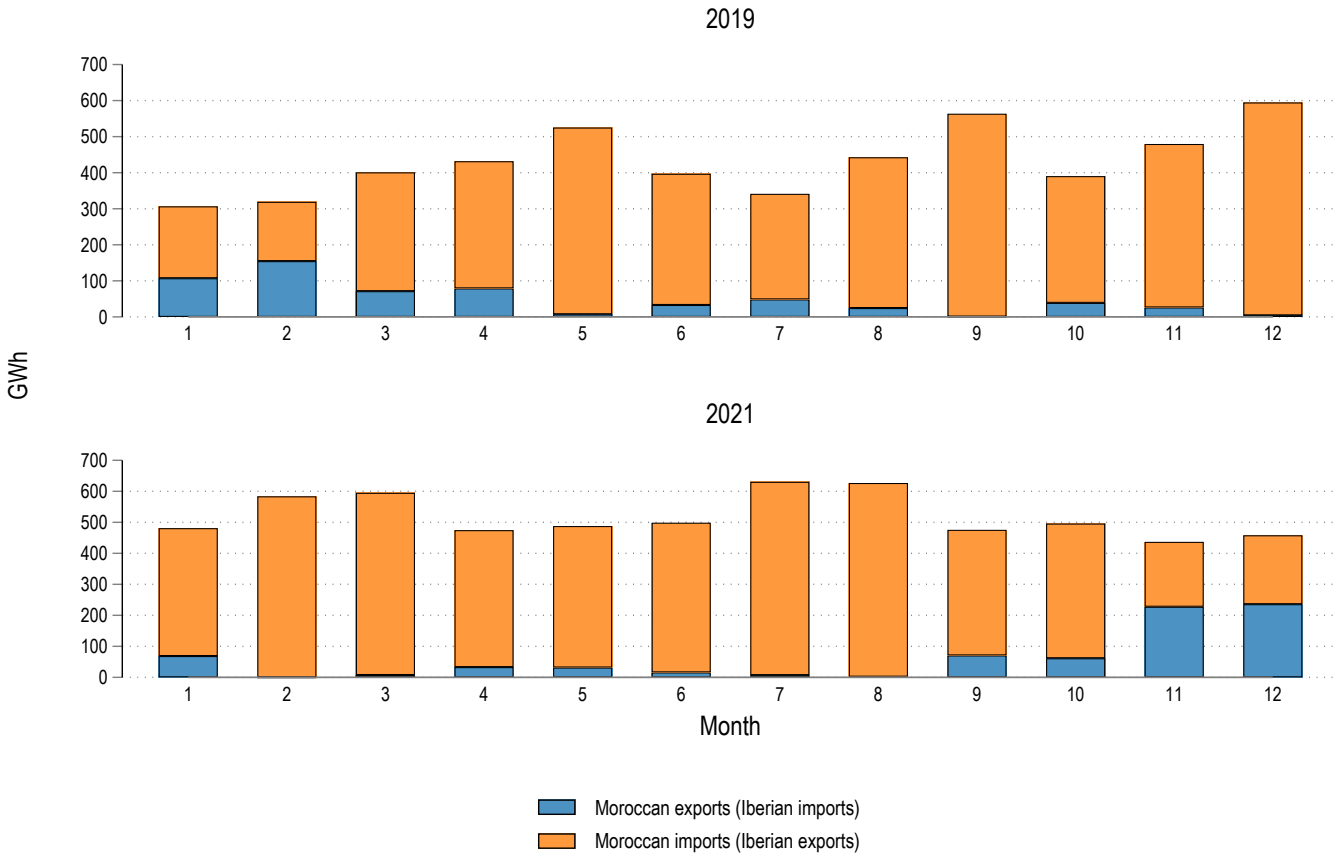
Aggregate cross-border electricity trade by month, in GWh



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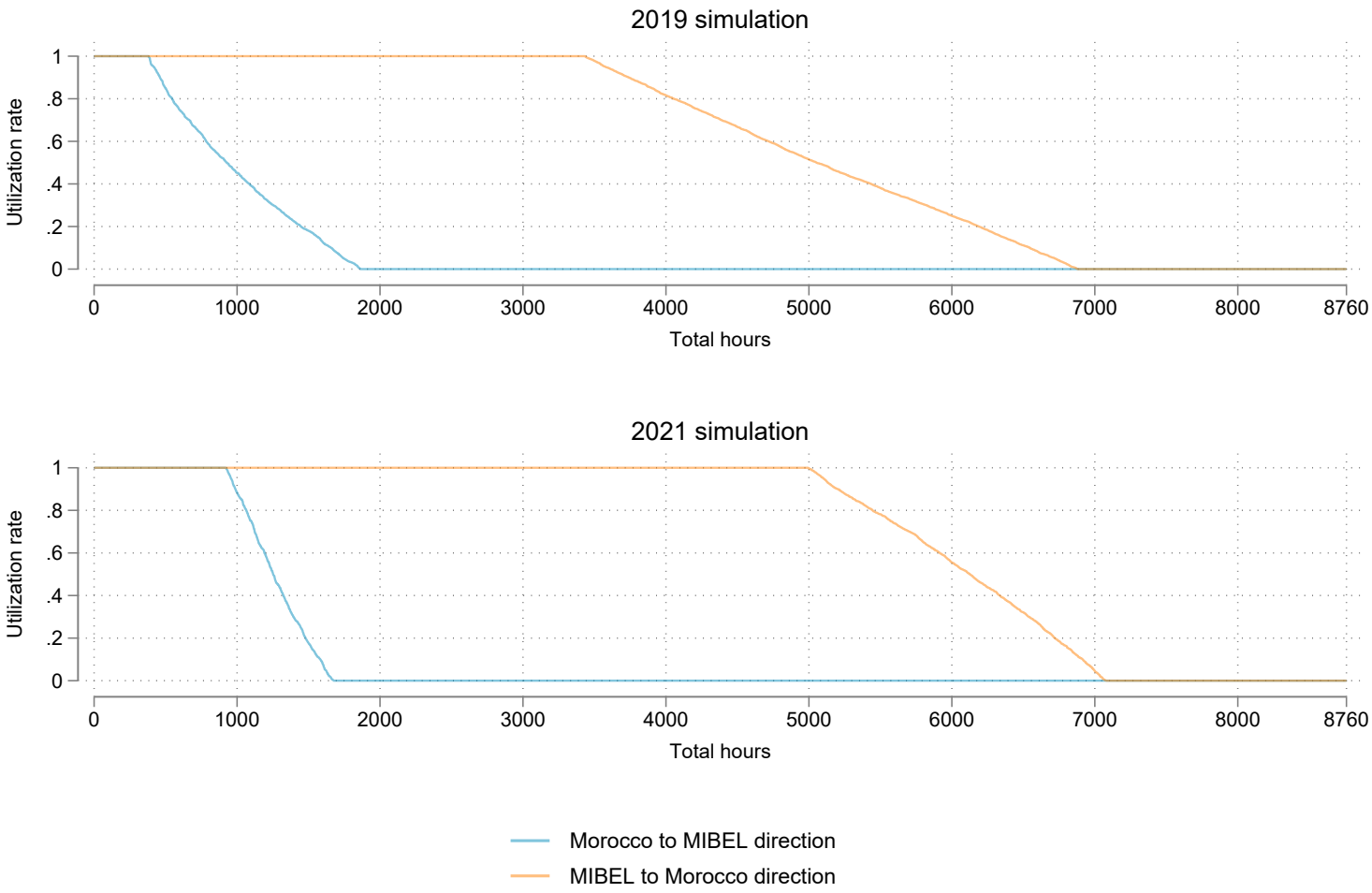
Hourly utilization rate of the interconnection in the current capacity scenario



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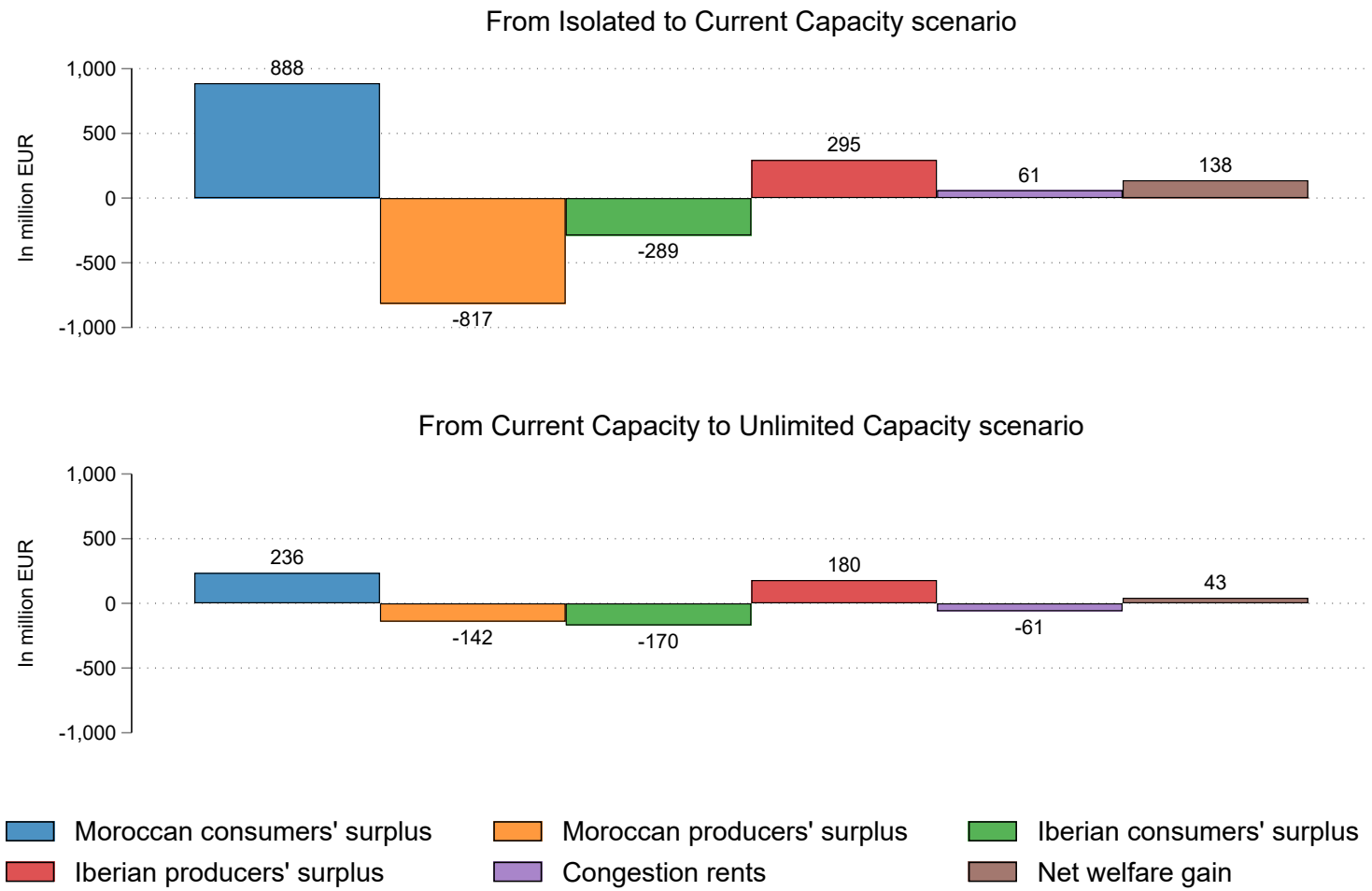
Social welfare changes across scenarios in 2019



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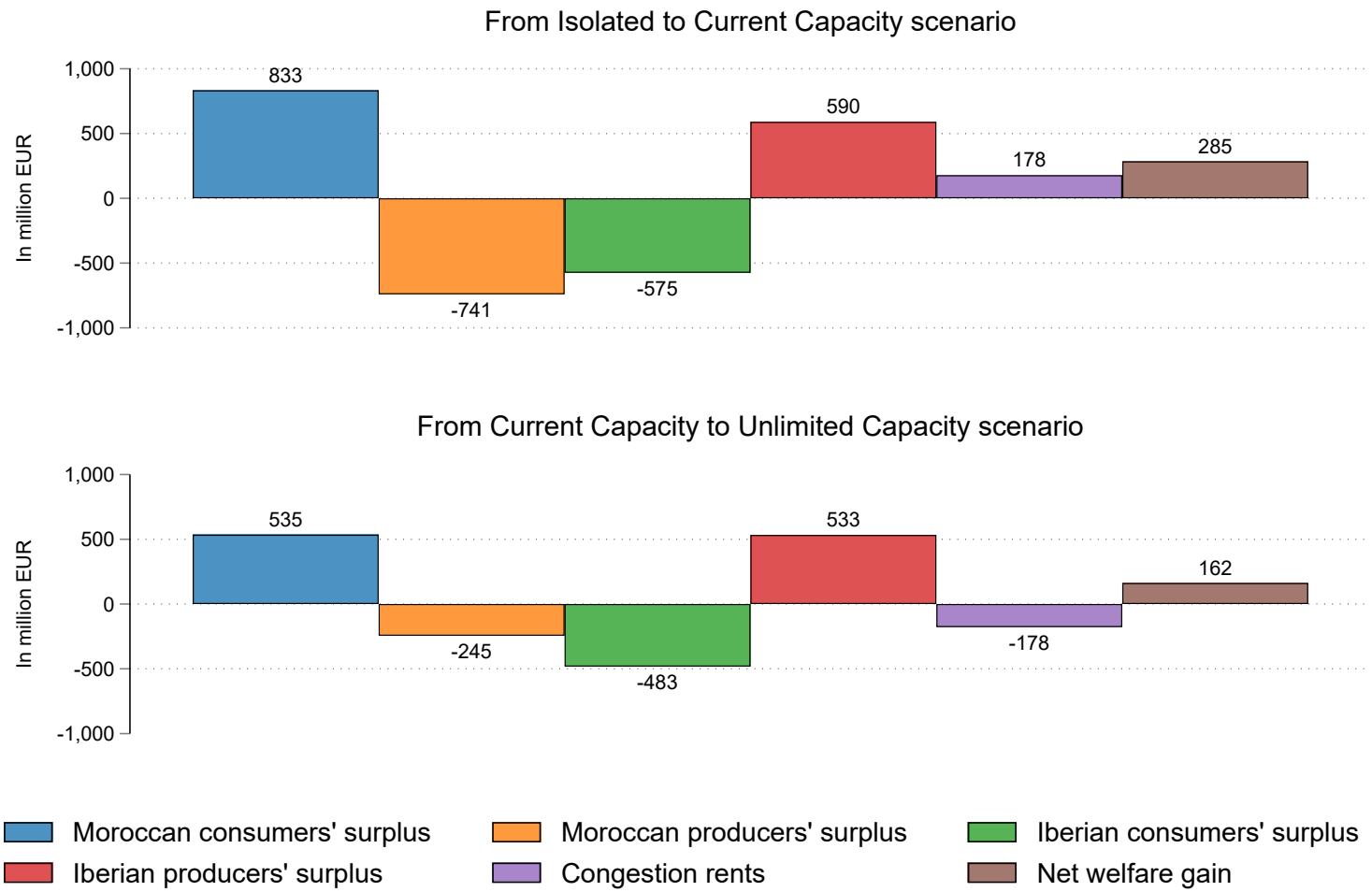

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Conclusions

- Our results indicate substantial welfare benefits from the existing interconnection in the hypothetical scenario for both simulated years.
- Further potential benefits are attainable by expanding the capacity of the interconnection, particularly in the MIBEL to Morocco direction.
- Welfare gains generated by grid interconnections are largely explained by cross-border price differences.
- Results from social welfare analyses of interconnections carried over a single year, as is common in the literature, cannot necessarily be generalized over longer time horizons.

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Ongoing sections

- We carry out a similar simulation, but this time for the year 2030, and with additional grid capacity scenarios.
  - Spanish supply and demand profiles in 2030 are built based on the "National Integrated Energy and Climate Plan (PNIEC) 2023-2030".
  - Moroccan supply and demand profiles in 2030 are built based on the Ministry of energy's planned projects and estimated demand growth.
- An econometric analysis quantifying the effect of the cross-border price-gap on the social welfare generated by the interconnection.

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Thank you for your attention !

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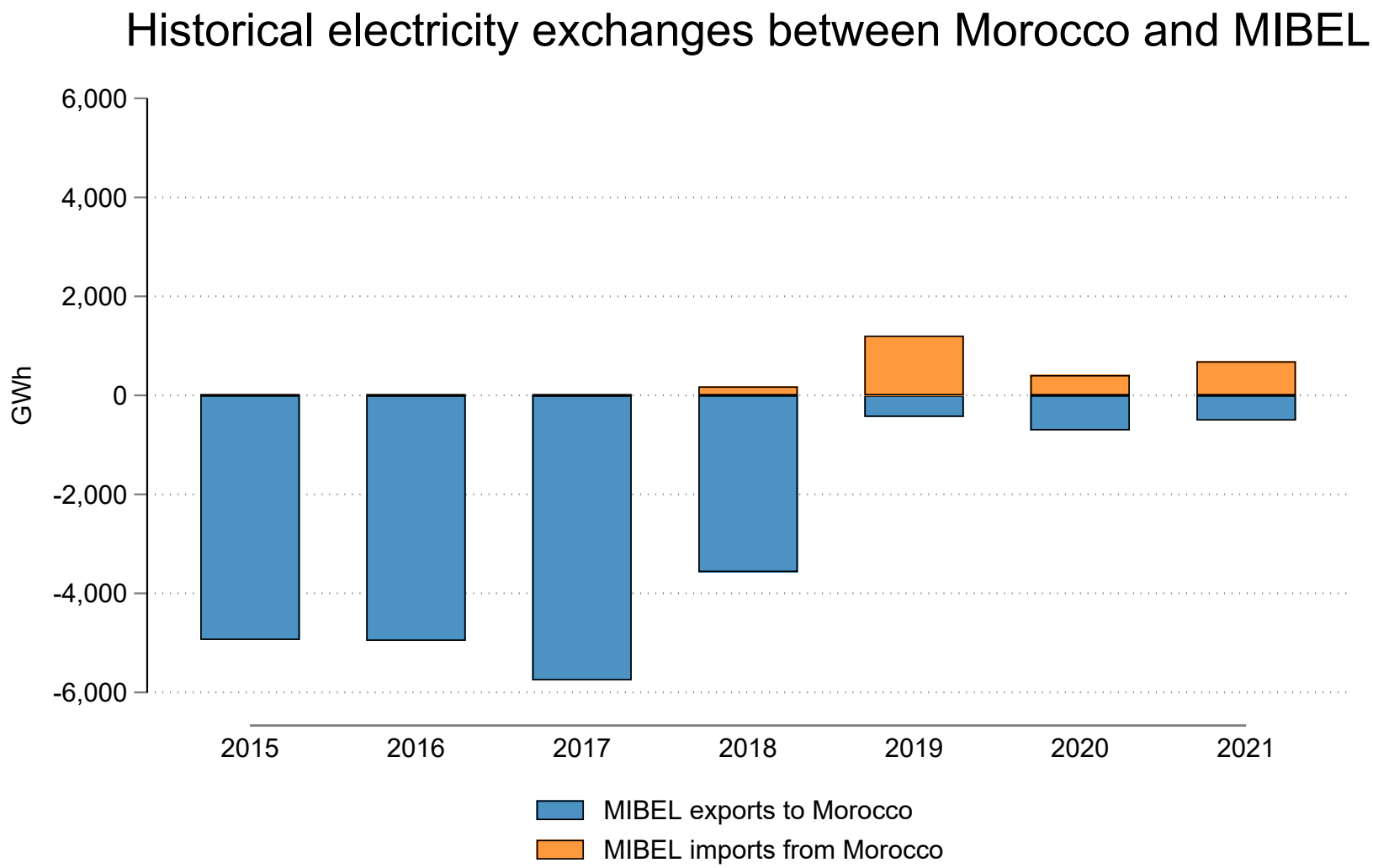
Cross-border electricity trade between the two regions



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Social welfare computations

$$\text{Interconnection Utilisation Rate} = \frac{Ex_d}{ATC_d} \tag{1}$$

$$\text{Consumer Surplus}_z = \sum_{j=1}^{l} \sum_{b=1}^{m} \left[(Pd_{jb}^{o} - MCP_z) \cdot Qd_{jb} \right] \tag{2}$$

$$\text{Producer Surplus}_z = \sum_{i=1}^{n} \sum_{b=1}^{m} \left[(MCP_z - Ps_{ib}^{o}) \cdot Qs_{ib} \right] \tag{3}$$

$$\text{Congestion Rent} = |MCP_z - MCP_{z'}| \cdot ATC_d; \tag{4}$$

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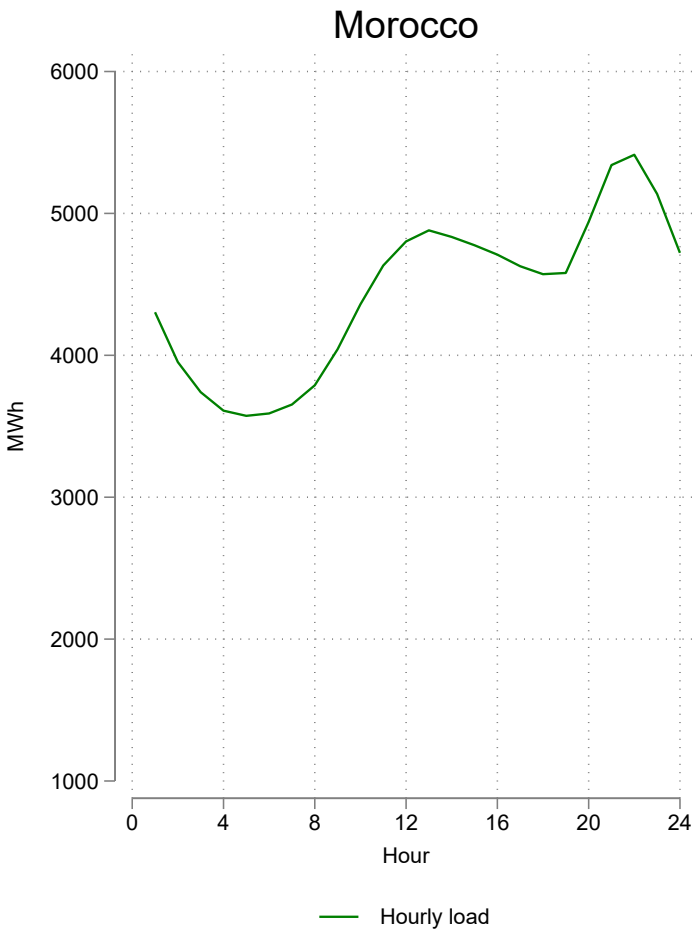
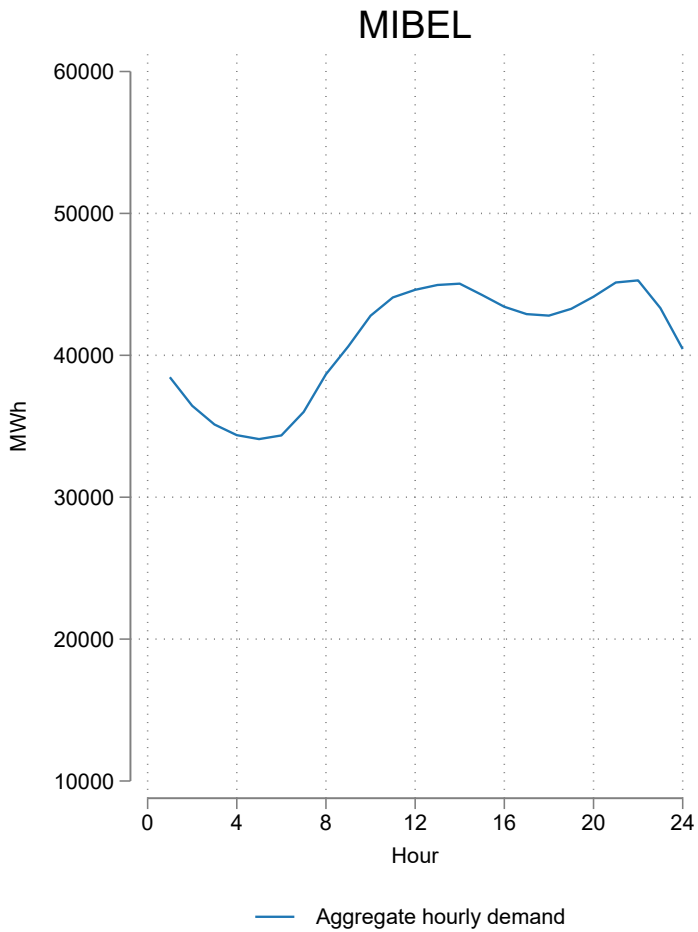
Hourly demand profiles





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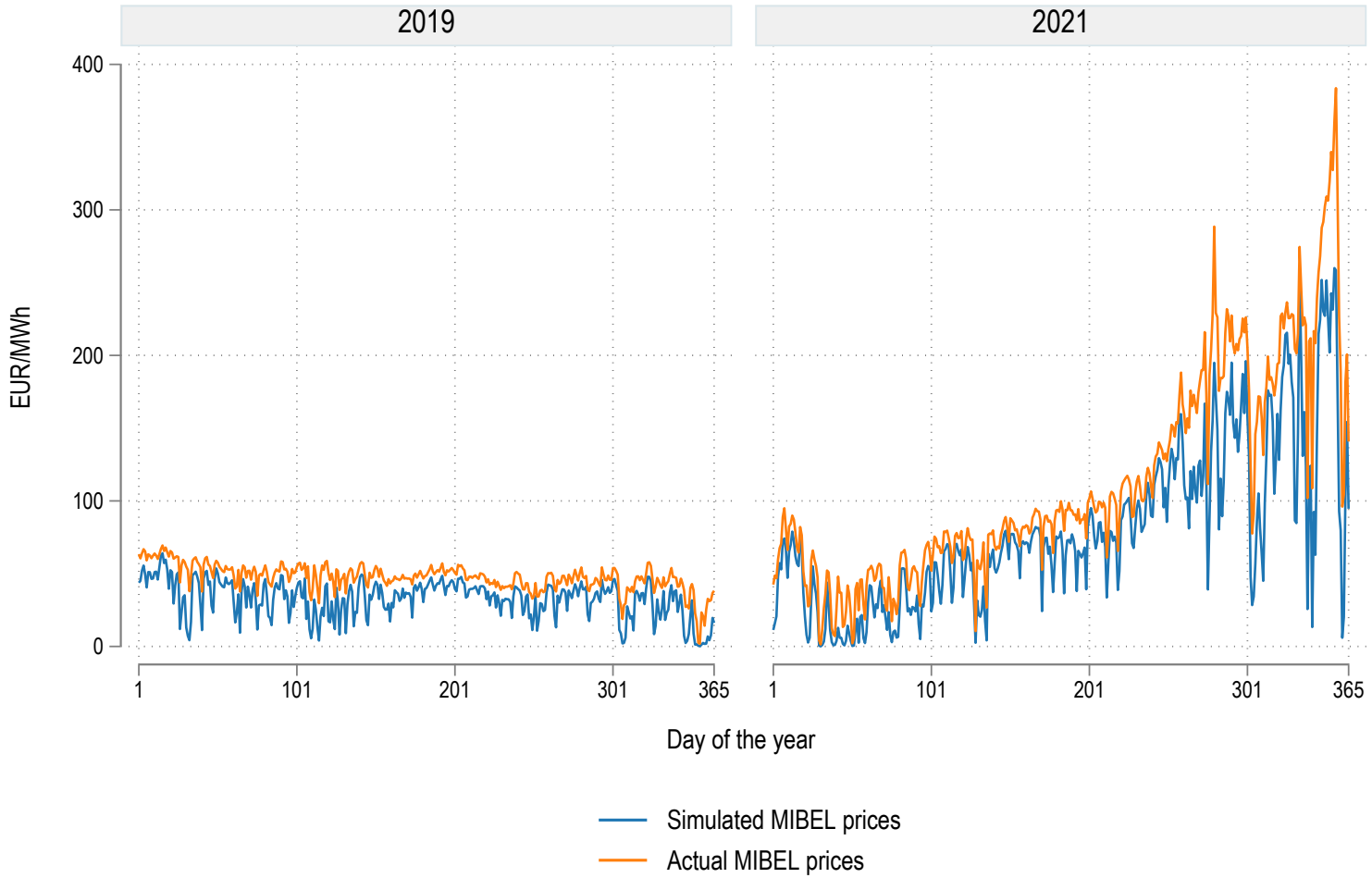
Simulated VS actual MIBEL



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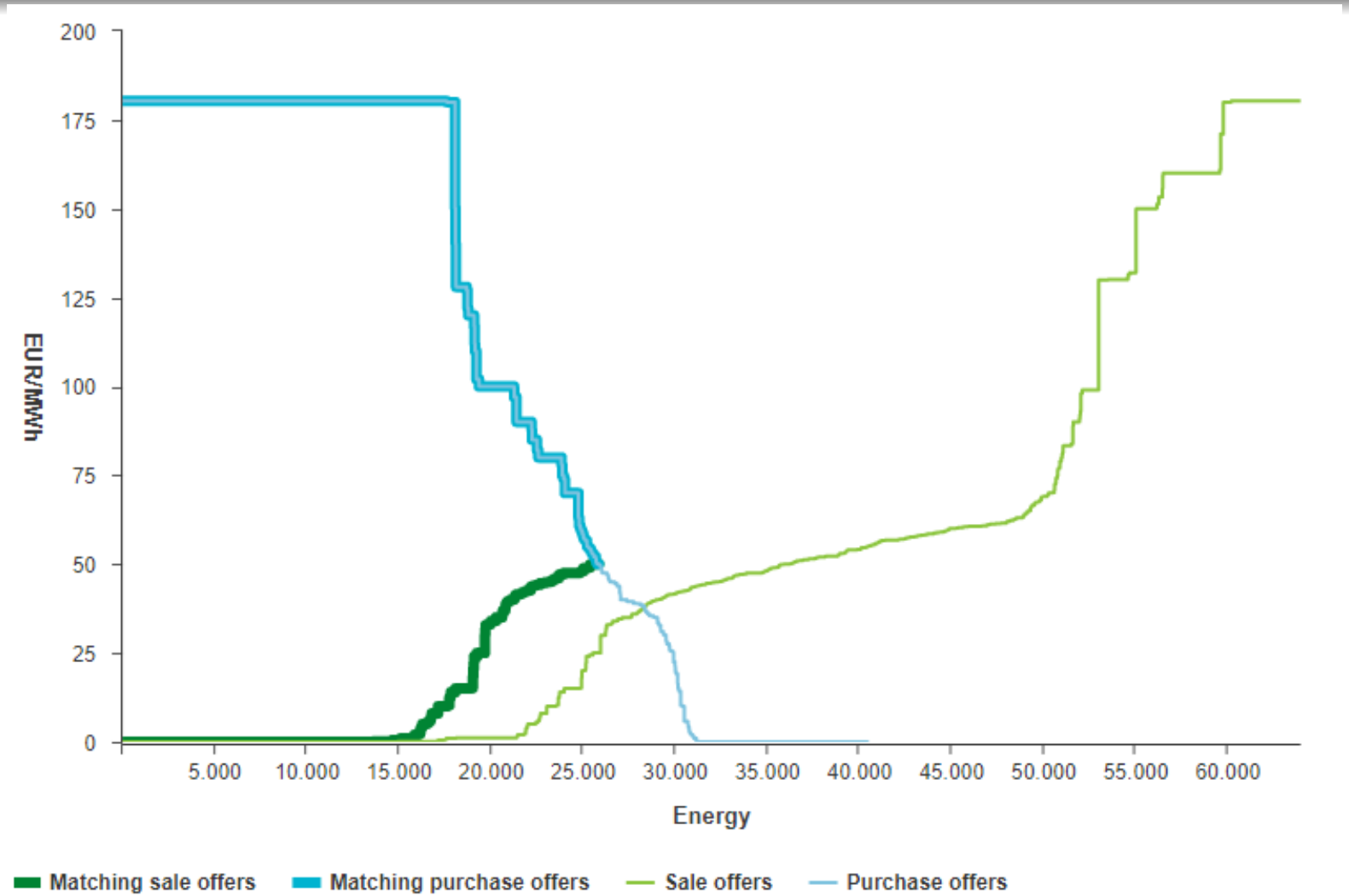
MIBEL clearing, before and after consideration of domestic transmission constraints and European coupling



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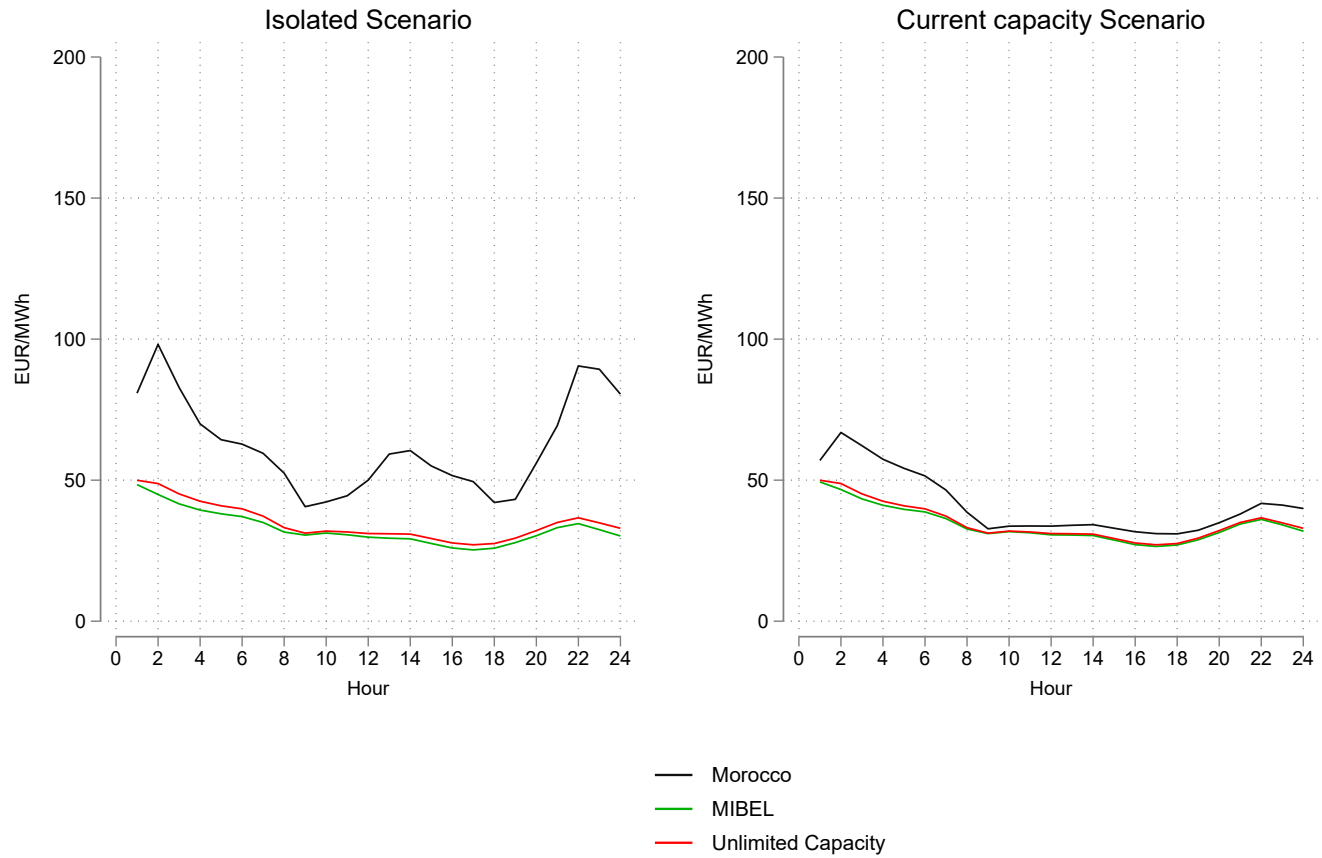
Average hourly market clearing prices in 2019



**Prices are higher in late night hours because domestic transmission constraints and complex execution conditions are not considered.*

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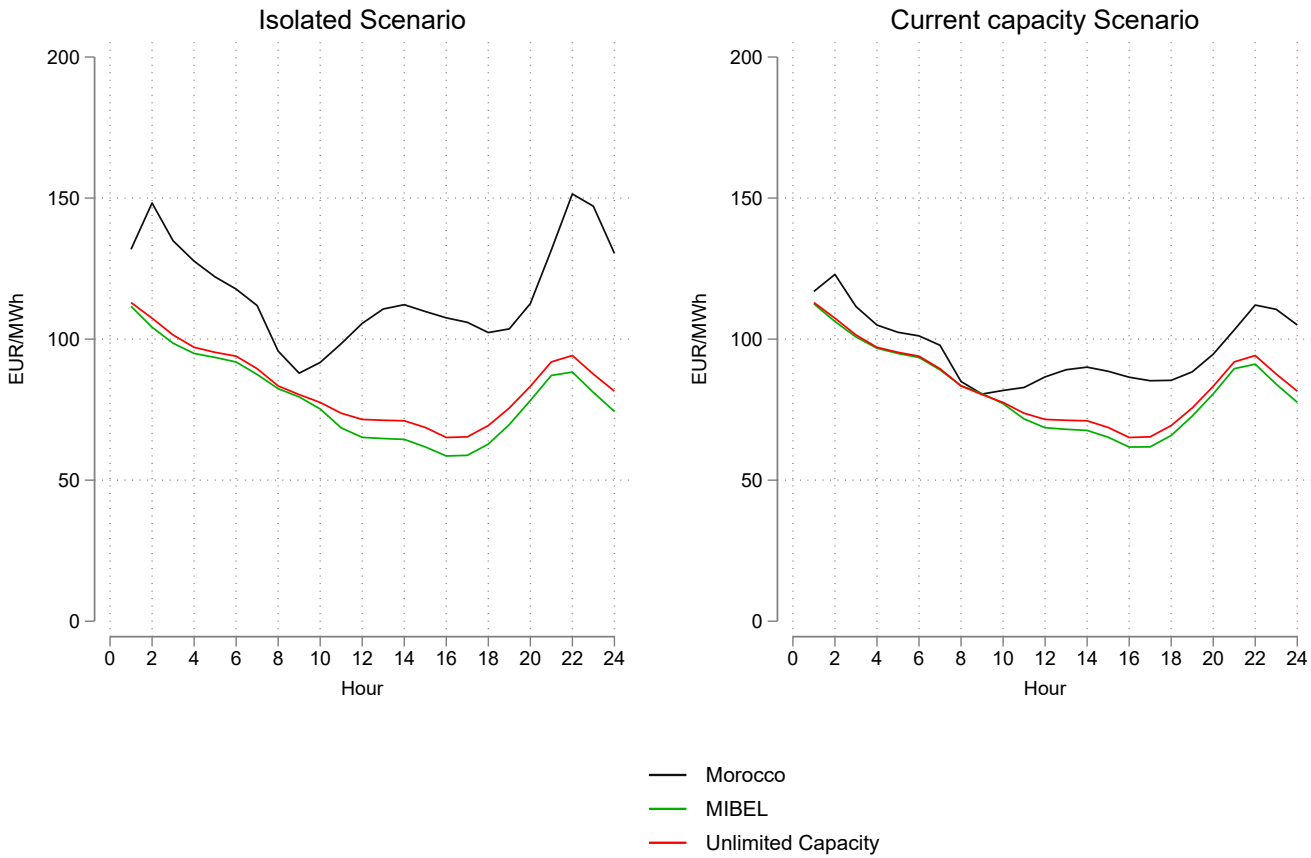
Average hourly market clearing prices in 2021



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Market coupling formulated as an optimisation problem

$$\max_{Qd_{zjb},Qs_{zib}} \left[\sum_{z} \left(\sum_{j=1}^{l} \sum_{b=1}^{m} (Pd^{o}_{zjb} \cdot Qd_{zjb}) - \sum_{i=1}^{n} \sum_{b=1}^{m} (Ps^{o}_{zib} \cdot Qs_{zib}) \right) \right], \quad (5)$$

$$\text{Subject to} \sum_{z} \sum_{i=1}^{l} \sum_{b=1}^{m} Qd_{zjb} = \sum_{z} \sum_{i=1}^{n} \sum_{b=1}^{m} Qs_{zib}, \quad (6)$$

$$\left| \sum_{i=1}^{l} \sum_{b=1}^{m} Qs_{zib} - \sum_{j=1}^{n} \sum_{b=1}^{m} Qd_{zjb} \right| \leq ATC_{d}, \quad (7)$$

$$\forall i, \sum_{b=1}^{m} Qs_{zib} \leq C_{zi}, \quad (8)$$

$$\forall i, Qs_{zib} \leq Qs^{o}_{zib}, \quad (9)$$

$$\forall i, Qd_{zjb} \leq Qd^{o}_{zjb}, \quad (10)$$

$$Qs_{zib} \geq 0, \quad (11)$$

$$Qd_{zjb} \geq 0. \quad (12)$$

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Market coupling formulated as an optimisation problem

Where Qd^{o}_{jb}, Pd^{o}_{jb} and Qs^{o}_{ib}, Ps^{o}_{ib} are respectively the pair of bid volumes and prices by purchaser j ($j = 1, 2, ..., l$) and generator i ($i = 1, 2, ..., n$) for their bid b ($b = 1, 2, ..., m \leq 25$), C_i is the installed capacity of power plant i, Qd_{jb} and Qs_{ib} are the decision variables of the optimization problem and represent the optimal volume to dispatch from each received bid.

Subscript z = MIBEL, Morocco identifies each market, Whereas ATC_d refers to the available transfer capacity in the trade direction d (from MIBEL to Morocco, or the reverse).

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