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Comparison of European electricity market designs

Kirstin Ganz, Luca Neumann, Louisa Wasmeier, Michael Hinterstocker
FfE, Munich
Tel.: +49-89-158-12-149
kganz@ffe.de

Abstract

The energy system is changing with the expansion of renewable energies. This structural change requires flexibility. This flexibility can be provided by small-scall flexible assets. However, the expansion of large quantities of small-scall flexible assets can only be realized based on profitable business models. Therefore, new marketing strategies for small-scale flexible assets are needed. On the one hand, this challenge is valid for the whole of Europe. On the other hand, marketing strategies are often explicitly developed only for a single country. Although there are efforts to create a common electricity market, the markets are rather different in detail due to the different conditions in each country (composition of generation and demand, history etc.). This leads to the research question, whether it is possible to transfer marketing strategies designed in Germany to other countries. To address this question, in this work, a holistic comparison of the different electricity market designs in Europe is performed.
For this purpose, the following methodology is applied: first, the system boundaries – both geographical and market design boundaries – are defined. This is followed by the identification of key figures to describe the market mechanisms of the different European market designs. In the last step, the differences between the market design of several European countries are compared to the German market design.
The geographical boundaries are based on the borders of the European Union, the membership of the power exchanges in the NEMO-Committee and is extended by the countries United Kingdom and Switzerland due to their central location and political relevance. In addition, smaller countries are pooled, resulting in 26 regions. In total 5 market mechanisms are considered: spot markets, forward markets, balancing services, existence of capacity mechanism and number of bidding zones. The market mechanisms are specified with in total 19 different key figures.
As a result, the countries Italy, Ireland, Spain, the United Kingdom, and the Czech Republic show the highest deviations from the German market design. The high rating can be derived mainly from the large (e.g. Italy) or small (e.g. Czech Republic) variety of trading products on the respective markets. In particular, the characteristics of balancing energy are the most influential factor when comparing the countries with each other.

Introduction

In the course of the decarbonization of the energy, sector constant fossil generation is replaced by volatile renewable energies. This leads to the necessity for flexibility to maintain a stable energy system. On the other side, the electrification of demand as well as ongoing improvements in the area of storage technologies introduces a large number of new flexible assets. To make this flexibility potential available to the energy system, new business models for small-scale flexible assets are currently developed. Yet, these business models depend on the preconditions of electricity markets and the regulatory framework. Thus, for one business model to be transferable to another country, the countries' market design needs to be comparable to a certain degree.
The European Union (EU) aims at establishing "common rules for the generation, transmission, distribution, energy storage and supply of electricity" [1]. Nevertheless, despite the EU single market regulation, there are still clear differences among the electricity markets of European countries [2]. Therefore, this work assesses the characteristics of electricity markets in European countries. It thereby aims to identify the major differences and similarities among the electricity market design of those countries. Electricity market design thereby can be characterized as the organization and distinction of the single market mechanisms [3]. Thus, this work takes a selection of market mechanisms into account and compares certain characteristics of those mechanisms as key figures for relevant European market regions. As a result, the identified differences and similarities of the market designs can be taken as a basis to transfer modeled revenues and costs for small-scale flexible assets from Germany to other European countries.
The methodology of this assessment is explained in the following chapter, describing the three steps of system boundary definition, key figure identification and market design evaluation. In the following chapter, the results of each step are presented. The last chapter draws concluding remarks and indicates possible directions for further research.

1. Methodology

The methodology is split in three parts: defining system boundaries, identifying key figures, and evaluating market design difference value (see Figure 1).

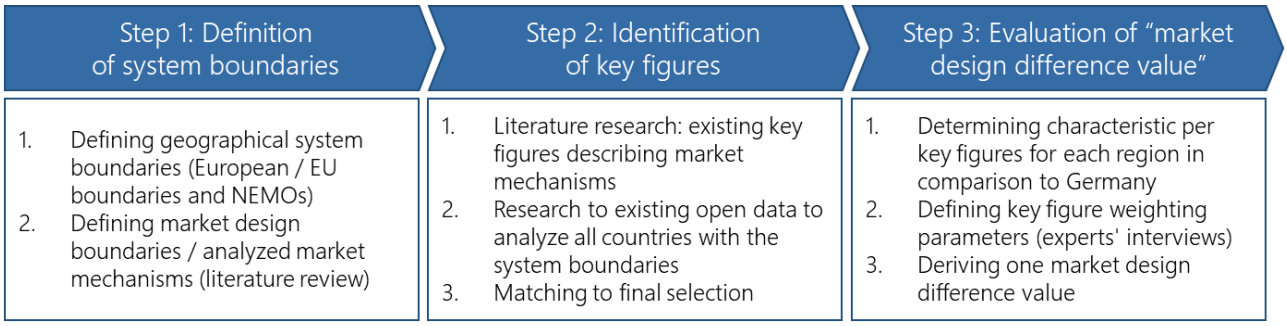

Figure 1 – Methodology

First, the system boundaries are defined. This includes the geographical boundaries as well as the market design boundaries. The geographical boundaries are based on the European/ EU borders and the Nominated Electricity Market Operators (NEMO) operating in Europe. Geographical boundaries were adjusted by the division of the NEMOs areas, such that public data availability is included in the boundary definition. Also, country size and economical relevance within Europe is considered leading to countries with lower

economical relevance being summarized to one region. The market design boundaries, referring to the market mechanisms analyzed, are determined via a literature review about existing markets in Europe.
The second step is to identify key figures describing the regions' market design. This is performed by a literature review about existing key figures, which is compared with possible open data of the relevant TSOs / NEMOs to determine a final selection of key figures.
The last step is the evaluation of the market design difference value. First, for each market mechanism of each region, a characteristic per key figure is determined. Depending on the difference of the associated characteristic to the same characteristic for Germany, each key figure gets a binary value P_i to show the difference to the German market design. Thus, when a country's characteristic does not differ from the German market design, the key figure is set as 0, and conversely when the characteristic clearly differs, the key figure is set to 1. Due to the varying degrees of impact of the key figures, these binary values P_i can't be summarized uniformly but must be weighted. To derive weighting parameters for each key figure (on each market) W_i, five institute-internal expert interviews are performed. The final weighting parameter is calculated as the mean value of these 5 interview participants, the authors' choice, and a non-weighted solution (to reduce the subjectivity of the interviews). An overall score for each country y is calculated as the sum of the binary values P_i multiplied with the weighting parameters W_i (see EQ. 1):

$$y = \sum_{i=1}^{m} P_i \frac{W_i^{interview\ 1} + W_i^{interview\ 2} + W_i^{interview\ 3} + W_i^{interveiw\ 4} + W_i^{interview\ 5} + W_i^{author} + 1}{7}, \quad (1)$$

with m as the number of key figures and $\sum W_i = 1$.
This score y provides information on the similarities and differences of the regions' electricity market design compared to Germany.

2. Results

The results are illustrated according to the methodology in 3 steps: definition of the system boundaries, identification of key figures, and evaluating market design difference value.

Step 1: Definition of the system boundaries
In total 26 regions in Europe are considered in this paper, illustrated in Figure 2 with their representative NEMOs. The regions are orientated at countries' borders with some exceptions: the Baltic countries which are considered as one region and Luxembourg and Northern Ireland are integrated in Germany and Ireland, respectively, as each these regions form one united bidding zone. Moreover, the two Danish market areas are analyzed as two separate regions, as they do not only have separate price building, but also different market design characteristics. Thus, the following regions were analyzed: Germany (including Luxembourg), France, Austria, Belgium, Finland, Great Britain (without Northern Ireland), Poland, Italy, Denmark 1 (western part of Denmark), Denmark 2 (eastern part of Denmark), Switzerland, Spain, Portugal, Sweden, Norway, Czech Republic, Netherlands, Ireland (including Northern Ireland) Slovakia, Romania, Hungary, Greece, Bulgaria, Croatia, Slovenia, and the Baltic countries (Latvia, Lithuania, Estonia).
The following market mechanisms are considered: 2 types of spot markets (day-ahead and intraday), 2 types of forward markets (future and options), and 4 types of balancing energy markets (FCR, aFRR, mFRR and RR). Also, it was evaluated if a capacity mechanism is existent in the considered regions, as well as the number of bidding zones within one region.

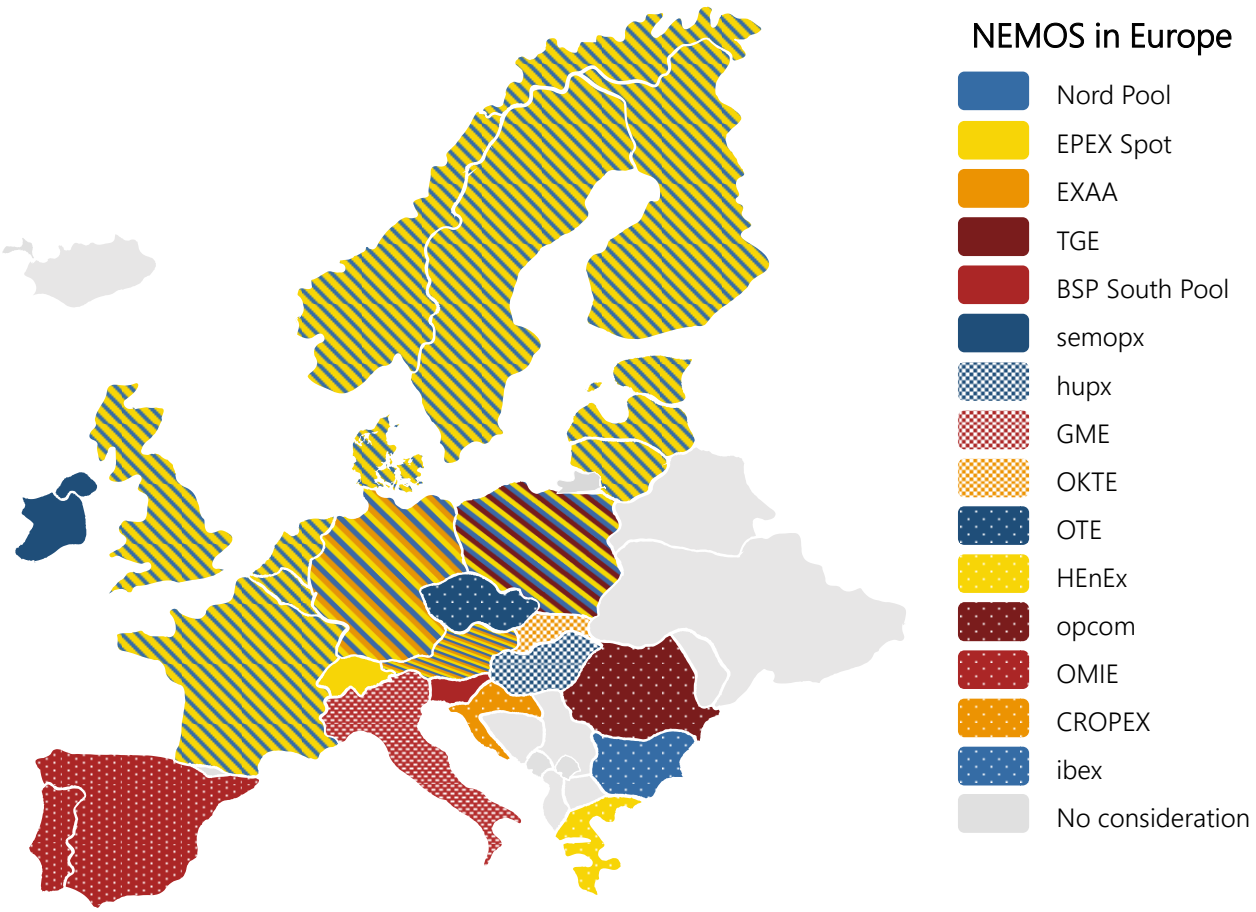

Figure 2 – Geographical system boundaries / considered regions with their respective NEMOs based on [4-21]

Step 2: Identification of key figures

For the identification of key figures, a literature research is performed [3,22,23]. Here, key figures such as prequalification conditions, time between trade and delivery, margin, price cap, pooling of assets, trading time, minimum bid size and transaction costs are mentioned. The key figures found in literature are then compared to publicly provided information by NEMOs and TSOs to obtain a final set of key figures with their characteristics and relevant markets (see Table 1).

Table 1 – Key Figures

Key figure	Market mechanism	Characteristic
Price formation	Spot markets, balancing services, and Forward markets	- Spot markets: marginal price and/or pay-as-bid - Forward markets: different variants of average price - Balancing services: marginal price and/or pay-as-bid and/or regulated price
Minimum duration of power delivery	Spot markets, balancing services, and Forward markets	- Spot markets: 15 min - 60 min, block products - Forward markets: daily - yearly - Balancing services: 15 sec - 8 h
Market coupling	Spot markets and balancing	- Spot market coupling associations: SIDC - Balancing services coupling associations: FCR and/or

	services	IGCC and/or Joint Nordic and/or PICASSO and/or MARI
Time period between trade and delivery	Spot markets and balancing services	- Spot markets: 0 h - 4 h - Balancing services: hourly to yearly
Form of procurement	Spot markets and balancing services	- Spot markets: Auction and/or continuous trading - Balancing services: market based and/or mandatory and/or hybrid
Fulfilment	Forward markets	Cash settlement/contractual fulfilment
Physical Delivery	Forward markets	None or weekly/monthly
Power Purchase Agreements	Forward markets	0- or 6- or 10-years duration
Cascading futures	Forward markets	Splitting longer time contracts into short time contracts or direct settlement
Planning process	Balancing services	Self-Dispatch Portfolio-Based or Self-Dispatch Unit-Based or Central Dispatch
Asset pooling	Balancing services	Distinction between existent and non-existent
Minimum bid size	Balancing services	0,1 MW - 10 MW
Ramp-up time until full power is provided	Balancing services	10 sec - 120 min
Activation rule	Balancing services	Merit-order, pro rata or combination of merit-order and pro rata
Price range	Spot markets	Classification into two ranges
Number of bidding zones	Bidding zones	1 – 7 zones
Existence of capacity mechanism	Capacity mechanism	Strategic Reserve or Central Buyer or Decentralized Commitment or Targeted Capacity Payment or New Capacity Tender or Energy Only Market (EOM)

Price formation and the minimal duration of power delivery were evaluated for all market mechanisms considered. The other key figures were not evaluated for each mechanism, as they are either not suitable for some of the mechanisms or no data is publicly available. For spot markets and balancing services, additionally it was evaluated if there is market coupling among different regions, the time period between trade and delivery, as well as the respective form of procurement.

Some key figures also refer only to one market mechanism if they reflect an important aspect of it. For forward markets, these are the form of fulfilment (cash or contractual fulfilment), if and for which time periods there exist products with physical delivery, if and for which time periods there is a trade of power purchase agreements in the region's forward market and if there is a form of cascading futures. Key figures assessed only for balancing services were the planning process for the dispatch, if there exists a form of asset pooling, the minimum bid size, the ramp-up time until full power is provided as well as the rule for activation. Furthermore, price ranges were classified into two categories as an additional key figure for spot markets.

In addition, two further key figures are introduced: number of bidding zones per country and existing capacity mechanism. As more bidding zones are expected to lead to higher

price volatility resulting in higher revenues for flexible assets, the number of bidding zone is also considered as a relevant key figure. In Europe, most countries have one bidding zone with a uniform zonal price. Exceptions are Italy and the Nordic countries Denmark (already split into two regions), Norway, and Sweden. Sweden into four, Norway into five, and Italy into seven zones [13,16]. The countries Germany and Luxembourg as well as Ireland and Northern Ireland – which are considered each as one region in this paper - share one bidding zone [10,21].
As a capacity mechanism influences the liquidity and the mix of technologies in the other markets, the existence of a capacity mechanism was included as an additional key figure. The capacity mechanisms of the relevant regions are illustrated in Figure 3. Of the considered regions, Austria, Denmark, the Netherlands, Switzerland, Slovakia, Hungary, Norway, Estonia, Latvia, Slovenia, Romania and the Czech Republic have so far no capacity mechanism. The most used mechanism in Europe is Central buyer so far. Central buyer is a centralized bidding process, where the assets are paid for the capacity as well as for the provided energy.

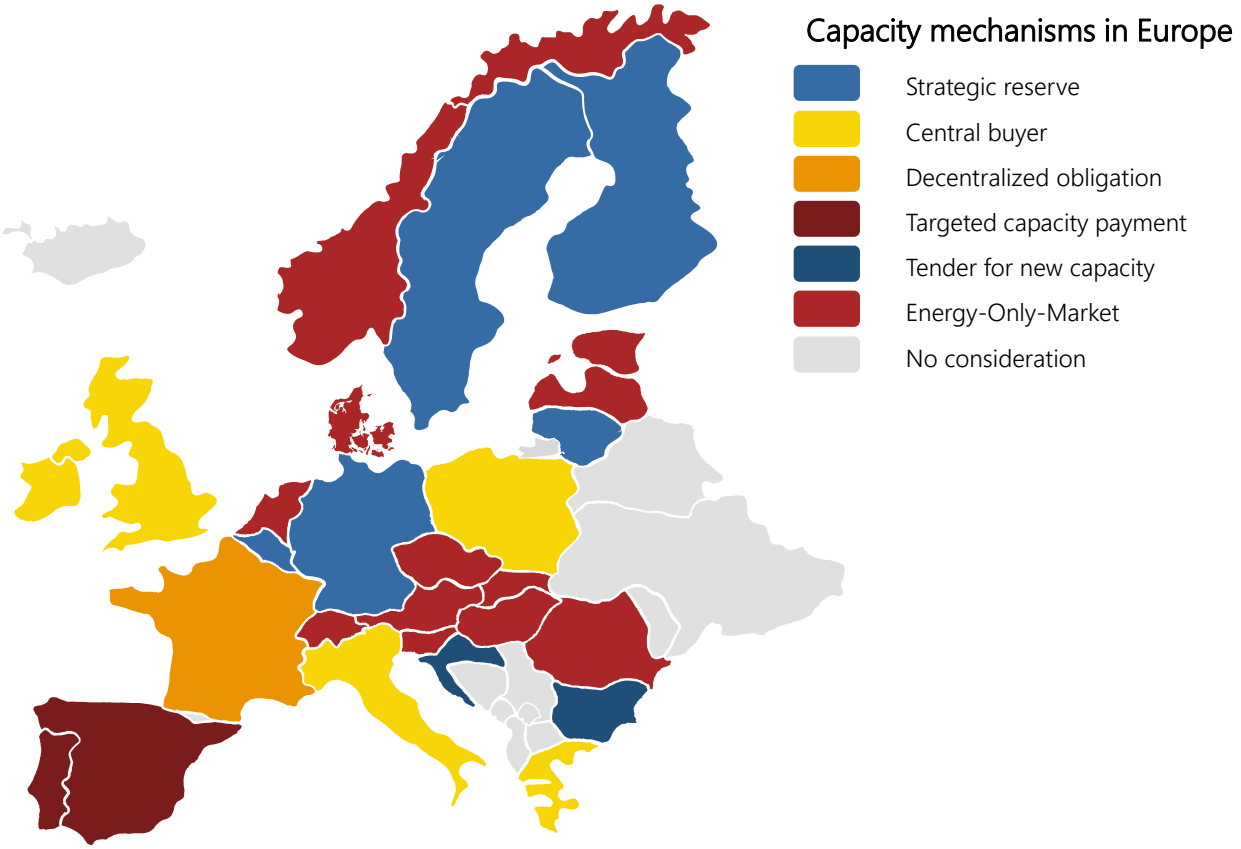

Figure 3 – Capacity mechanism based on [2,23-26]. For Spain, targeted capacity payment is shown even though there is discussion for a new mechanism [27].

The key figures for the different markets plus the two additional key figures lead to 19 key figures. Day-ahead markets where not included into the final comparison, as in the considered regions this mechanism was harmonized to an extent that no relevant differences occurred among the selected key figures.

Step 3: Evaluation of market design difference in comparison to German market design

The final result of this paper is the evaluation of the market design difference in comparison to Germany (see Figure 4). Most of the considered regions are already uniformly standardized in many market design features due to the efforts to create a single European market. Nevertheless, there still do remain significant differences. Regions with the highest deviation in comparison to Germany are Italy, Ireland, Great Britain, Spain, and Czech Republic. In opposite, for regions like the Baltic countries, Austria, France, Switzerland, Slovakia, Belgium, Croatia, and the Netherlands, the market design is relatively harmonized with German design.

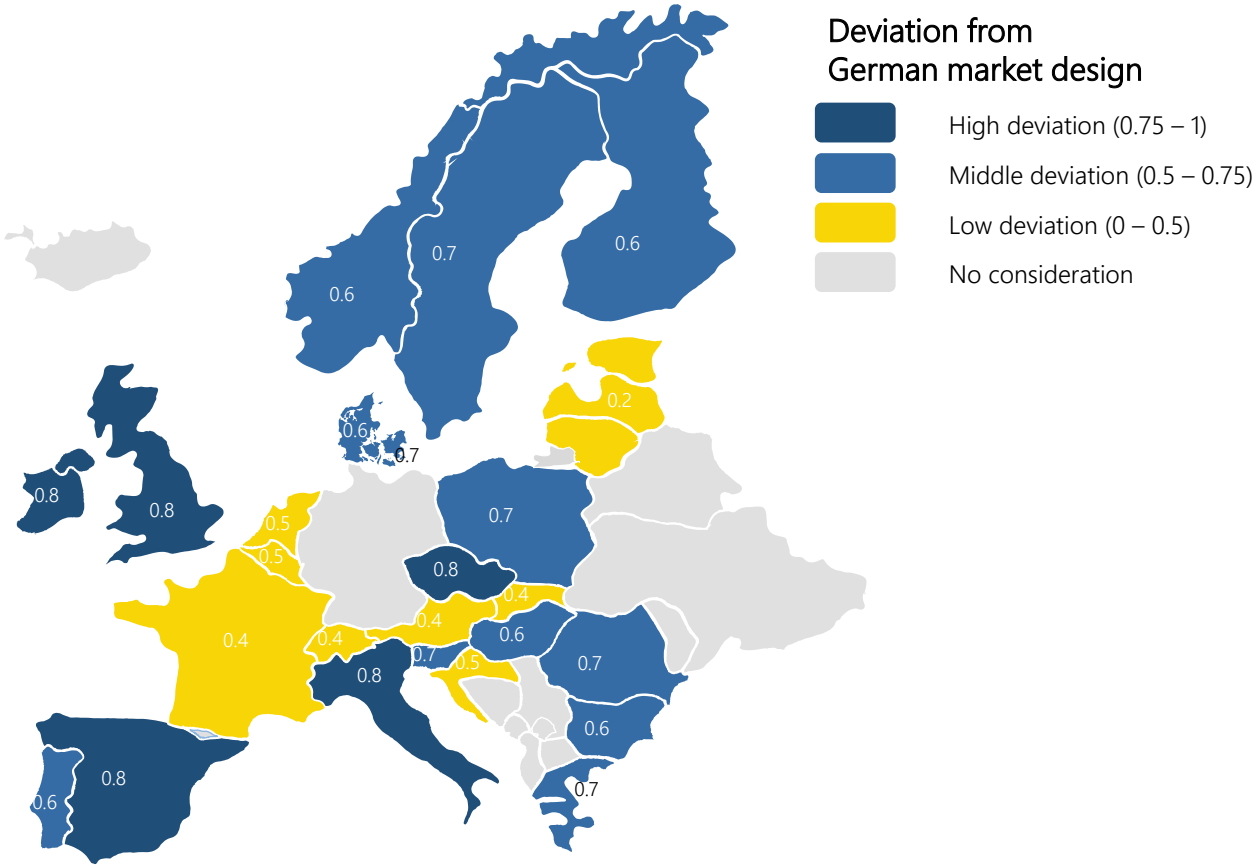

Figure 4 – Deviations in comparison to German market design

Taking a closer look at the high deviation countries, mainly three differentiating aspects can be identified:

1. Low harmonization of balancing services (no market coupling and other product design): more types of FCR (Ireland, Great Britain) or mFRR (Czech Republic) or an existing Replacement Reserve (Great Britain, Italy)
2. More than one bidding zone (Italy)
3. A generally limited market design (Czech Republic)

The differences split into the different market mechanisms are demonstrated in Table 2.

Table 2 – Deviations per market in comparison to Germany

Region compared to Germany	Bidding zones + capacity mechanism	Intraday market	Balancing services	Forward markets	Overall score
Baltic	0.08	0.00	0.07	0.00	0.15
Belgium	0.00	0.00	0.30	0.17	0.47
Bulgaria	0.08	0.12	0.21	0.15	0.55

Denmark 1	0.08	0.00	0.43	0.10	0.61
Denmark 2	0.08	0.00	0.56	0.10	0.74
Finland	0.00	0.00	0.46	0.10	0.56
France	0.08	0.00	0.28	0.05	0.40
Greece	0.08	0.16	0.28	0.15	0.66
Great Britain	0.08	0.05	0.55	0.10	0.77
Ireland	0.08	0.20	0.53	0.00	0.81
Italy	0.14	0.14	0.46	0.10	0.84
Croatia	0.08	0.15	0.26	0.00	0.48
Netherlands	0.08	0.00	0.33	0.08	0.48
Norway	0.14	0.00	0.34	0.10	0.59
Austria	0.09	0.00	0.11	0.17	0.37
Poland	0.08	0.00	0.43	0.17	0.68
Portugal	0.08	0.15	0.34	0.00	0.57
Rumania	0.08	0.12	0.39	0.15	0.73
Sweden	0.07	0.00	0.49	0.10	0.66
Switzerland	0.08	0.05	0.23	0.08	0.43
Slovakia	0.08	0.00	0.22	0.15	0.44
Slovenia	0.08	0.11	0.32	0.15	0.65
Spain	0.08	0.15	0.48	0.06	0.77
Czech Republic	0.08	0.12	0.46	0.11	0.77
Hungary	0.08	0.10	0.32	0.11	0.61

3. Conclusion

Despite the European Union aiming towards electricity market harmonization, the analysis of European electricity market mechanisms still shows a broad range of variants for the market design. The identification of appropriate key figures and the respective characteristics yet enables to quantify those differences. Thus, in this work we assess the differences of the market mechanisms of spot markets, futures markets, balancing services, as well as the existence of a capacity mechanism and the number of bidding zones. We therefore evaluate the differences within those mechanisms relative to the German market for 26 identified European regions using public data of the relevant NEMOs and TSOs.

Thereby, the spot markets are the most harmonized market mechanism due to the broad participation of the countries in market coupling, while the future markets vary strongly depending on the coordinator responsible in this region. Moreover, also the non-market specific characteristics (the existence of a capacity mechanism and the number of bidding zones) vary among the regions compared.

The countries with the strongest deviations in market design from the German markets were Italy, Ireland, Spain, the United Kingdom, and the Czech Republic. Here, either a high variety of trading products (e.g., Italy) or a low variety of trading products (e.g., Czech Republic) causes the difference. The highest impact on the evaluation has the market mechanism balancing services due to many considered sub-markets and characteristics. Moreover, also the form of the capacity mechanism and the number of bidding zones chosen by the countries are decisive for the contrasts in the market design.

It should be noted that over-the-counter-trading (OTC trading) was not considered in this paper. However, the exchange of European electricity products takes place predominantly

through this form of trading. A further investigation of the characteristics of OTC trading thus can yield valuable insights on the European market harmonization.
Furthermore, the high deviations in the European market design raise the question of how these differences impact business models for small-scale flexible assets. This might be especially relevant for marketing strategies targeting balancing services, as these showed the highest deviations in market design. By this analysis further insights could be derived, which characteristics hinder or which on the other hand enable and incentivize the integration of those assets into electricity markets.

References

[1] European Union (2019) directive (EU) 2019/944 of the European parliament and of the council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU. Official Journal of the European Union, L 158/125. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019L0944, last downloaded on 2022-06-03.
[2] Gómez, T., Herrero, I., Rodilla, P., Escobar, R., Lanza, S., de La Fuente, I., Llorens, M. L., & Junco, P. (2019): European Union Electricity Markets: Current Practice and Future View. IEEE Power and Energy Magazine, Bd. 17, Nr. 1, S. 20–31.
[3] Nicolosi, M., & Burstedde, B. (2021) Transformation des Strommarktes bis 2050-Optionen für ein Marktdesign mit hohen Anteilen erneuerbarer Energien Abschlussbericht. URL: https://www.umweltbundesamt.de/publikationen/transformation-des-strommarktes-bis-2050-optionen, last downloaded on 2022-12-01.
[4] BSP SouthPool (2022) BSP SouthPool Energy Exchange. General Information and Trading Products. URL: https://www.bsp-southpool.com/trading/general-information.html, last downloaded on 2021-12-10.
[5] CROPEX (2022) Power Exchange. URL: https://www.cropex.hr/en/market-data/general.html, last downloaded on 2021-12-09.
[6] eex (2022) Power Derivatives Market. URL: https://www.eex.com/en/markets/power-derivatives-market, last downloaded on 2021-12-06.
[7] entso-e (2022) Single Day-ahead Coupling (SDAC). URL: https://www.entsoe.eu/network_codes/cacm/implementation/sdac/, last downloaded on 2021-11-27.
[8] entso-e (2022) Single Intraday Coupling (SIDC). URL: https://www.entsoe.eu/network_codes/cacm/implementation/sidc/, last downloaded on 2021-11-27.
[9] EPEX SPOT (2021) Trading at EPEX SPOT. URL: https://www.epexspot.com/sites/default/files/download_center_files/21-03-09_Trading%20Brochure.pdf, last downloaded on 2021-10-12.
[10] EPEX SPOT (2022) Market Data. URL: https://www.epexspot.com/en/market-data, last downloaded on 2022-06-03.
[11] EXAA (2022) EXAA. Handel mit EXAA. URL: https://www.exaa.at/energiehandel/handel-mit-exaa/, last downloaded on 2021-12-10.
[12] ExEx (2022) Energy Marktes. URL: https://www.enexgroup.gr/web/guest/energy-markets, last downloaded on 2021-12-10
[13] GME (2022) Spot Electricity Markets. URL: https://www.mercatoelettrico.org/En/Mercati/MercatoElettrico/MPE.aspx, last downloaded on 2021-12-09.
[14] hupx (2021) products list and specification: hupx day-ahead market. annex iii.a of hupx market rules. Version 2.0. URL:

https://hupx.hu/uploads/Kereskedes/Szabalyzatok/Piaci_szabalyzatok/product%20list/III.A%20HUPX%20Day-ahead%20Market%20-%20Product%20List%20and%20Specifications_ENG_v2.0_clean.pdf, last downloaded on 2021-12-09.
[15] ibex (2022) Instruction products traded specification in accordance with the power exchange operational rules. URL: https://ibex.bg/download/instruction-products-traded-specification-in-accordance-with-the-power-exchange-operational-rules-in-force-from-13-01-2022-v4/?wpdmdl=51654&refresh=61eebe215a95c1643036193, last downloaded on 2021-12-10.
[16] Nord Pool (2022) Trading. URL: https://www.nordpoolgroup.com/trading/Day-ahead-trading/, last downloaded of 2021-12-10.
[17] OKTE (2022) FAQ. URL: https://www.okte.sk/en/short-term-market/faq/, last downloaded on 2021-12-10.
[18] OMIE (2022) Electricity Market. URL: https://www.omie.es/en/mercado-de-electricidad, last downloaded on 2021-12-12.
[19] opcom (2022) Trading-Products. URL: https://www.opcom.ro//tranzactii_produse/tranzactii_produse.php?lang=en&id=1, last downloaded on 2021-12-10.
[20] OTE (2022) Short-term Markets. URL: https://www.ote-cr.cz/en/short-term-markets/electricity/intra-day-market?date=2022-01-24, last downloaded on 2021-12-10.
[21] semopx (2022) The Day-Ahead Market. URL: https://www.semopx.com/markets/day-ahead-market/, last downloaded on 2021-12-10.
[22] Poplavskaya, K., & de Vries, L. (2019): Distributed energy resources and the organized balancing market: A symbiosis yet? Case of three European balancing markets. Energy Policy, Bd. 126, S. 264–276.
[23] European Commission (2016a) Commission staff working document on the final report of the sector inquiry on capacity mechanisms. URL: https://ec.europa.eu/energy/sites/ener/files/documents/swd_2016_385_f1_other_staff_working_paper_en_v3_p1_870001.pdf, last downloaded on 2022-01-20.
[24] ACER & CEER (2020) Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2019 Electricity Wholesale Markets Volume. URL: https://documents.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Market%20Monitoring%20Report%202019%20-%20Electricity%20Wholesale%20Markets%20Volume.pdf, last downloaded on 2021-10-29.
[25] Bublitz, A., Keles, D., Zimmermann, F., Fraunholz, C., & Fichtner, W. (2019): A survey on electricity market design: Insights from theory and real-world implementations of capacity remuneration mechanisms. Energy Economics, Bd. 80, S. 1059–1078.
[26] Zappa, W., Mulder, T., Junginger, M., & van den Broek, M. (2018). A Quantitative Evaluation of Capacity Remuneration Mechanisms in Europe. 2018 15th International Conference on the European Energy Market (EEM), S. 1–6.
[27] Djunisic, S. (2021) Spain proposes rules to set the stage for capacity market. URL: https://renewablesnow.com/news/spain-proposes-rules-to-set-the-stage-for-capacity-market-738557, last downloaded on 2021-12-18.