German Japanese Energy Transition Council

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Electricity Market Design

Instruments to support the investment in flexibilities in Germany and Japan

Wuppertal Institut

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Wuppertal Institute for Climate, Environment and Energy
Döppersberg 19
42103 Wuppertal
Germany
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The Institute of Energy Economics Japan
Inui Bldg. Kachidoki, 10th, 11th Floor
13-1, Kachidoki 1-chrome, Chuo-ku
Tokyo 104-0054
Japan
https://eneken.ieej.or.jp/en/

Authors

Mitsuaki Ota, Kenichi Onishi (Institute of Energy Economics Japan)
Stefan Thomas, Fiona Bunge (Wuppertal Institute)

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Contact

GJETC Secretariat
gjetc@wupperinst.org
Phone: +49 202 2492-X
Fax: +49 202 2492-10

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List of Abbreviations, Units and Symbols

Abbreviations	
ACER	European Union Agency for the Cooperation of Energy Regulators
aFRR	Automatic Frequency Restoration Reserve
Agora	Agora Energiewende
ATC	Available Transfer Capability
BEV	Battery Electric Vehicle
BNetzA	Bundesnetzagentur
BMWK	Federal Ministry for Economic Affairs and Energy
CHP	Combined Heat and Power
DENA	Deutsche Energie-Agentur (German Energy Agency)
DR	Demand Response
DSO	Distribution System Operator
EEG	Erneuerbare-Energien-Gesetz (Renewable Energy Act)
Fig.	Figure
EOM	End of Message
EnWG	Energiewirtschaftsgesetz (Energy Industry Act)
ETS	Emission Trading System
EU	European Union
FIP	Feed-In Premiums
GWh	Gigawatt-hour
HSS	Home Storage System
IPP	Independent Power Producer
ISS	Industrial Storage System
JPEX	Japan Electric Power Exchange
kWh	Kilowatt-hour
LNG	Liquefied Natural Gas
METI	Ministry of Economy, Trade, and Industry
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
OTC	Over the Counter
PCR	Primary Control Reserve
PKNS	Plattform Klimaneutral Stromsysteme (Platform for Climate-Neutral Power Systems)
PtH	Power to Heat
PV	Photovoltaic
SCR	Secondary Control Reserve
Tab.	Table
TCR	Tertiary Control Reserve
TSO	Transmission System Operator
TWh	Terawatt-hour
V2G	Vehicle-to-Grid

Units and Symbols	
%	Per cent
€	Euro
CO_2	Carbon dioxide
CO_2 eq.	Carbon dioxide equivalents
H_2	Hydrogen
H_2O	Water
kt	Kiloton
kW	Kilowatt
kWh	Kilowatt hour
m	Million

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Executive Summary

This study sets out to investigate the need for reforms in electricity market design, particularly on the existing and proposed reform options to support decarbonization through the increased use of flexibility resources in Japan and Germany. The focus of the analysis is on reform options that strengthen investment in flexibility resources. These resources can be either flexible low-carbon power plants or other flexibility resources notably on the demand side, such as demand response and distributed storage. Although transformation needs are emerging in other aspects of electricity markets, they are not equally relevant for both countries. The main reasons why investments in flexibility were identified as relevant in both countries is to 1) reduce the pressure and costs of further grid expansion, 2) support the expansion of renewables by 3) improving their integration into the markets, and 4) minimizing the overall system cost.

The central difference in the market design between both countries is that Japan has implemented a capacity market while Germany, as an EU Member State, works with an "energy only market"(EOM) until now. Following the identification of similarities and differences in the existing market design, six reform options to directly or indirectly stimulate investments in flexibility resources were analysed in more detail with regard to their advantages and disadvantages, role of actors, dispatch procedures, and legislation and regulation needed. The options can be succinctly summarized as follows:

Option 1 describes the uniform capacity instruments with consistent prices for both new and existing assets. This reform option is already implemented in Japan but rarely discussed in Germany.

Option 2 discusses the uniform capacity instruments with distinct conditions for new and existing assets while maintaining a uniform price for each class. This option is not discussed in Japan and probably not in Germany.

Option 3 is a specific capacity instrument for new assets through capacity auctions, introducing differentiation based on asset or product type. The option is frequently discussed in Japan, since Long-term Decarbonized Power Source Auctions have been implemented in the beginning of 2024. Although not yet implemented in Germany, it is a topic of frequent discussion and might be the approach for the future capacity market planned from 2028 onwards.

Option 4 describes various specific capacity instruments such as fixed payments for demand response or government grants for batteries. It is marginally discussed in Japan, whereas it has been the main type of policy instruments for flexibility resources implemented and planned in Germany.

Option 5 aims to incentivize flexibility resources operated by system operators in the implementation of the revenue regulation. This option is not discussed in Japan, but relevant for Germany's future energy market reforms, including incentives for TSOs and DSOs to adopt flexibility services and prioritize energy efficiency.

Option 6 provides price incentives through time-of-use or dynamic components for final customers. It is so far of lower relevance in Japan but already mandated in Germany, where dynamic prices must be offered if smart meters are available, and time-variable grid fees will be offered to owners of heat pumps and BEVs, both from 2025.

From a policy perspective, in Japan, the electricity industry has shifted its focus towards competition since the full liberalization in 2016. However, the increasing emphasis on carbon neutrality

as a policy priority in recent years is expected to drive the accelerated expansion of renewables. Despite this positive shift, the rise of Feed-in-Tariff (FIT) power plants with low marginal costs entering the wholesale market is reducing the capacity of traditional thermal power plants, which historically served as power sources to balance supply and demand. This underscores the critical need to secure balancing capacity, especially for decarbonized power sources. In the current framework of free competition, systematically procuring the necessary capacity is challenging. Therefore, governmental support is deemed crucial to facilitate the required investments. Japan has already implemented measures such as capacity markets and long-term auctions for decarbonized power sources, aiming to systematically secure the flexible power sources essential for achieving carbon neutrality.

Changes to the electricity market design are currently being actively discussed at both the European Union (EU) level and within Germany. In this debate, we recommend the following priorities. Firstly, the application of the 'energy efficiency first' principle is important. This will involve a cost-benefit analysis of various flexibility resources other than power plants (such as demand response and distributed energy storage) as alternatives to the expansion of supply-side resources (both generation capacity, such as hydrogen-ready gas power plants, and the Transmission System Operator (TSO) and Distribution System Operator (DSO) networks). Looking ahead, the capacity market for new resources planned for 2028 should also prioritize the integration of least-cost demand-side flexibility resources over the investment in new power plants. For the latter, a specific focus on auctioning CHP plants is recommended, including in auctions for hydrogen-ready power plants planned before 2028. To bridge the transition until the full operation of the capacity market, it is advisable to develop additional specific capacity instruments (reform option 4) tailored to demand-side flexibility resources. Accelerating the deployment of smart meters is essential. Further enhancements could be achieved by introducing time-dependent elements into power prices, grid fees, and potentially taxes and levies (as proposed by reform option 6). Adjusting the revenue regulation of TSOs and DSOs to facilitate the integration of costs for flexibility resources into network tariffs will also be important, steering away from an exclusive focus on grid expansion (as suggested by reform option 5). This comprehensive approach would enable Germany to navigate the challenges of the future electricity market with close to 100% of renewable energy sources effectively.

In conclusion, the comparison of electricity market design policies in Japan and Germany reveals distinct approaches to fostering investments in flexibilities. Both nations exhibit a commitment to renewable energy integration and system flexibility, yet to date they employ diverse instruments to achieve these goals. However, it may be that the reform options used by both countries might somewhat converge in the future. Germany now wants to develop a capacity market mostly for new assets by 2028. The country may take a closer look at the Long-term Decarbonized Power Source Auctions in Japan to see if something can be learned for the design of the new German capacity market, e.g., regarding the cap on revenues from other power markets. Japan may learn from Germany's experiences in the implementation of option 6 and/or other instruments to stimulate the use of distributed storage like BEVs and heat pumps, in case there will be a need and a potential for their deployment in the long term.

1 Introduction

The global energy landscape is undergoing a major transformation with a focus on renewable energy. Germany has announced its intention to achieve carbon neutrality by 2045, while Japan aims for carbon neutrality by 2050, which drives the accelerated introduction of renewable energy to meet these targets. In Germany, the share of variable renewables such as wind and solar photovoltaics (PV) in power generation is increasing, with the target of reaching 80% by 2030. Japan aims to have renewable energy account for 36-38% of its power generation by 2030. However, this transition to renewable energy presents a series of complex challenges for the electricity system and electricity market design that necessitate careful consideration.

The output of renewables depends on the season and weather, which creates new challenges to match supply and demand. If the conditions are favorable, they can generate more electricity than the electricity demand, and if left unchecked, the balance between supply and demand may be disrupted. In order to introduce the required larger amounts of renewables and make them the main power source, it is essential to secure new resources that can absorb surpluses or cover the lacking amount of power generation, that is, appropriate flexible and controllable resources.

In this study, we examine issues in electricity market design, for which solutions would be needed to ensure that carbon neutrality can be achieved in both countries. In Chapter 2, we conduct a comparative analysis of potential research themes related to electricity market design and describe why we focus this study on promotion measures for investment in flexibility resources. We suggest a definition of flexibility resources and their potential uses.

Chapter 2 also includes an explanation of the Japanese and German electricity markets, and discusses the challenges of electricity market reform in both countries. Based on this, we assess the potential of resources in both countries to provide flexibility.

Chapter 3 presents an overview of potential reform options in electricity market design for promoting investment in flexibility resources. Specifically, we discuss six selected important reform options, of which the first three are related to capacity market concepts:

- **Option 1** Uniform capacity instruments with uniform price for new and existing assets,
- **Option 2** Uniform capacity instruments with differentiated conditions for new and existing assets but uniform price for each class,
- **Option 3** Specific capacity instruments using capacity auctions with differentiated products, specific by type of asset: e.g., uniform auction for new assets with type-specific caps or multipliers leading to multiple prices; separate auctions by type.

As related to other reform options to stimulate flexibility investment, we discuss

- **Option 4** Other specific capacity instruments for flexibilities. Examples include: fixed payments per kW/kWh of demand response: government grants for batteries or V2G systems,
- **Option 5** Allowing the future costs of flexibilities in the regulated tariffs of TSOs and DSOs,
- **Option 6** Making power prices, grid fees, and possibly even taxes and levies time-dependent (time of use) or even dynamic (real-time pricing).

Then, we provide a general explanation of the advantages and disadvantages of each option. Following this, Chapter 3 explains about the status of implementation and consideration of these six options in Japan and Germany.

In Chapter 4, based on the analysis in the previous chapters, we compare the usefulness of flexible resources and the relevance of investment promotion measures in Japan and Germany. On this basis, we make policy recommendations for promoting flexible investment in Japan and Germany.

Chapter 5 wraps up the study up with conclusions and an outlook.

2 Needs for the future electricity market design to support the energy transition

2.1 Scoping of needs for electricity market reform, and selection of priority area(s) for the study

The global energy landscape is undergoing a significant transformation with a strong focus on renewable energy sources. In Germany, the share of variable renewables like wind and photovoltaic (PV) in power generation is increasing and could potentially account for 80% or more in the final decarbonized power system. In Japan, the prevalence of renewable energy sources is increasing too, although at a somewhat slower pace. However, this shift towards renewables leads to a set of complex consequences and challenges that require careful consideration.

The following chapter first discusses the challenges for electricity market design that arise from the power sector transition towards higher shares of variable renewable energies. The chapter then covers the outcomes of a scoping workshop where the study focus was refined and key challenges relevant for both Germany and Japan were identified. Investment in flexibility resources emerged as a common primary concern, which is why this topic was chosen as the study's focal point. This chapter, therefore, discusses a definition of flexibility, potentials flexibility resources, and their usefulness and potential in both countries.

2.1.1 Four areas of challenges for electricity market design

In early 2023, the German expert commission on the Monitoring Process "Energy of the Future" published a comprehensive analysis regarding different reform options for the electricity market design in Germany (Löschel et al, 2023). The Commission introduces different conditions for a successful transformation of the energy market and discusses the challenges that particularly Germany is facing. The report presents various overarching conditions for the success of the transformation and conclude that changes are needed in four main areas. The first of these areas is the coordination of the electricity market, especially within the wholesale market and regarding the changes required for the stronger use of flexibilities. The second area are challenges in the investment conditions, especially in renewables, flexible power plants, and other flexible options. The third area reflects the signals for local differentiation, that may need to be improved within the wholesale markets, but also for addressing renewables. Finally, power prices and costs are discussed as the fourth area, where changes are necessary to ensure that costs remain affordable for both industries and small consumers. Table 1 presents an overview of the four main areas and the subdomains of challenges for electricity market reform.

Tab. 2-1 Areas of challenges for electricity market reform

Coordination	Investment	Signals for local differentiation	Power Prices/Cost
Wholesale Markets	Renewables	Wholesale markets	Industry
Flexibilities	Flexibile Power Plants	Renewables	Small consumers
	Other Flexibility Options		

The main challenges of market coordination

Market coordination, on the one hand, concerns the functioning of wholesale markets in general. Their task is to ensure that power supply and demand in a bidding zone match at all times. On the other hand, improving the integration of flexibilities into the markets (wholesale and system services) is a special challenge to reduce system costs and improve reliability, and this challenge is becoming more relevant during the energy transition.

For instance, the German expert commission (Löschel et al., 2023) emphasizes that the operation of power plants is constrained by technical limitations that are typically represented through hourly bidding. To improve the coordination of plant operations, there is a need to expand the bidding options for more precise technical representation. Furthermore, enhancing the representation of available flexibility could increase allocation efficiency, and various bidding form extensions are possible for achieving this (Löschel et al., 2023, p.45).

In the current system in Germany, it is possible to submit "single bids" or "block bids." The expert commission suggests expanding the bidding systems to include "multi-part bids," which are already part of the U.S. electricity market design. In addition, they suggest a modification on the demand side. This modification could involve adjusting demand-side bids to capture flexibility potentials on the demand side, ultimately reducing uncertainties in the electricity market (Löschel et al., 2023, p. 46).

Within literature, flexibility is defined as "the alteration of feed-in or withdrawal in response to an external signal (price signal or activation) with the aim of providing a service within the energy system." (own translation) (Eurelectric, 2014 cited in Löschel et al., 2023, p. 47). Such flexibilities can be offered by various technologies, including *flexible low-carbon power plants* such as hydrogen-fired gas turbine or combined-cycle plants, and *other flexibility options*. The latter include assets such as storage of power, e.g. in stationary batteries or battery-electric vehicles (BEV) (Okamura, Kolde et al., 2022), heat, and other products; electrolysis; and demand response. Flexibilities can also be provided by various actors, such as utilities, industry, and private households. However, this requires the market coordination of flexibilities.

The expert commission (2023) also delves into the significance of flexibility in congestion management for industry, commerce, and private generators, alongside the existing barriers to its implementation. In striving for widespread adoption of load shifting in the industrial and commercial sector, numerous challenges emerge, including data privacy concerns and ensuring a stable energy supply during peak demand periods. Furthermore, the regulatory framework fails to establish adequate monetary incentives for implementation of load shifting. The private sector is increasingly offering opportunities to enhance flexibility in energy demand, primarily driven by developments such as e-mobility and non-fossil heating solutions like heat pumps. However, the private sector faces challenges such as inadequate digital infrastructure, insufficient financial incentives, and the existing regulatory framework impeding progress (Löschel et al., 2023, p. 48)

Flexibilities can also play a crucial role in supporting the congestion management in distribution grid operation, since the electrification of the heat and mobility sectors primarily occurs within distribution networks. Flexibility in both generation or grid injection and energy consumption, as well as the grid-supportive deployment of energy storage, can help prevent congestion in the distribution grid. This ensures the secure operation of the power grid even when network expansion is reduced or delayed (Löschel et al., 2023, p. 48f).

The main challenges regarding the investment conditions

In both Germany and Japan, investments in both the power sector and the demand sectors are primarily driven by the private sector, although particularly in Germany municipal utilities also play an important role in the energy sector. To enable investments, a robust market framework that limits system costs, avoids adverse effects on market design, and aligns with the energy transition's timeframe while ensuring supply and system security, is essential.

The German expert commission (2023) initially distinguishes three areas of investment: renewables, flexible power plants, and other flexibilities like demand flexibility and storage. These areas face different challenges. In Germany for example, these include a volatile energy price environment, trust issues that may be stemming from recent crisis management affecting market-based strategies, and the necessity for adjustments to refinancing instruments due to European subsidy regulations (Löschel et al., 2023, p. 56).

Renewable energy is characterized by their availability depending on natural conditions. According to the expert commission within this context, the central challenge of refinancing lies in the potential decrease in revenues during periods of lower solar and wind resources, due to low market values during periods of high solar and wind production. However, predicting the future development of these market values, which are defined as the relationship between achievable prices at different production hours and the average wholesale electricity price throughout the year, is extremely difficult due to their dependence on various influencing factors like the development of power plant capacities abroad or storage options (Löschel et al., 2023, p. 57). There is, therefore, the need to provide a reliable economic return for investment in renewable power generators.

In the case of Flexible Power Plants, the central challenge lies in the multitude of uncertainties they bring. Firstly, it is unclear which future loads they need to offset (Löschel et al., 2023, p. 59), which in Germany but not in Japan is closely related to developments in neighboring countries due to connected markets. Secondly, some of these power plants that would operate with hydrogen face a kind of double investment challenge: financing the power plants themselves and providing suitable financing mechanisms to have access to green and cost-effective hydrogen (Löschel et al., 2023, p. 59).

Regarding other flexibilities, such as demand flexibilities and storage options, uncertainties in the cost structure and insufficient data are a challenge. For demand flexibilities, the combination of uncertainties about future peak loads on the hand and uncertainties about the volatile character of renewables on the other hand, are a challenge. The expert commission also identifies an investment gap between the potential revenues under current power market regulations and pricing structures, and the need of investment in demand flexibilities, especially for addressing peak loads (Löschel et al., 2023, p. 59f).

For storage options, two kinds of storages can be distinguished, i.e., short time storages like batteries and seasonal storages, e.g., via hydrogen. The first kind of storage faces similar challenges as the demand response. A particularity, especially of short-term storage, is that synergies (co-benefits) can be leveraged from other areas, such as battery electric mobility. The expert commission also suggests introducing separate incentive systems for demand flexibility and various types of storage, at least in the initial phase (Löschel et al., 2023, p. 60).

The main challenges regarding signals for local differentiation

Germany, as many other European countries, is treated as a single national bidding zone with uniform electricity prices. Within the electricity system, existing grid bottlenecks are resolved ex-post through redispatch measures in the short term, involving first fossil but then also renewable power plants; in the medium to long term, bottlenecks should be reduced and eventually removed through grid expansion. Due to uniform prices, there are no location-specific incentives for electricity generators to invest more in generation plants or flexibilities in areas of shortage. As a consequence, electricity generators in regions with bottlenecks do not see high peak prices. Hence, there is a lack of regional incentives to invest in flexible capacities, which could lead to an increased need for grid expansion, if not addressed adequately. In turn, this could lead to significantly increased costs for network expansion and congestion management (Löschel et al., 2023, p. 83). This risk is sparking discussions about alternative instruments with efficient localization signals. These instruments could include a split into several bidding zones – as it is already partially the case in Japan, namely in case of congestion at the interconnection lines between the TSO areas – or even nodal pricing.

The main challenges regarding electricity costs

Due to the energy crisis, electricity prices have increased for both residential, commercial, and industrial customers, particularly in Germany, in 2022 and early 2023. The increase created a need to limit these prices, especially for residential customers (Löschel et al., 2023, p. 100). Even though prices have significantly decreased in the course of 2023, they still remain above the long-term average (Löschel et al., 2023, p. 99). The primary drivers of rising electricity prices are the costs of natural gas, coal, and in Germany, CO_2 certificates from the EU Emissions Trading

Scheme (ETS). The several components that play a crucial role in price formation include price developments in wholesale markets, transmission and distribution network usage fees, taxes, levies, and other charges (Löschel et al., 2023, p. 99). The German expert commission (2023) has observed that for industrial companies, the share of additional price components is significantly lower compared to residential customers. Policymakers face substantial challenges in addressing the high uncertainties in the development of electricity prices, especially for residential consumers (Löschel et al., 2023, p. 111). They must balance the need to ensure affordable electricity supply with the need to strengthen the flexible expansion of renewables and maintain adequate price signals to stimulate energy efficiency. In this regard, policy reforms creating incentives for energy savings and the development of models for energy communities or 'tenant electricity' can help residential consumers.

2.1.2 Selection of the relevant priority areas for this study, supported by a Scoping Workshop

With respect to the four areas of challenges and the subdomains discussed in chapter 2.1, the study team assessed their urgency and relevance for Germany and Japan.

Regarding market coordination, the direction of the wholesale market design is largely settled in both countries, and a further exploration by the GJETC not urgently required. While there is a pressing need to improve the market integration of flexibilities in Germany, given the plans to expand the share of renewables in power generation to 80 % by 2030 already, such high shares or even the 50 % already achieved in Germany lie much further in the future for Japan, so studying them under the aspect of market coordination was considered not to be relevant for the GJETC.

In contrast, conditions for the investment in both flexible low-carbon power plants and other flexibility options are considered of high to very high relevance for both countries. Although these may become relevant for Japan only in the long run, studying them already now was considered useful to support an early preparation for the respective potential future electricity market reforms that may be needed. In contrast to flexibilities, instruments to stimulate the further expansion of renewable power generation are an important subject but have been researched elsewhere, so the GJETC may not bring a lot of added value.

The need to discuss regional differentiation is highly diverging between both countries, and also less relevant for the energy transition, so this is not assessed as a priority area for the GJETC. The same is the case regarding the challenges and needs to address electricity costs. Since the investment conditions play a crucial role in the transformation of the electricity market design and are highly relevant for both countries, we therefore decided to focus on flexibilities and investments. This decision was confirmed by the subgroup of GJETC members participating in the scoping workshop organized by the GJETC secretariats on 25 September 2023. To provide inputs for the further analysis of this topic, further questions were discussed at the scoping workshop, these are presented in chapter 2.1.3. Other questions discussed at the workshop related to the most relevant policy options to stimulate investment in flexibilities, which are covered in chapter 3.

2.1.3 Analyzing policy options to stimulate investment in flexibilities: using case applications to make it more concrete

To further improve the clarity of the subject of this study, we need to develop a common understanding of the term 'flexibilities' or 'flexibility resources' regarding their purpose in the power system and markets, and of the types of such resources that are available.

How can 'flexibility' be defined, and what can it be used for? The following box presents a good overview of a potential definition and the purposes of flexibility, as presented by Eurelectric, the voice of the electricity industry in Europe (Eurelectric, 2014).

"**Use of flexibility**

On an individual level flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system. The parameters used to characterise flexibility include the amount of power modulation, the duration, the rate of change, the response time, the location etc.

The possible market uses for flexibility are threefold:

- **Portfolio optimisation**

Portfolio optimisation is used by market players to meet their energy obligations resulting from energy markets at minimum costs by arbitrating between generation and demand response on all different time horizons.

- **Balancing**

This refers to the procurement of balancing services (capacity) and activation of balancing energy by the TSO to balance demand and supply through the balancing energy market. This is related to all actions and processes, from balancing gate closure time until real-time through which TSOs ensure, in a continuous way, the maintenance of the system frequency within a predefined stability range.

- **Constraints management in transmission and distribution networks**

Flexibility services will allow network operators to tackle network constraints in all timescales, maintaining reliability and quality of service and maximising integration of distributed energy resources."

Source: Eurelectric, 2014

Since 2014, the wording used in the literature and in EU electricity market legislation has changed to 'congestion management' instead of 'constraints management'. Therefore, for the third purpose of flexibility resources, we will use the term 'congestion management' hereafter.

The three general use cases outlined in the box may differ in the characteristics of their needs for flexibility resources. For example, balancing has durations for the use of flexibilities between seconds and 15 minutes, whereas situations of surplus generation or demand in wholesale markets, which provide incentives for portfolio optimization, or network congestions may last up to several hours.

One question that was raised at the scoping workshop aimed to determine which spatial and market dimensions were most important to be addressed by instruments to stimulate flexibilities from the experts' point of view. The experts particularly highlighted the relevance of the transmission and distribution system level, while local systems and the substation level play only a minor role in their view.

A second question posed was, whether power markets or the networks / grids were more relevant for the development and utilization of flexibilities. Once again, there was a strong consensus between the German and Japanese members, with the majority of each group prioritizing power markets.

However, there is the need for further discussion, e.g., on whether analysis of power markets should focus on the balancing power market or the general wholesale market, or both. The relevance of the three uses for the energy markets and systems in Japan and Germany will be discussed in chapters 2.2 and 2.3, respectively. Therefore, for the purpose of completeness, we will first discuss all potential types of flexibility resources and their potential use.

The following table presents an overview of the types of flexibility resources that could be supported by policy options to stimulate investment in them. The policy options may also differ in how relevant or effective they may be for the various types of flexibility resources, so this will be one criterion for the analysis of the policy options in chapter 3.

Tab. 2-2 Types of flexibility resources that could be analyzed as case applications

Flexible low-carbon power plants	Power plants using 100% green or blue hydrogen or ammonia or other derivatives (gas turbines, combined-cycle power plants) *Distinction whether using CHP (preferable for energy efficiency reasons, but investment in heat storage is needed) or not* **Potential uses:** portfolio optimization, balancing, congestion management
	Gas power plants ready to be converted to 100% green or blue hydrogen or ammonia or other derivatives *Critical question: When (future calender year) would conversion have to take place?* **Potential uses:** portfolio optimization, balancing, congestion management
	Flexible use of biomass power plants *Distinction whether using CHP (preferable) or not* **Potential uses:** portfolio optimization, balancing, congestion management
Other flexibility options	Demand response (in general, other subtypes than demand-side storage resources listed below; includes cold storage and flexible electric production lines in industry combined with product storage) **Potential uses:** portfolio optimization, balancing (mostly with aggregation), congestion management
	Grid-integrated batteries (to store green power) **Potential uses:** balancing, congestion management
	Building-integrated batteries (to store green power) **Potential uses:** portfolio optimization, balancing (with aggregation), congestion management
	Battery electric vehicles (using low-carbon power) **Potential uses:** portfolio optimization, balancing (with aggregation), congestion management
	Electrolysis (using low-carbon power) **Potential uses:** portfolio optimization, balancing, congestion management (may depend on the purpose, for which the electrolysis was built and financially supported)

	Small-scale CHP or heat pumps and other electric heat generators in connection to heat storage **Potential uses:** portfolio optimization, balancing (with aggregation), congestion management

Note: most types of demand-side flexibility resources may need aggregation to participate in wholesale markets or management of network congestions too, but it is not a formal precondition like for balancing markets, where the table mentions aggregation explicitly.

In addition to the types of flexibility resources listed in the table above, some resources may be used to provide reactive power. These include repurposing of thermal power plants, using their generator sets to provide reactive power, and the flexible use of wind and PV power plants for reactive power. This use case is considered too special for this study.

Furthermore, the curtailment of resources, especially PV and wind power, is of course an option to adapt supply to demand or network congestions. However, no investment is needed for that; and in fact, many of the flexibility resources listed above are meant to avoid the need to curtail renewable power generation, but need investments to be created. And this is the subject of this study. Similarly, the expansion of network capacity is the default infrastructure option to mitigate network congestions, for which flexibility resources may provide an alternative.

2.2 Existing policies and market design in Japan, and analysis of the challenges

This chapter analyses the relevance of the challenges for the development of the electricity market design and of flexibility resources, which were discussed in chapter 2.1, for Japan. As the basis for the analysis, the chapter starts with a brief introduction to the existing energy market design in Japan.

2.2.1 Energy market design

In 1886, the private company Tokyo Electric Lighting commenced operations as the nation's first electric power company. After the end of the second World War, nine vertically integrated private power companies – Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku, Kansai, Chugoku, Shikoku and Kyushu Electric Power Companies – were established in 1951. Okinawa Electric Power Co. joined as a tenth member with the return of Okinawa to Japan in 1972. These companies are responsible for supplying electricity to each region.

At the end of the 20th century, the electric utility industry started to be liberalized. In 1995, the independent power producers (IPP) were allowed to provide electricity wholesale services. In 2000, electricity retail supply for extra-high voltage users (demand exceeding 2MW) was liberalized. The scope of retail liberalization was then expanded in April 2004 to users of more than 500kW, and subsequently in April 2005 to users of more than 50kW. After the Great East Japan Earthquake in March 2011, numerous discussions were held to maintain a stable supply and reduce energy costs, and in 2013, the policy to implement three-phase reforms of the electric power system was adopted. As a result, full retail liberalization finally started in April 2016, and legal unbundling in the transmission/distribution sector started in April 2020.

Electricity in Japan is traded within the wholesale electricity market (kWh market) via JEPX, which was established in 2005. JEPX offers three types of trading: spot market, intraday market and forward market. The spot market manages electricity transactions for the following day (day-ahead, thirty-minutes products). The intraday market manages electricity transactions for the current day (intraday, thirty-minutes products). The forward market manages electricity transactions for a specific future period (one year, one month, one week). Following the UK and U.S., Japan has started the auction of the capacity market (kW market) since 2020 and the transactions in the balancing market (ΔkW market) in 2021.

Spot and intraday markets

In Japan, nine TSOs, with the exception of Okinawa, have their own bidding zone in the spot market and intraday market. When there is no congestion between TSOs, the bidding will lead to uniform prices across bidding zones. However, if trading is not possible within the available transfer capacity of an interconnection line, the contract calculation will be performed again taking into account the available transfer capacity. This could lead to different spot prices between bidding zones. This is referred to as "market splitting." On the other hand, in recent years there has been an ongoing discussion on dividing bidding zones within each TSO area.

Balancing power market(s)

Balancing power markets are essential in ensuring the stability and reliability of the electricity supply system. In Japan, nine TSOs, again the exception being Okinawa, are responsible for the procurement of balancing power capacities. The balancing market is separated from the day-ahead and intraday markets and set up by the TSO. In Japan, five types of balancing power products exist. These are the Primary Control Reserve (PCR), Secondary Control Reserve (SCR) ①, Secondary Control Reserve (SCR)②, Tertiary Control Reserve (TCR)① and Tertiary Control Reserve (TCR)②, for which the requirements are set by the TSO and procured by separate auctions.

PCR activates automatically within 10 seconds and must be available for more than 5 minutes; SCR① activates automatically within 5 minutes and must be available for more than 30 minutes; SCR② activates automatically within 5 minutes and must be available for more than 30 minutes; SCR① responds to load fluctuations during an emergency, whereas SCR② responds to load fluctuations during normal times (METI, 2017). TCR① activates automatically within 15 minutes and must be available for 3 hours (bloc time of products), and TCR② activates automatically within 45 minutes and must be available for 3 hours (bloc time of products). In the balancing market, procurement of low-speed TCR② began in 2021, TCR① procurement began in 2022, and the other products will begin in 2024.

Management of network congestions

In Japan, there are various instruments that address network congestions. The Organization for Cross-regional Coordination of Transmission Operators, JAPAN (OCCTO) has been facilitating and rendering a more affordable use of the electric power network by maximizing the use of the existing network. To this end, OCCTO has been conducting a probabilistic evaluation of the power flow as well as the N-1 inter-tripping scheme and non-firm access connections. These three efforts are called 'Japanese connect and manage'.

Probabilistic evaluation of the power flow is a methodology to increase available transmission capacity by assumed power flow given the actual situation and assessing network. As to the N-1 Inter-Trip scheme, in Japan, from the viewpoint of network reliability, etc., power system development is conducted to secure stable and adequate transfer capacity even if an N-1 contingency occurs. The N-1 Inter-trip scheme is a measure to utilize this capacity under no contingency situation by inter-tripping a generator when N-1 contingency occurs. A non-firm access connection is an initiative to enable new power sources to be operated without having to increase facilities on the assumption that output curtailment will be implemented, if operational capacity is expected to be exceeded during normal times.

Further, OCCTO continues to study new network operation rules, such as the re-dispatching method. From December 2022, in order to eliminate congestion in the main power grid during normal times, the OCCTO started operating the re-dispatching method that controls the output of balancing power sources of TSO/DSO according to merit orders.

2.2.2 Analysis of the current and future challenges

Similar to other countries, Japan has a rapidly growing share of renewable energy. Out of these market structures, a number of challenges arise. Table 2-3 below summarizes the relevance of challenges in Japan.

Tab. 2-3 Relevance of challenges for Japan

Challenge	Relevance of challenge for Japan
1) Coordination	
1a) wholesale markets	**Less relevant for GJETC** In Japan, with the increasing introduction of variable renewables, there's a growing need for more efficient procurement of supply power (kWh) and balancing power(ΔkWh). Additionally, during the transitional phase towards decarbonization, there is a need for stable and efficient power supply and demand operations that consider the lead times required for importing fossil fuels. For this reason, Japan is currently considering its wholesale market reforms. Specifically, we're exploring the concept of a simultaneous market that consolidates the spot market and balancing market. This market structure would enable the simultaneous contracting of supply power (kWh) and balancing power (ΔkW). However, while such market development could encourage investment in flexible power sources, it represents an indirect measure to support flexibility investment. Hence, within this study group, this theme is considered a lower priority.

Challenge	Relevance of challenge for Japan
1b) flexibilities	**Less relevant for GJETC** Japan is currently working on the detailed design of market rules, with the aim of starting participation in the balancing market for low-voltage resources such as household storage batteries and EVs in 2026. This measure will make it possible for storage batteries installed in general households to be used in the balancing market, which is expected to encourage people's desire to introduce storage batteries and lead to increased investment. Nevertheless, as an approach to boost investment in flexible resources, it is considered an indirect measure and ranks as a lower-priority theme within this study group.
2) Investment	
2a) renewables	**Highly relevant** In Japan, with the introduction of FIT in 2012, a large number of renewable power plants, mainly PV, were introduced. On the other hand, under the FIT system, renewables are paid a fixed price, so there is no incentive to shut down renewable power plants in situations of generation surplus. From the perspective of reducing renewable surcharges, renewable power companies were also required to generate electricity while taking into account the power supply and demand. For this reason, instead of the fixed-price purchase mechanism seen in the FIT system, the feed-in premium system (FIP) provides renewable energy power companies with a specific premium (subsidy amount) upon selling renewable electricity in the wholesale electricity market. This system started in 2022.The introduction of the FIP system is expected to expand the aggregation business, which involves aggregating small-scale renewable energy sources and combining them with storage batteries to manage supply and demand. In this way, in Japan, the direction of renewables investment support schemes is clear, and a lot of prior research has already been conducted, so it is considered as low priority within this study group.
2b) flexible power plants	**Highly relevant in the long run** In Japan, thermal power sources, which traditionally provided flexibility, are expected to be largely phased out in favor of large-scale introduction of renewables. Therefore, as a framework for securing supply capacity to compensate for the intermittency of renewables, capacity market auctions began in 2020 (actual supply and demand will begin in 2024). The introduction of capacity market is expected to promote medium to long-term investment in power sources, but there are issues such as only one-year contracts being allowed in Japan's capacity market, which may not provide an incentive for new investment. In addition, as an additional auction in the capacity market, a long-term decarbonized power source auction is scheduled to begin in January 2024 in order to promote investment in new construction and replacement of decarbonized power sources. Specifically, by allowing power sources that win bids to earn fixed cost-level capacity revenue for 20 years in principle. It provides predictability of long-term revenue while recovering the huge initial investment. Hence, it would be beneficial for Japan and Germany to share the details and issues of such power investment support schemes.
2c) other flexibility resources	**Highly relevant in the long run** The long-term decarbonized power source auctions will also include other flexibility resources, such as pumped hydro and storage batteries. Therefore, it would be beneficial for Japan and Germany to share the content and issues of such power investment support measures within this study group

Challenge	Relevance of challenge for Japan
3) Signals for local differentiation	
3a) wholesale markets	**Less relevant for GJETC** In Japan, nine TSOs, with the exception of Okinawa, have their own bidding zone in the spot market and intraday market. When there is no congestion between TSOs, the area prices are uniform. On the other hand, discussions regarding nodal pricing, which establishes marginal prices for individual nodes, have been advancing in recent years. Nodal pricing itself reveals locations where congestion is occurring by transmitting the marginal price for each location. This is an indirect support measure in the sense that it is expected to encourage investment in areas where congestion is occurring. Therefore, it is considered to be low priority as a theme for this study group.
3b) renewables	**Less relevant for GJETC** As stated in 2a), the direction of renewable energy investment in Japan is clear, and much prior research has already been conducted, so it is considered to be a low priority topic for this study group.
4) Power prices/costs	
	Less relevant for GJETC Power prices have been high in Japan since 2011, but did not rise further as much as they did in Germany in 2022/23. Therefore, this is not considered a priority issue for the GJETC to study. On the other hand, in Japan, efforts are underway to efficiently utilize inexpensive electricity generated from renewables by aligning demand with fluctuations in electricity prices. Demonstrations involving charging shifts for electric vehicles using dynamic pricing are also being conducted.

As a consequence of this analysis, the need for policy reform to enhance the electricity market design is highest for the investment in both renewable energies and flexibilities, as well as for integrating flexibilities in the markets and system operation. However, for the investment needed in the expansion of power generation from renewable energies, the necessary policy frameworks in Japan are already under specific development. In Japan, the capacity market has started in 2020 and the long-term decarbonized power source auction was introduced in January 2024 to secure the necessary power supply for a long-term period. Therefore, selecting investment in flexible power plants and other flexibility resources will be a good choice for the focus subject of this study.

2.2.3 Relevance of flexibility resources and their use cases

This section discusses the need for flexibilities in portfolio optimization, balancing, and congestion management in Japan.

Portfolio optimization

Portfolio optimization describes a strategic combination of different energy resources of renewables, demand response, storages and other power plants to meet electricity demand in an economically and ecologically efficient way. The strategy for growth of power from renewable energy sources to 36-38% by 2030 amplifies the necessity for flexibilities in Japan already in the short and medium term. As solar PV and wind power exhibit volatility, an increase in occurrences of either energy surplus or deficit is expected. This doesn't just entail fluctuations throughout the day but also across seasons. For instance, in winter, there are fewer hours of sunlight, and the amount of solar power generated is lower than in summer. In addition, demand peaks in the evening, but as the amount of solar power generation decreases, there is a greater possibility that power supply and demand will become tight. Addressing these fluctuations promptly necessitates a considerable demand for new flexibility options. This is further increased because the capacity of flexible coal power plants will be decreasing in Japan.

Balancing

Traditionally, thermal power has been the primary source for balancing. Hydroelectric, which is predominantly pumped storage, constitutes the remaining portion. Additionally, a small percentage is contributed by batteries and demand response mechanisms. In the years ahead, the potential for such new types of resources will be on the rise, while the presence of fossil fuel-based thermal power plants, particularly inefficient coal, is expected to retreat from the market, with natural gas to follow suit, albeit at a later stage.

Congestion management

Flexibility plays a crucial role in managing congestions in the energy system. Hence, on one hand, the need for flexibility resources to reduce or defer the need for network expansion and upgrading is increasing. On the other hand, in Japan, the south west (Kyusyu) has a large potential for solar power generation, whereas the north (Hokkaido) has large potential for wind power generation. Hence, it is necessary to expand the grid to ensure the power flow from those areas to urban areas. For this reason, the OCCTO has considered a future master plan for a wider-area interconnection system.

In Table 2-4, the potential usefulness of the types of flexibility resources from Table 2-2 for the three main use cases is discussed, along with preconditions that may be needed (e.g. labelling of renewable power), and what is their potential in Japan at least in qualitative terms; quantitative data are presented if they were easily available.

Tab. 2-4 Types of flexibility resources and their relevance and potential in Japan

Types of flexibility resources	Usefulness in Japan for the main use cases	Potential in Japan
Flexible low-carbon power plants		
Power plants using 100% green or blue hydrogen or ammonia or other derivatives (gas turbines, combined-cycle power plants) Distinction may be needed whether using CHP (preferrable for energy efficiency reasons, but investment in heat storage is needed) or not	**portfolio optimization:** high **balancing:** high **congestion management:** high	**High** According to scenarios for carbon neutrality(METI. (2021a)), 1% of power generation should be hydrogen and ammonia by 2030 10% of power generation should be hydrogen and ammonia by 2050 as a reference case(METI. (2021c)).
Gas power plants ready to be converted to 100% green or blue	**portfolio optimization:** high **balancing:** high	**High**

Types of flexibility resources	Usefulness in Japan for the main use cases	Potential in Japan
hydrogen or ammonia or other derivatives Critical question: When (future calender year) would conversion have to take place?	**congestion management:** high	during the transition phase from Coal, LNG and Oil to green hydrogen and ammonia
Flexible use of biomass power plants Distinction whether using CHP (preferrable) or not	**portfolio optimization:** high **balancing:** high **congestion management:** high	**Medium** Currently, biomass is not providing flexibility in the balancing power market
Other flexibility options		
Demand response (in general, other subtypes than demand-side storage resources listed below)	**portfolio optimization:** high **balancing:** medium **congestions:** medium	**High**
Grid-integrated batteries (to store green power)	**portfolio optimization:** high **balancing:** high **congestion management:** high	**High** According to the Green innovation strategy issued in 2021 (METI (2021b)), it aims for a cumulative installed capacity of 24GWh by 2030, including household use, commercial use, and industrial use.
Building-integrated batteries (to store green power)	**portfolio optimization:** high **balancing:** high **congestion management:** high	**High** According to the Green innovation strategy issued in 2021(METI (2021b)), it aims for a cumulative installed capacity of 24GWh by 2030, including household use, commercial use, and industrial use.
Battery electric vehicles (using low-carbon power)	**portfolio optimization:** high **balancing:** medium **congestion management:** medium	**High** According to the Green innovation strategy issued in 2021(METI (2021b)), it will increase domestic automotive storage battery manufacturing capacity to 100 GWh by 2030.
Electrolysis (using low-carbon power)	**portfolio optimization:** medium **balancing:** medium **congestion management:** medium	**High** According to the Basic Hydrogen Strategy issued in 2023(METI(2023)), Japan-related companies' global water electrolysis capacity target is set at 15 GW for 2030.
Small-scale CHP or heat pumps and other electric heat generators in connection to heat storage	**portfolio optimization:** medium **balancing:** medium **congestion management:** medium	**Medium** not yet considered as a flexibility resource

Note on Grid-integrated batteries, Building-integrated batteries, Battery electric vehicles, *Electrolysis:* If they are fed by electricity produced from renewables, the problem in Japan is that there is no way to check whether the electricity fed back from batteries or the hydrogen energy is produced from renewables. This is why tracking in non-fossil certificates becomes important.

2.3 Existing policies and market design in Germany/EU and analysis of the challenges

In the same way as for Japan in chapter 2.2, this chapter analyses the relevance of the challenges for the development of the electricity market design and of flexibility resources discussed in chapter 2.1 for Germany. As the basis for the analysis, the chapter starts with a brief introduction to the existing energy market design in Germany and the EU.

2.3.1 Energy market design today

In 1880, the first power plants with operating companies were established, integrating power plants, grids, and supply under a single entity. This integration led to the formation of vertically integrated monopolies. However, since the 1990s, the EU gradually liberalized its electricity markets under the paradigm that only the networks are *natural* monopolies, while competition in generation and supply would improve economic efficiency of the market. Germany went even faster than the EU legislation and fully liberalized the energy market in 1998, allowing competition in retail supply for all types of customers, including residential. As a consequence, the energy sector underwent an unbundling of production, transmission and distribution, and retail supply actors, which is summarized in figure 2-1.

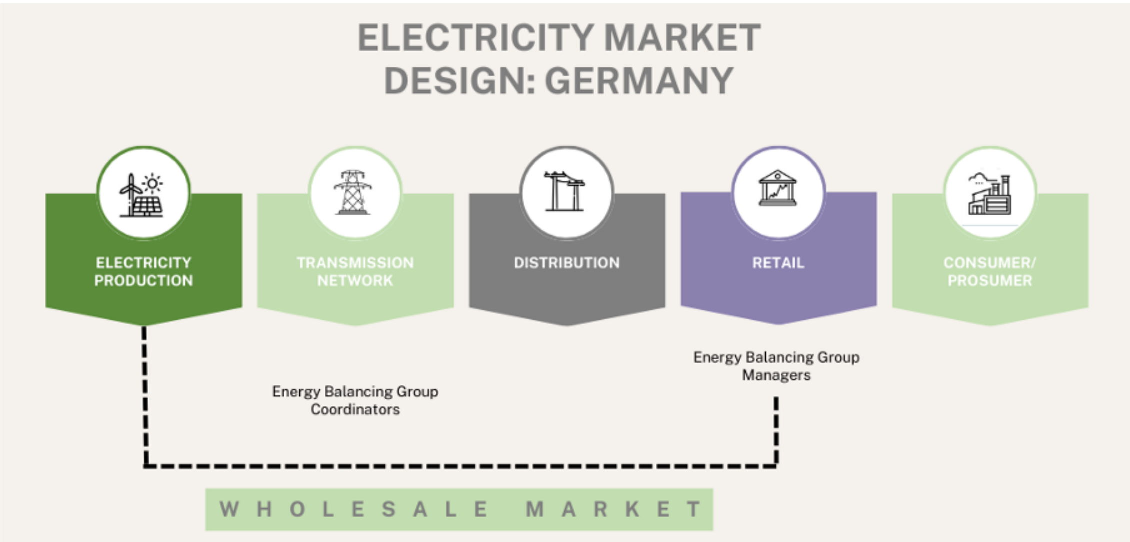

Fig. 2-1 Functions of actors in the unbundled energy market in Germany

In the EU, the European Commission defines three potential methods of unbundling of the Transmission System Operators (TSO), with at least one being mandatory based on the preferences of individual EU countries. These three types include ownership unbundling, independent transmission system operators, or independent system operators (European Commission, n.d.)

In Germany, unbundling is regulated in the Energy Industry Act and encompasses paragraphs 6 to 10. Germany has four TSOs and allows all three EU models. For distribution network operators

(DSOs), unbundling is implemented through four types of requirements, two of which are independent of the number of customers. 'Accounting Unbundling' requires a separation of accounts and bookings, while 'Informational Unbundling' necessitates a separation of data and the IT structure between retail suppliers and distribution system operators. The third and fourth types, 'Operational Unbundling' and 'Corporate Legal Unbundling', are mandated only when there are at least 100,000 customers connected to the distribution network operated by the DSO. In such cases, it becomes necessary to physically separate staff into distinct offices and different companies under the umbrella of a single holding group.

Spot and intraday markets

Electricity is traded within the energy-only market (EOM), either via Over-The-Counter (OTC) trading or via exchange-based trading in the wholesale market. The EOM can extend over a number of EU Member States, by coupling of the market zones. Each encompasses two market types: the spot market and the futures market. In exchange-based trading, the spot market, situated in Brussels (EPEX spot), manages electricity transactions for the following day (day-ahead, hourly products) and the current day (intraday, fifteen-minute products) as described by Wawer (2022). Various authors, such as the German Expert Commission on the energy transition and the Federal Environmental Agency (UBA), have underscored the significance of the day-ahead and intraday spot market within the German electricity market.

Although the EU energy market legislation allows the introduction of national capacity markets, Germany has not yet created such a market. However, it has introduced several capacity instruments (cf. chapter 3.4).

In contrast to some other European countries, Germany operates in one single price bidding zone. However, in the last few years there has been an ongoing discussion on the introduction of different market zones. Especially, a separation in two zones for the North and South of Germany is considered.

In Europe, price discrepancies arise among several countries with uniform prices, especially when the flow of electricity between these countries is restricted by the available transmission capacities (ATCs). This creates varying incentives for investments across different price zones (Löschel et al., 2023).

Balancing power market(s)

Balancing power markets are essential in ensuring the stability and reliability of the electricity supply system. In Germany, the four Transmission System Operators are responsible for the procurement and dispatch of balancing power capacities. The TSO companies are Amprion GmbH, TenneT TSO GmbH, 50 Hertz Transmission GmbH and EnBW Transportnetze AG. Hence, the balancing market is separated from the day-ahead and intraday markets and set up by the Transmission System Operator (TSO). In Germany, the following three types of balancing power markets exist: Primary Control Reserve (PCR or FRR), Secondary Control Reserve (SCR, distinguished into aFRR+ and aFRR-), and Tertiary Control Reserve (TCR, mFRR+ and mFRR-), for which the requirements are set by the TSO and procured by separate auctions. Primary control activates automatically within 30 seconds and must be available for up to 15 minutes; SCR activates automatically within 5 minutes by the relevant TSO, as described in Chapter 2.3.3., figure 2-2.

Management of network congestions

In Germany, various instruments address network congestions based on the time frame. Short-term measures involve redispatching fossil and renewable plants as requested by grid operators. Historically, grid operators compensated only for imbalances in balancing groups resulting from redispatch measures in larger conventional power plants, excluding compensation for curtailed renewable electricity production, known as feed-in management (Bundesnetzagentur, 2020) (own translation). In recent years, the frequency of redispatches has increased due to a higher proportion of renewables, inadequate grid connections between regions (e.g., high wind energy concentration in the north and production density in the south), and insufficient flexible power plants. Presently, the prevailing mechanism is redispatch 2.0 (introduced in 2021 under the NABEG), which incorporates power plants up to 100 kW (Next Kraftwerke, n.d.). However, there is an ongoing discussion about a revised concept known as redispatch 3.0 (for instance, see Krueger et al., 2023).

In the long run, network congestions will be managed through grid expansion and storage options. According to the Expert Commission (Löschel et al., 2023), a central problem is a lack of price signals for the producers, since price zones are mostly organized within countries on the spot market. As a consequence, a future energy market design needs to be improved by incentivizing location related investment.

2.3.2 Analysis of the current and future challenges

In comparison to other countries, Germany has a high share of power producers and already a high and rapidly growing share of renewable energy. Out of these market structures, a number of challenges arise. Table 2-5 summarizes the relevance of challenges in Germany and Japan.

Tab. 2-5 Relevance of challenges for the future electricity market design in Germany

Challenge	Relevance of challenge for Germany
Coordination	
1a) wholesale markets	**Not as urgent as it seemed in 2022** Many advocates of the energy-only market have argued that occasional very high price spikes will provide an incentive to invest in new capacity. However, the prices of up to 300 Euros/MWh that emerged over several weeks during the energy price crisis, which was evoked in 2022 by Russia's war of aggression against Ukraine, showed that it is difficult for politics to explain and tolerate such high prices. The merit order principle with the last offer setting the price for all led to high windfall profits for generators with low marginal costs. A discussion arose, whether the market should be split in one for 'inframarginal' generators, with a price limit, and one for generators with marginal costs depending in fuel prices. The decrease in wholesale power prices during 2023 has calmed down this discussion, so that reforms to wholesale market do not seem as urgent than in 2022.

Challenge	Relevance of challenge for Germany
1b) flexibilities	**High** Germany already has around 50% of power from renewable energies and has the target of reaching 80% by 2030. The increase will almost completely be PV and wind power. This will create high needs for flexible resources to balance supply and demand in the wholesale market and to manage network congestions. However, particularly for demand-side flexibilities and storage, there is currently no incentive to provide them to the market or grid. For example, power prices for most electricity consumers are constant in time, and load charges for larger customers are connected to individual peak loads, not to system peak loads or congestions. There is ample room and high need for removing disincentives or providing incentives to provide flexibility, already in the next few years.
2) Investment	
2a) renewables	**High** Investment in renewables is key to enabling a decarbonized electricity system in the future. Until 2030, Germany aims to build 260 GW of solar PV and 140 GW of wind power. Various challenges exist for the increased expansion of renewables that are constraining investment within the current electricity market design. Needs for action include grid expansion between north and south, planning and installation capacities, investments in various flexibilities, as well as changes within the regulatory framework. Volatile energy price environment at European level, state aid law, adaptation of refinancing instruments are further issues at hand. However, there is already a lot of research in this area, which is why this study does not focus on this topic.
2b) flexible power plants	**High** For implementing a higher share of renewables, supply and system security are important. In Germany, the need will already be high during the next years, due to the plans to increase the share of renewable power generation to 80 % by 2030. Flexible Power plants are one important option for Germany to achieve this, for instance, to enable grid stability and as a backup for peak demands or during 'dark doldrum' periods. Due to the phase-out of nuclear power in Germany in April 2023 and the plans to phase out coal power 'ideally' by 2030, gas power plants fired with hydrogen or, during the transition phase, natural gas are the priority solution. However, adding generation capacity and gas storage to existing biogas power plants is another option. Demand for gas power plant capacities will depend on the use of other flexibilities, and uncertainty is high. Estimates vary between 60 and 90 GW until 2035 (Samadi, 2022). However, there are a variety of challenges regarding the investment structure in power plants. Especially to enable the conversion to hydrogen power plants at a later point. This will need investments inside and outside of the electricity market design to make preferably green hydrogen available at reasonable prices.

Challenge	Relevance of challenge for Germany
2c) other flexibility resources	**Very high** The use of other flexibility resources requires a massive investment too, but it may be lower than for new gas power plants and partly avoid them. Today, the portfolio lacks an integration of renewables and flexibilities, and very different types of capacity instruments are implemented but do not yet unlock all of the potential. Simultaneously, flexibilities offer the potential to reduce the pressure on grid expansion especially in the distribution network, and thereby provide a cheaper alternative at certain points due to the high cost of grid expansion. Hence, research on investment structures into flexibility resources like demand response and storage options is of high relevance for Germany to enable a cost-efficient and stable integration of renewables. This is also urgently needed during the next 5 to 10 years already.
3) Signals for local differentiation	
3a) wholesale markets	**Disputed** The need and potential ways to provide signals for local differentiation is a very disputed topic in Germany. The basic idea of signals for local differentiation is to reduce network congestions and the corresponding needs for redispatch by incentivizing consumers to use power more effectively depending on the load situation and encouraging the development of new generation and flexibility in certain regions. On the one hand, it is argued that the current single national bidding zone with uniform prices lacks incentives to address such regional differences. Above that, existing subsidy instruments for storage take insufficient account of system usefulness, which could even lead to rising costs of grid expansion. Solutions that are discussed are a split into two or more regional market zones, or nodal pricing. Currently, a split in two market zones (North and South) is debated. Not surprisingly, the Northern federal states are advocating this, since the average power prices in this region with a lot of wind energy are expected to decrease somewhat, while the Southern states are opposing it, being afraid of increasing prices. A concern is the complexity of implementation of such a system and the general concern to interfere with market dynamics. Finally, there are also legal and regulatory challenges, that need to overcome. Although this is a highly relevant and pressing issue for Germany, the relevance for this study may not be so high, since there is already a lot of analysis available. In addition, regional price differences within Germany are already much higher than what is expected from a split in two bidding zones, because of the fact that distribution grid fees vary based on the locality or region, due to varying share of renewable power generation connected to the distribution grids, in combination with the current regulation that local grid fees must cover the connection costs. However, this may soon be resolved by the regulator via reallocation of these costs evenly across the country.

Challenge	Relevance of challenge for Germany
3b) renewables	**Moderate** Wind and PV systems have marginal costs close to zero. Hence incentives regarding the investment decision are crucial for them. These incentives could take network congestions into account, by being set at higher levels for building renewable power plants in regions with a lack of capacity. In fact, this is already the case for wind power in the German renewable energy act. In comparison, a splitting of the bidding zone would be less important since investments into renewables at the right place would lead to their dispatch quasi automatically serving the system needs. For that reason, signals for local differentiation for renewables are less relevant for the work at hand than it is the case for the general investment structure.
4) Power prices/ costs.	
	Moderate Power Prices and costs are, as in most economies, an important topic in Germany. In 2022 and early 2023, electricity and gas prices rose to unprecedented levels, causing high concern. However, in the meantime, they reduced a lot, although still being higher than before 2021. Therefore, in the current discussion other critical aspects like security and long-term investments are more relevant to secure a carbon-neutral energy system and the corresponding energy market design. In fact, investment in renewable energy generation and the accompanying flexibilities is seen as the way forward to reducing power prices back to affordable and competitive levels.

As a consequence of this analysis, the need for policy reform to enhance the electricity market design is highest for the investment in both renewable energies and flexibilities, as well as for integrating flexibilities in the markets and system operation. However, for the investment needed in the expansion of power generation from renewable energies, the necessary changes in the legislation at EU and German levels are already in concrete development. In the EU, in the recent revision of the electricity market legislation, double-sided contracts for difference and the promotion of power purchasing agreements are the main instruments included. In Germany, several improvements in detail to the established toolbox in the renewable energy law are planned.

Therefore, selecting investment in flexible power plants and other flexibility resources will be a good choice for the focus subject of this study from the German perspective.

2.3.3 Relevance of flexibility resources and their use cases

This section discusses the need for flexibilities in portfolio optimization, balancing, and congestion management in Germany.

Portfolio optimization

In Germany and Europe, a robust and efficient use of flexibility is central for portfolio optimization. The targeted growth of power from renewable energy sources in Germany to 80% in 2030 amplifies the necessity for flexibilities in Germany already in the short and medium term. As solar PV and wind power exhibit volatility, an increase in occurrences of either energy surplus or deficit is expected. This doesn't just entail fluctuations throughout the day but also across seasons. For instance, while winter yields considerably more wind energy, summer solar energy production can surpass winter levels by around six times in Germany. Furthermore, winter sees a notable spike in heating energy demand, which will increasingly be served via electric heat pumps. Addressing these fluctuations promptly necessitates a considerable demand for new flexibility options. This is further increased because the capacity of flexible coal power plants is decreasing in Germany.

Balancing power market

Traditionally, hydroelectric power has been the primary source for balancing, with almost half of the prequalified power capacity derived from hydro resources, which is predominantly pumped storage. Thermal power plants, including approximately 7% from biomass, constitute the remaining portion. Additionally, a small percentage is contributed by batteries, demand response mechanisms, and even wind power (aFRR- and mFRR-). In the years ahead, the potential for such new types of resources is on the rise, while the presence of fossil fuel-based thermal power plants, particularly coal, is expected to diminish from the market, ideally by 2030, with natural gas to follow suit, albeit at a later stage.

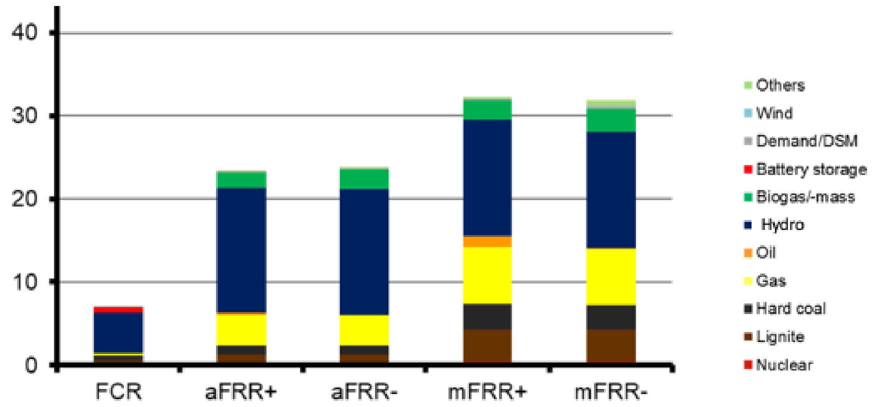

Fig. 2-2 Prequalified capacity in Germany's balancing power market

Source: 50 Hertz et al. (2023)

Congestion management

Flexibilities play a crucial role in managing congestions in the energy system. Hence, the need for flexibilities is increasing to reduce or defer the need for network expansion and upgrade, at both the Transmission System Operator (TSO) level and the Distribution System Operator (DSO) level. At the TSO level, the North's wind power contrasts with the South's photovoltaic energy and industrial loads. At the DSO level, the power flow from rural areas (net power producers) to urban centers (net power consumers) needs to be ensured. This requirement trickles down to the substation level, necessitating adjustments and flexibilities to accommodate electric vehicles, heat pumps, and rooftop PV systems.

In Table 2-2, the potential relevance of the types of flexibility resources for the three main use cases are discussed. The following Table 2-6 specifies the relevance in Germany with more detail and outlines, which preconditions may be needed for their use (e.g. labeling of renewable power) as well as their potential in Germany in a qualitative and quantitative way (if data is easily available).

Tab. 2-6 Types of flexibility resources and their usefulness and potential in Germany

Types of flexibility resources	Usefulness in Germany for the main use cases	Potential in Germany
Flexible low-carbon power plants		
Power plants using 100% green or blue hydrogen or ammonia or other derivatives (gas turbines, combined-cycle power plants)	**portfolio optimization:** high, because of high potential and seasonal/long duration flexibility **balancing:** high, because of high potential and usefulness for many products in the balancing power market **congestion management:** medium, if located well (mostly transmission or high voltage distribution; useful if well distributed across the country, especially on the deficit side of network congestions)	**High:** According to scenarios for decarbonized system in 2045, ca. 5 to 8 % of power generation should be from hydrogen, mostly in winter; for energy efficiency reasons, would be best if generated in CHP in district heating or industry, but investment in heat storage is needed. The electricity flexibility potential of heat storage in CHP in Germany has been estimated to be more than 50 GWh_{el}. This compares to pumped storage hydro capacities existing in Germany of 40 GWh_{el} (Ninomiya et al., 2019). The capacity of hydrogen (or biogas, see below) power plants needed in 2045 has been estimated to be between 60 and 90 GW in different scenarios (Samadi, 2022). This compares to around 87 GW of thermal power plants in 2020. This capacity could also be used for the balancing market. This hydrogen demand could be produced from surplus power in the summer, or imported. Time horizon: medium to long term (government plans first tender of 4.4 GW now, in operation ca. 2028)
Gas power plants ready to be converted to 100% green or blue hydrogen or ammonia or other derivatives	Same as for 100% clean hydrogen plants; they are cheaper but damaging the climate until the date of conversion to clean hydrogen.	**High:** potential during the transition phase from coal to 100% renewables and clean hydrogen (in Germany: mostly medium term, conversion to hydrogen up to 2035/40).

Types of flexibility resources	Usefulness in Germany for the main use cases	Potential in Germany
Critical question: When (future calender year) would conversion have to take place?		
Flexible use of biomass power plants Distinction whether using CHP (preferrable) or not	Mostly the same as for clean hydrogen power plants; they are more distributed, so even better for managing network congestions at the DSO level than large hydrogen power plants. However, biogas storage may rather be economically adequate for several days than for seasonal storage, which somewhat reduces usefulness for portfolio optimization.	**Medium to high:** Currently, ca. 2 to 3 GW are prequalified in the balancing power markets (cf. figure 2-2). Studies[1] show: they could provide up to 15 GW for portfolio optimization and possibly balancing power, if biogas storage and higher generation capacity were installed in existing plants. time horizon: short to medium term (capacity may reduce in long term)
Other flexibility options		
Demand response (in general, other subtypes than demand-side storage resources listed below) This includes industrial demand response in production facilities, for example using flexible electric production lines (e.g., Aluminium) in connection to product storage, and all kinds of cold storage, including in warehouses.	**portfolio optimization:** medium – highly relevant (end-user side), but only up to several hours **balancing (mostly with aggregation):** medium, because most loads cannot be increased **congestion management:** high – can be used at all grid levels, depending on location of production processes or cold warehouses **Precondition:** smart meters or at least digital meters with energy management system	**Medium:** There are several studies on the potential for demand response in Germany. For example, Agora et al. (2022) assume that a potential of ca. 4 GW can be used in the increasingly decarbonized power system, both in 2030 and 2035. Other studies find higher potentials. Currently, up to 200 MW are prequalified in the German balancing power markets (cf. figure 2-2).
Grid-integrated batteries (to store green power)	**Portfolio optimization and balancing:** due to the unbundling, batteries owned and operated by TSOs or DSOs may not participate in the market medium for batteries built by operators of renewable power plants or other market actors, due to limited duration of storage.	**Medium:** Theoretically, the potential of grid-integrated battery storage is high but limited by the cost-effectiveness. Other than the HSS or BEV, the investment is due only for the storage. While Agora et al. (2022) estimate the need for 6 GW of 'large storage' for 2035, Agora/FfE (2023) show that this need can

[1] For example, https://visuflex.fnr.de/flex-infos/stromversorgung-deutschland

Types of flexibility resources	Usefulness in Germany for the main use cases	Potential in Germany
	congestion management: locally high; for up to several hours or a few days	be completely avoided by using HSS, BEV, and heat pumps as alternative flexibilities. Currently, up to 630 MW of batteries of all types are prequalified in the German balancing power markets (cf. Figure 2-2).
Building-integrated batteries (to store green power)	**portfolio optimization:** medium, due to limited duration (on end-user side but also for system with adequate incentives) **balancing (with aggregation):** medium, due to limited duration **congestion management:** medium overall, but high at the local/substation level **Preconditions:** 1) smart meters or at least digital meters with energy management system 2) Grid codes and market rules must allow the participation of demand-side batteries to markets 3) aggregation 4) taxes and charges must only apply to final – net of discharge – consumption, so that bidirectional charging does not lead to double costs	Home storage systems (HSS) The potential may be **quite high**. Agora/FfE (2023) assume that by 2035, 12 million HSS may be installed in Germany, with a power capacity of around 50 GW, and an energy storage capacity of ca. 150 GWh. HSS grew by 52% in terms of battery energy in 2022 (compared to 2021) 220,000 HSS (1.9 GWh / 1.2 GW) were installed solely in 2022. (Figgener et al, 2023) Industrial storage systems (ISS): **medium** They grew by 24% in 2022 (compared to 2021), with a total of 1,200 ISS (0.08 GWh / 0.04 GW) installed.
Battery electric vehicles (using low-carbon power)	**portfolio optimization:** medium (on end-user side but also for system with adequate incentives and aggregation); for several hours or a few days **balancing (with aggregation): medium** **congestion management:** medium overall, but high at the local/substation level **Preconditions:** 1) smart meters or at least digital meters with energy management system; 2) a user must trust the automated service to charge and discharge in line with their needs; to be assured that their vehicle is charged and ready to drive when they need it (quoted from Burger,	**Very high:** Assuming 11 kW charging points, ca. 15 million BEV in 2030 and 33 million in 2035 would provide a theoretical potential of ca. 170 GW and slightly over 1,000 GWh of storage capacity for smart charging or vehicle-to-grid use in 2030. By 2035, this may grow to 330 GW and 2,100 GWh (Agora/FfE, 2023). Even if not all of these vehicles participated in flexibility supply, and considering that the vehicle must be charged and ready to drive when it is needed, the potential in practice may be very high. In electricity system simulations, BEV provided ca. 70% of the total flexibility potential of households (Agora/FfE, 2023, see below this table).

Types of flexibility resources	Usefulness in Germany for the main use cases	Potential in Germany
	2023). 3) standards for vehicles and charging infrastructure that cover a wide range of applications. For example, if the EN ISO 15118-20 standard for communication between EVs and charging points is implemented in charge point and vehicle regulations, it will ensure full and unrestricted compatibility between cars and devices of different manufacturers (Burger, 2023). 4) grid codes and market rules must allow the participation of demand-side batteries to markets 5) taxes and charges must only apply to final – net of discharge – consumption, so that bidirectional charging does not lead to double costs	The electric vehicle (EV) market grew with 693,000 new EV (27 GWh / 43 GW (DC) / 4.5 GW (AC)) by 34% in terms of battery energy (in comparison to 2021). (Figgener et al, 2023)
Electrolysis (using low-carbon power)	**portfolio optimization:** high; in combination with hydrogen power plants, also seasonal storage is possible **balancing:** high **congestion management:** medium to high (usefulness for flexibility may depend on the purpose, for which the electrolysis was built and financially supported: if it is production of green hydrogen coupled to PPAs, it will rather aim for high hours of use; if it is coupled to grid electricity, flexibility potential will be higher) **Precondition:** power used for electrolysis must be exempt from end-user taxes and charges	**High:** The German government plans for 10 GW of electrolyzer capacity for 2030. Long-term decarbonization scenarios may require 40 GW or more by 2045. For example, Prognos et al. (2021) estimate a need to use 150 TWh of electricity for producing hydrogen in 2045, and assume 4,000 hours/year of use of the electrolyzer capacity. This yields ca. 37.5 GW of electrolyzer capacity. This is a scenario with relatively low need for hydrogen.
Small-scale CHP or heat pumps and other electric heat generators in connection to heat storage	**portfolio optimization:** medium to high (on end-user side but also for system with adequate incentives); up to several days **balancing (with aggregation):** medium	**High:** Small-scale CHP may be seen as a part of the CHP potential mentioned for the hydrogen power plants above. For heat pumps, Agora/FfE (2023) estimates a flexibility potential of 50 GW and 2,200 GWh in 2035, assuming the installation of 9 million units by then.

Types of flexibility resources	Usefulness in Germany for the main use cases	Potential in Germany
	congestion management: medium to high, especially at the local/substation level **Preconditions:** 1) smart meters or at least digital meters with energy management system; 2) although the building can be used as a heat storage to some extent, through variation of indoor temperatures, the installation of additional heat storage tanks will greatly enhance the flexibility potential.	However, the high energy storage capacity requires the installation of heat storage tanks of between 700 and 1,500 l for each house, which is not common today and requires extra investment. Additional potential would be available from large heat pumps in district heating systems, as well as from direct electric heaters integrated into heat storage tanks in these systems. The latter may absorb lots of surplus power from renewable energy, but are much less energy-efficient than heat pumps.

Note on Grid-integrated batteries, Building-integrated batteries, Battery electric vehicles, Electrolysis: If batteries are fed by electricity produced from renewables, the problem in Germany is that under current legislation, the electricity fed back from batteries loses its 'renewable' quality. This is a problem that needs to be solved. For the hydrogen energy produced from electrolysis, there are now EU regulations regarding the conditions that have to be met to certify the hydrogen as 'renewable'.

According to a recent study for Agora Energiewende (Agora and FfE, 2023), the flexible use of BEV, heat pumps, and HSS together could achieve the following results by 2035:

- A combined flexibility potential of ca. 4.5 TWh of storage capacity and shifting ca. 100 TWh over the year, which is more than 10% of the power consumption expected by then. Of the 100 TWh/year, ca. 70% would be provided by BEV, ca. 20% by HSS, and 5 % by heat pumps.
- Economic net savings of EUR 4.8 billion/yr, due to reduced need for new power plants (ca. 7 of 61 GW expected capacity needs by 2035 without flexibility) and large storage batteries (28 GWh), but slightly increased grid upgrades with annualized costs of EUR 0.6 billion/yr
- Around 600 Euro/year of savings for an average household able to offer flexibility.

3 Analysis of reform options to stimulate investment in flexibilities

3.1 Screening of reform options

This chapter first presents options for the reform of the electricity market design or other instruments that are discussed in the literature or policy proposals in order to stimulate investment in flexibility resources, which were identified as priorities in chapter 2.1. These reform options are introduced separately for two areas of flexibility resources: either new flexible power plants, which can at least be converted to become zero carbon emitters in the medium term, or other types of assets (cf. chapter 2.1.3) to provide flexibilities, particularly on the demand side.

In the second step, the options are screened for their likely potential to identify the most promising ones. In addition, the potential impact is distinguished for the time scale – short, medium, or long term. Short term means up to 3 or 4 years from now, medium term around 5 up to 10 years, and long term within 10 years from now and later.

3.1.1 Overview of reform options

The following table presents reform options found in the literature or in policy proposals in both countries, Germany and Japan, as well as the EU. This list is certainly not exhaustive, but most likely includes typical solutions found in the public and scientific debate.

Tab. 3-1 Overview of reform options to stimulate investment in flexibilities

Flexible low-carbon power plants	
	"Energy only market" (EOM) with reserve assets (Current German model)
	Systemic investment framework (Uniform capacity instruments for new and existing assets; variants: a) with uniform price; b) with differentiated conditions for new and existing assets)
	Specific capacity instruments using capacity auctions with differentiated products
	Decentralized capacity market (obligation for energy suppliers to purchase certified capacity along with energy)
	Strategic reserve
Other flexibility resources	
	Direct support or regulation
	Systemic investment framework (i.e., Uniform capacity instruments, including both power plants and other flexibilities, variants a) and b) as above)
	Specific capacity instruments using capacity auctions with differentiated products

	Decentralized capacity market (obligation for energy suppliers to purchase certified capacity along with energy)
	Other specific capacity instruments for flexibilities, e.g., fixed payments per kW/kWh of demand response; government grants for batteries or V2G systems
	Regulation/standards on investment in flexibilities; e.g. legal requirements to make energy-using equipment (e.g. heat pumps) or energy generators remote-controllable, have smart inverters, install BEV charging points in buildings and make them controllable, require car manufacturers to install V2G applicability in all BEVs
	Rethink rules for the forecast of power capacities required to meet demand, e.g. for the EU, European Resource Adequacy Assessments (ERAA), to assess system flexibility beyond adequacy of conventional supply resources to enable Demand-Side Flexibility in Capacity Remuneration Mechanisms
	Providing incentives for using flexibilities, e.g. DR and storage, to system operators (TSOs/DSOs) in their regulated revenue
	Allow future costs for necessary expansion of (smart) distribution grids in revenue regulation of DSOs; also in benchmarking calculations; cancel benchmarking for gas DSOs (need to reduce and partly dismantle grid)
	Indirect support or regulation
	Roll-out of smart meters/submeters (necessary precondition for many flexibilities)
	Indirect support through enabling regulations and price signals for the use of flexibilities, providing an indirect incentive to invest
	Nodal pricing (to provide regionalized price signals)
	Allowing aggregators/value stacking (from different markets and resources) in all markets and mechanisms
	Energy communities/energy sharing/peer-to-peer trading
	Regional flexibility markets, e.g. for all flexibilities, or for use of renewable power that would otherwise have to be curtailed
	ToU power prices (and feed-in tariffs)
	Grid fee system incentivizing use of flexibilities (ToU, RTP; interruptible grid use, eg BEV)
	Making taxes and levies time-dependent too
	Market incentives for system-serving behavior
	Waiving grid fees, levies, and energy taxes for storage and electrolysis

Sources: Löschel et al. (2023); European Commission (2023); Neuhoff et al. (2023); RAP (2023a)

3.1.2 Screening of reform options to select the most relevant options for further analysis

At the scoping workshop on 25 September 2023, the GJETC members who participated were first asked, for which of the longlist of reform options listed in Table 3-1 they see the highest potentials to stimulate investment in flexibility resources.

Flexible low-carbon power plants

It is a result of the analysis of challenges that an "energy only" market with reserve assets (as it is currently the case in Germany, while Japan already has a capacity market) may not be sufficient to stimulate the massive investments in diverse types of flexibility resources, which are needed for a secure and cost-efficient power supply with high shares of variable renewable power generation (e.g., Löschel et al., 2023). Therefore, the experts stated that either *specific capacity instruments* or *a full-fledged capacity market* have a high potential for stimulating investment in flexible low-carbon power plants. The capacity market, also called systemic investment framework, may have different effectiveness for power plant investments, depending on whether there is a *uniform price* for all plants or *differentiated prices for new and existing assets*. Therefore, there are three options that should be covered:

- Systemic investment framework / Uniform capacity instruments with uniform price
- Systemic investment framework / Uniform capacity instruments with differentiated conditions for new and existing assets
- Specific capacity instruments using capacity auctions with differentiated products

The GJETC experts see these instruments as effective for stimulating investments in flexible low-carbon power plants in the medium and long term.

Other flexibility options

This category of flexibility resources is much more diverse than the flexible low-carbon power plants. Therefore, the effectiveness of instruments that could be included in a reform of the electricity market design and regulation may vary depending on the type of flexibility resource. Some instruments are type-specific by themselves, such as the example of direct regulation/standards on investment in flexibilities listed in Table 3-1.

Nevertheless, the GJETC experts considered some of the instruments as potentially more effective than others, and hence worth a closer examination in this study. These instruments include *specific capacity instruments* and *systemic investment framework* that were also considered for the flexible power plants. While the specific capacity instruments would indeed offer specific financial incentives or remuneration for the other flexibility resources, the systemic investment framework would span across both, flexible low-carbon power plants and other flexibility resources, creating a direct competition between them. To the extent that the other flexibility resources are as reliable as but cheaper than the power plants, this would offer an advantage for the other flexibility resources.

Among the other direct support or regulation instruments, *allowing the future costs of flexibilities in the regulated tariffs of TSOs and DSOs* was also thought to be effective. This would include two from the Table 3.1, namely *1) Providing incentives for using flexibilities, e.g. DR and storage, to system operators (TSOs/DSOs) in their regulated revenue* and 2) *Allow future costs for* *necessary expansion of (smart) distribution grids in revenue regulation of DSOs; also in benchmarking calculations*. It would support own investments by the system operators or also their programs to support investments by grid users, provided these have the right incentive to operate the flexibilities in a system-serving way. This instrument could already stimulate investments in the medium term, according to GJETC members.

None of the participating members voted for *regulation/standards on investment in flexibilities*. Although these may be very effective for the type of flexibility they regulate, their applicability may be country-specific, so we do not include them in the selection of options to be studied in detail here.

Out of the list of indirect support or regulation instruments, the *roll-out of smart meters and submeters* was considered an important precondition for investment in, and use of flexibilities. This can be effective in the short term already. However, this is predominantly an issue in Germany, because Japan has already achieved a high penetration of smart meters. Regarding submeters, their use may require explicit allowance, but it may be a minor problem compared to cost-effectiveness issues of the flexibility resources themselves. Therefore, we will not go into detail for this policy option.

Another option for direct support, namely to *require better consideration of flexibilities in the rules for the forecast of power capacities required to meet demand*, was not even discussed at the workshop. We consider this mainly as a preparatory step for capacity auctions covered either under the specific or uniform capacity instruments discussed above.

Out of the long list of reform options for *indirect support through enabling regulations and price signals for the use of flexibilities, providing an indirect incentive to invest* listed in Table 3-1, four were discussed at the scoping workshop. Three out of these were considered among the more effective instruments, while *allowing aggregators/value stacking (from different markets and resources) in all markets and mechanisms* was not among them. This reform option is already partially implemented in Germany and Japan.

Making power prices, grid fees, and possibly even taxes and levies time-dependent (time of use) or even dynamic (real-time pricing) can be very effective in transporting the highly fluctuating wholesale power prices in markets with high shares of PV and wind power down to individual customers, and hence send the price signal to use existing storage or demand response potentials, and to invest in metering devices and energy management systems needed, or even in new storage. This can take effect already in the short term.

For storage and electrolysis, *waiving grid fees, levies, and energy taxes* can also be effective in the short term. However, it is relatively easy to implement and may not need further analysis.

Finally, some experts also considered *nodal pricing* to provide effective price signals needed at the regional or local level. However, introducing this may need a lot of analysis and effort, and only be possible and hence effective for flexibilities in the long run. For Germany, introducing *two or more bidding zones* may be feasible in the medium term already. However, since Japan already has this model, it does not seem a good fit for a GJETC analysis to explore new ground together, although Germany may learn for the implementation of this model from Japan.

There may be potentially effective instruments among the other instruments mentioned in Table 3-1, but for reason of limited resources for this study, we will have to forego a further analysis of these.

Summarizing, the following reform options to support other flexibility resources were selected for further analysis in this study. The list is sorted from the most general to the more specific and from targeting upstream market actors to consumers/prosumers, but does not entail a ranking by effectiveness.

- Systemic investment framework / Uniform capacity instruments with uniform price
- Systemic investment framework / Uniform capacity instruments with differentiated conditions for new and existing assets
- Specific capacity instruments using capacity auctions with differentiated products
- Other specific capacity instruments for flexibilities
- Allowing the for costs of flexibilities in the regulated tariffs of TSOs and DSOs
- Making power prices, grid fees, and possibly even taxes and levies time-dependent (time of use) or even dynamic (real-time pricing)

Since the first three types of capacity instruments are the same as for flexible power plants, overall, there are six types of reform options we will analyze in more detail in this study.

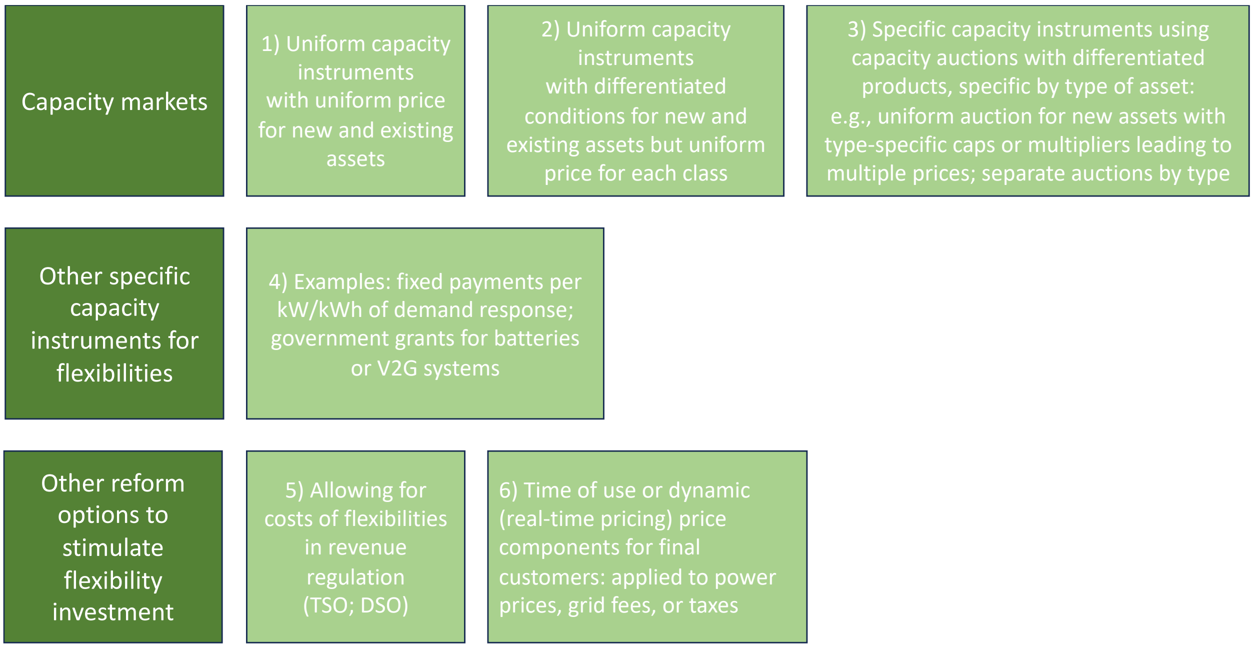

Fig. 3-1 Types of reform options selected for detailed analysis

3.2 General analysis of the selected reform options

In this section, we analyze in general, how the six reform options would improve the situation for investment in flexibility resources. Seven criteria serve to structure the analysis:

- What are **preconditions** needed to implement the reform option?
- Which **advantages**, and
- which **disadvantages** may the reform option have?
- What are the **roles of different actors**, such as policy-makers, regulators, and market actors?
- Which **legislation or regulation** would be needed?
- How would **dispatch** of the flexibility resources be organized or supported?
- How **relevant or effective** are they for the various types of flexibility resources identified in chapter 2.1?

3.2.1 Systemic investment framework / Uniform capacity instruments with uniform price

Systemic investment framework / Uniform capacity instruments with uniform price refers to a capacity market with a uniform price for all new and existing assets. The following describes the preconditions, advantages, disadvantages, roles of actors, laws and regulations, and relationship with the resources identified in 2.1 in such a capacity market.

Preconditions

In countries that have not fully liberalized the electricity retail market, major electric power companies, which are guaranteed a return on investment through regional monopolies and regulated tariffs, systematically construct and maintain the power generation facilities necessary to meet their supply obligations and supplies electricity to all consumers. Once the retail market fully liberalizes, power generation companies but also other market participants will need to recover their investments through the wholesale electricity market (kWh market). However, power generation companies face uncertainty in recovering construction and maintenance costs of power generation facilities or flexibility resources solely through the wholesale electricity market. This uncertainty arises due to the expansion of trading volume in this market and the decrease in market prices associated with the increased adoption of renewable energy. In addition, retail electricity companies need to ensure the supply capacity that meets their demands, but many of them do not have power generation facilities. Given these circumstances, both power generation companies and retail electricity companies want to have a capacity market (kW market) to ensure that the necessary power supply capacity meets the demand. The opening of the capacity market is expected to secure the necessary supply capacity for new and existing facilities.

For distributed resources of power generation, demand response, and storage, aggregation is likely to be needed due to the effort of preparing a bid to the capacity market, and managing the participation if the bid is successful. In addition, smart meters are a technical condition for the participation of these resources.

It will also be necessary to perform an assessment of the need for the amount of capacity that should be opened to tender. In this form, a capacity market will use calls for tender for a certain year several years into the future, e.g., four years in the case of the Japanese capacity market. The auction is usually organized for all capacity that is needed to meet demand in the year concerned.

Advantages

One advantage of the capacity market is that it is possible to secure the supply capacity needed in the future in advance. In the capacity market, auctions are usually held three to four years in advance of actual supply and demand, and the necessary supply capacity is purchased. This enables power generation companies and other market participants to make capital investments and maintain power generation and other facilities with a certain predictability of investment returns because they no longer solely rely on electricity sales revenue in the wholesale power market. For retail electricity providers, it becomes easier to procure the 'supply capacity,' ensuring electricity is available when needed in the future. This leads to more stable business operations.

As a second advantage, this system helps mitigate the risk of future tight supply and demand by securing sufficient capacity in advance to meet the peak demand, even during times of high demand.

As a third advantage, this system may also make it less likely that wholesale electricity prices will rise due to insufficient procured electricity. It is expected that this will enable electricity to be supplied to consumers at a stable price over the medium to long term.

Disadvantages

One disadvantage of the capacity market is that it may increase the cost burden on consumers in the short term. This is because retail electricity companies bear the cost of the capacity market, and the retailer is likely to pass on the cost of the capacity market to the electricity bill of the consumer.

A second disadvantage is observed in scenarios like Japan's capacity market, where the contract period is one year. If one intends to continue the contract, one needs to participate in a new auction. Given the uncertainty of winning bids annually, there's a risk that incentives for encouraging investments in new constructions may diminish.

Some analysis finds that capacity payments to existing power plants may increase the cost of expanding renewable energies to consumers or taxpayers. The reason is that due to the capacity payment, more conventional power plants will participate in the energy market, leading to lower wholesale market prices and hence, lower value of the power from renewable energies. In the case of fixed feed-in tariffs or contracts for difference, this will increase the cost of renewable energy levies or the amount of public budget to cover the difference to power market prices. Hence, consumers or taxpayers would pay twice: for the capacity market and an increase of spending on the renewable energy support scheme (Nicolosi and Burstedde, 2021). This result would also hold in a similar way for other types of capacity markets or payments rewarding existing power plants (e.g., strategic reserves). In addition, if the capacity payment per consumer is a fixed annual charge, it will further limit the incentives for demand response. Therefore, making these payments dynamic, such as other components of the electricity prices (cf. chapter 3.2.6), will improve the incentives for demand response and storage (RAP, 2023b).

Role of actors

In the capacity market, a neutral organization (like OCCTO in Japan) forecasts the maximum electricity demand expected in the future and assesses the required supply capacity to meet that demand. Then, to fulfill the procurement needs, the neutral organization will request power sources that can be provided in the future. Power generation companies and other market participants send in bids to provide capacity and if awarded a contract, they conduct maintenance on power plants and other assets to ensure their ability to supply electricity and receive a contribution fee from the neutral organization. Retail electricity companies pay a fee to the neutral organization in exchange for ensuring that they have the power supply capacity they will need in the future.

Legislation/regulation

Under the Electricity Business Act, retail electricity companies are obligated not only to secure the amount of electricity they supply (kWh), but also to secure supply capacity (kW). After starting the capacity market, a neutral organization will secure the supply capacity (kW value) necessary for the entire country through the capacity market, and that organization will collect the cost from retail electricity companies as capacity contributions. Therefore, for retail electricity companies, the capacity market is positioned as a means to fulfill the obligation of securing supply capacity under the Electricity Business Act.

Limiting the capacity instrument to low-carbon or decarbonized power sources will need to be ensured through adequate prequalification conditions.

Dispatch

Capacities that have been awarded in a power auction may participate in the energy markets like any other resource. In fact, they will have to participate particularly at times of tight supply and high prices. Depending on national legislation and regulation and the characteristics of the flexibility resources, these capacities may or may not participate in the balancing power market as well. Their use for managing network congestions will probably depend on whether this conflicts with their use in the energy market and as firm capacity, i.e., when and where the network congestions occur.

For distributed resources including storage and demand response, aggregation may be needed to enable their participation in the energy market in a similar way to the capacity market.

How relevant or effective is this option for the various types of flexibility resources identified in chapter 2.1?

Capacity market auctions may target thermal power above a certain scale (e.g., 1,000 kW in Japan), nuclear power, large-scale hydropower, geothermal/biomass/waste, storage batteries, wind power, and solar power. Renewable energy power sources, private power generation and batteries, and Demand Response (DR) units below a specific scale (less than 1,000 kW in Japan) can collectively participate in auctions if their combined capacity surpasses a certain threshold.

In that sense, it is possible to support some of the flexible power sources identified in 2.1 as well as renewable energies (DR, storage batteries, wind, solar, etc.). However, the incentives from the typical short-term contracts may not be sufficient to stimulate investment in new decarbonized power sources and flexibility resources, as discussed under *Disadvantages* above.

3.2.2 Systemic investment framework / Uniform capacity instruments with differentiated conditions for new and existing assets

This reform option represents a capacity market that guarantees capacity revenues for new and existing power generation or flexibility assets through separate auctions. They may differ in duration, typically one year for existing assets and up to 15 years for new assets, or other preconditions, and may lead to different prices for new and existing assets. However, different types of new assets will compete in the same auction, and there will be a uniform price between them. The following shows the preconditions, advantages, disadvantages, roles of actors in this system.

Preconditions

Even if a fully uniform capacity market is introduced, the prospect of long-term investment recovery is uncertain due to the full liberalization and one-year capacity contracts, and there are concerns that power source investments, which require long construction periods and large investment amounts, will stagnate. Therefore, from the perspective of securing power source investment, it is necessary to introduce a system to secure long-term fixed income for new power source investments. Furthermore, to achieve carbon neutrality in 2050, it is necessary to invest in new and replacement of decarbonized power sources as well as to replace the balancing power of thermal power with decarbonized power sources.

For distributed resources of power generation, demand response, and storage, aggregation and smart meters will be required for participation in this type of capacity instrument.

A necessary precondition is to perform an assessment of the need for the amount of capacity that should be opened to tender. The auction for new resources and existing assets would cover the gap between the demand forecast and the predicted capacity in the target year.

Advantages

One advantage of this system is that power generation companies and other participants offering distributed resources through aggregation can obtain capacity income at a fixed cost level over a long period of time. As a result, this system offers participants predictability in long-term income while recouping the substantial initial investment. This system is, therefore, more appropriate to stimulate new investments than the capacity market with uniform prices for all assets.

As a second advantage, under this system, bids for new power or flexibility supplies from power generation companies and others are awarded through a competitive auction. After bidding, power sources are generally awarded based on the lowest bid price, considering a mix of power source types. The winning bids are those that meet the requested quantity. Therefore, compared to the single-price system, it is expected that the overall cost will be lower.

As the third advantage, "in this system, unlike the capacity market with uniform price, it doesn't uniformly request a starting operational period. Instead, considering the construction lead time for each power source allows for flexibility in determining the start of operations. This opens up the possibility for various decarbonized power sources to participate in bidding" (METI, 2022).

Disadvantages

This system targets decarbonized power and flexibility resources such as hydrogen or ammonia co-fired/dedicated-fired thermal power, biomass-fired thermal power, energy storage batteries, solar power, wind power, and others. Typically, some of these resources have higher generation costs compared to conventional thermal power generation. As one disadvantage, therefore, there's a possibility that because retailers who bear the cost will pass it on to consumers, this may ultimately increase the cost burden on them. However, the award based on the lowest bid price may mitigate this risk to a large extent.

As a second disadvantage, also, if all profits obtained from other markets are recognized within this system, there's a possibility that the profits of power generation companies could rise without limits. Japan's system requires a refund of profits earned in other markets. This measure may create a risk of reducing investment incentives for power generation companies.

As a third disadvantage, through the joint auctions for all types of resources and the awarded based on the lowest bid price, this system may still not provide enough incentives for the investment in innovative technologies. These may still have higher costs or implementation barriers today, so that they fail to be awarded in this system, but may be needed in the future, and may have the potential for learning curves leading to competitive costs in the future.

Same as in the Uniform capacity instruments with uniform price (chapter 3.2.1), if the capacity payment per consumer is a fixed annual charge, it will further limit the incentives for demand response. Therefore, making these payments dynamic, like for other components of the electricity prices (cf. chapter 3.2.6), will improve the incentives for demand response and storage (RAP, 2023b).

Role of actors

Similar to the capacity market with uniform prices for all assets, a neutral organization (e.g., OCCTO in Japan) holds an auction for new investment in decarbonized power sources and flexibilities and determines the winning power sources and winning bid prices. Power generation companies and other participants, e.g., aggregators, bid in the auction and provide supply or flexibility capacity if they win the auction. Retail electricity companies pay capacity contributions.

Legislation /Regulation

Similar to the uniform capacity market, this system imposes legal obligations such as the Electricity Business Act on each actor. Winning bidders will have to provide the capacity they bid to the market. Power generation companies are obligated to supply electricity if they have concluded an electricity supply contract with a general power transmission and distribution company. In order to fulfill the obligation to secure supply capacity under the Electricity Business Act, retail electricity utilities must pay the capacity contributions. Limiting the capacity instrument to decarbonized power sources will need to be ensured through adequate prequalification conditions (RAP, 2023b).

Dispatch

The same applies as for the uniform capacity market.

How relevant and effective is this option for the various types of flexibility resources identified in Chapter 2.1?

This system is able to support decarbonized power sources and flexibility resources, such as large-scale thermal power (hydrogen or ammonia-only combustion and mixed combustion, biomass-only combustion), storage batteries, hydropower, geothermal power, nuclear power, solar power, wind power, demand response, etc. Therefore, this reform option supports many of the decarbonized power sources and other flexibilities identified in chapter 2.1, provided that adequate prequalification conditions are in place. However, the incentives from this system may not be sufficient to stimulate investment in innovative new decarbonized power sources and flexibility resources that still have higher production or transaction costs, as discussed under *Disadvantages* above.

3.2.3 Specific capacity instruments using capacity auctions with differentiated products

This type of specific capacity instruments will use capacity auctions too, but provide differentiated conditions for investment in different types of new decarbonized power plants or other flexibility resources. They can be capacity markets with similar types of auctions and conditions for all types of assets, but with separate conditions or even separate auctions, leading to separate prices, for the different types of assets. It could take, i.a., the following forms:

- Mixed types of power/flexibility sources are auctioned simultaneously, and new power/flexibility sources are awarded in the order of lowest bid price, as in the previous option. However, there are caps on the amount of each type of resource allowed to bid, e.g., storage batteries, pumped storage, and replacement of existing thermal power plants. The long-term decarbonized power supply auction scheduled to be introduced in Japan falls under this system.
- Multipliers are applied to the winning bid prices for resources meeting flexibility requirements (e.g., response time, duration). In Belgium, for example, so-called derating factors consider the effective capacity provided, e.g., 91% for open gas turbines, 31 % for storage of one hour, 13 % for offshore wind.
- Separate auctions, leading to separate prices, for the different types of assets. This system would be similar to an auction system for renewable power generators with separate auctions, e.g., for rooftop PV, utility-scale PV, onshore wind, and offshore wind power.

Preconditions

The preconditions, in general, are the same as for the *Uniform capacity instruments with differentiated conditions for new and existing assets*. Depending on the form of implementation of the specific capacity auctions, the amount of the caps or capacity for separate auctions, or the multipliers per type of resource have to be defined.

Advantages

Compared to the truly uniform auction for new assets (chapter 3.2.2), the specific capacity instruments are more effective in providing sufficient incentives for the investment in innovative technologies.

Caps: It will be easier for the regulatory body to manage the type and level of resources they want to deploy than in a truly uniform auction for new assets.

Separate auctions: It will be easier for the regulatory body to manage the type and level of resources they want to deploy than in a truly uniform auction for new assets.

Multiplier auction system: By considering a premium factor for non-fossil resources, the number of successful bids for non-fossil resources increases. Furthermore, since resources are awarded in a single capacity market, competitiveness and overall liquidity of resources can be ensured.

Disadvantages

Compared to the truly uniform auction for new assets (chapter 3.2.2), the selection is not determined by economic competition alone. As a consequence, there is a risk that economic efficiency may not be maximized, depending on the implementation of the caps, multiplier, or separate auctions.

Caps: If the cap is not set appropriately, economic efficiency may not be maximized. However, since the auctions are not separated, if the cap for a specific resource is not reached, it is possible to allocate it to other resources.

Separate auctions: If the amount of capacity for each type of flexibility resource or the ceiling price is not set appropriately, economic efficiency may not be maximized.

Multipliers: If the multiplier is not set appropriately, economic efficiency may not be maximized.

Role of actors

The actors and their roles, in general, are the same as for the *Uniform capacity instruments with differentiated conditions for new and existing assets*.

Dispatch

The same applies as for the uniform capacity market.

Legislation /Regulation

Since this is a specific capacity market, the legislation or regulation will be the same as for the uniform capacity market, plus some specification for the form of implementation for addressing the specific types of flexibility resources (caps, multipliers, or separate auctions).

How relevant and effective is this option for the various types of flexibility resources identified in Chapter 2.1?

As stated in advantages, caps and separate auction will make it easier for the regulator to manage the type and level of resources they want to deploy than in a truly uniform auction for new assets. In this system, the regulator is able to prioritize among the specific resources identified 2.1. Multipliers set for the auction can set a premium factor for non-fossil resources identified in 2.1. As a result of that, the share of non-fossil capacities that have been awarded in a power auction is expected to increase.

3.2.4 Other specific capacity instruments for flexibilities

Specific capacity instruments do not have to use auctions. They could also offer fixed payments per kW or kWh of generation of flexibility capacity, by either the TSO or DSO, or by the state, or be investment grants, e.g., for batteries in a lump-sum of money or as a percentage of the investment costs. Several such capacity instruments exist in Germany (cf. chapter 3.4).

Preconditions

The government or the regulator needs to understand the need for the type of flexibility resource and the cost-effectiveness of the investment in them from the perspective of the investor, in order to set the incentive in the right form and at the right level. Potential positive or negative cross-impacts to other parts of the energy markets should also be assessed before launching a specific instrument.

As for other capacity instruments, smart meters are a technical precondition for the use of distributed resources in the energy or balancing power market. For managing network congestions, a simple remote-control device of the TSO or DSO may be sufficient.

Advantages

Compared to other types of capacity instruments, especially to capacity markets, advantages of such specific capacity instruments may include:

- aggregation may not be needed in the case of investment grants;
- grants are easy to administer;
- no precise estimate of the required amount of flexibility capacity is necessary beforehand;
- the financial support schemes may lead to quicker market deployment of some types of flexibility resources than through capacity markets, which will also bring down costs faster.

Disadvantages

In the case of investment grants, the actual use of flexibility for the market or the grid may not be guaranteed. In the example of home or commercial storage batteries, they may simply maximize the own use of PV power by consumers, unless there are requirements attached to the grant and or additional incentives for system-serving use, such as dynamic energy prices (cf. 3.2.6);

In addition, specific capacity instruments may lead to higher costs than capacity markets, since no competitive bidding is involved in selection of the assets.

Role of actors

The actors involved and their respective roles will depend on the type of flexibility resource and specific instrument, for example,

- Payment for industrial demand response in exchange for the TSO to be able to use it for redispatch: The TSO calls off the decrease or increase of power and pays for it; the industrial company prequalifies and ensures that the call-off can be made or sends denial in advance.
- Investment grant for a HSS or ISS battery: the state runs the program and pays the grant; the home or building owner invests and receives the grant; if the battery is used to serve a market or manage network congestions, this may need an aggregator in addition.

Legislation /Regulation

This is likely to be specific to the type of capacity instrument. A law or regulation may be needed to create a scheme of payment for industrial demand response, while it will be less needed for specific grant programs. Allowing the DSO to limit the charging power of BEVs or the power uptake of heat pumps will certainly also need a law or regulation.

Dispatch

The organization of dispatch of the flexibilities will depend on the type of instrument as well. For a scheme of payment for industrial demand response, the payment is directly linked to the demand response event. In the case of investment grants, it needs additional incentives and controls, e.g., through dynamic energy prices.

How relevant and effective is this option for the various types of different types of flexibility resources identified in Chapter 2.1?

A payment for industrial demand response in exchange for TSO to be able to use the demand response for redispatch can be effective for large industry companies; possibly also for medium-sized companies at the regional/DSO level. Grants can be very effective for stimulating investment in battery storage (HSS, ISS) and for BEV charging stations that enable smart charging or V2G, but will need additional incentives to use of flexibility for the market or the grid, e.g., dynamic energy prices (cf. chapter 3.2.6).

3.2.5 Allowing the future costs of flexibilities in the regulated tariffs of TSOs and DSOs

This includes 1) Providing incentives to system operators (TSOs/DSOs) in their regulated revenue for using own flexibilities and those of third parties, e.g. DR and storage, and 2) Allowing anticipated future costs for investments in more flexible (e.g., smart) components of distribution grids, which help to defer or avoid reinforcement of the grids, in revenue regulation of DSOs.

Preconditions

Legislation and regulation must be in place, see below. TSO/DSO network development planning must take potentials of own flexibilities (e.g., grid-integrated batteries, smart transformers, temperature management of powerlines to enable higher capacity than originally designed) and those of third parties into account.

Smart meters are required for some forms of third-party flexibilities.

Advantages

If the grid-integrated batteries and other flexibilities are able to defer or avoid the expansion of grid capacities at lower cost than the expansion, this will be an economic advantage in managing network congestions.

Compared to other policy instruments, e.g., capacity markets, this instrument provides a more direct way to stimulate the investment in grid-integrated or grid-serving flexibilities. The assessment of needs and cost-effectiveness, and the funding of the costs, will also be integrated into existing planning and regulation schemes, so the lead time to implement it will likely be shorter than for other instruments.

Disadvantages

Other than in a capacity market, the selection of resources will not be made in a competitive way. However, the electricity networks, as natural monopolies, are subject to revenue regulation anyway, as a substitute for competition. This regulation would also cover the costs of flexibility resources.

Role of actors

The TSOs and DSOs need to integrate grid-integrated flexibilities and those of third parties, particularly power consumers and distributed generation, into their network development planning. The regulator will need to allow the costs of the flexibility resources in its revenue regulation, if the flexibility reduces overall system costs of energy supply and use. The TSOs and DSOs then invest in their own flexibilities and their operation, such as those mentioned above, or provide incentives for power consumers and distributed generation to invest into making their storage or generation available. Time-dependent grid fees that reflect network congestions (cf. chapter 3.2.6) are an option for such incentives on the consumer side. For generators, this may be implemented through redispatch and the corresponding economic compensation. However, the grid-integrated and demand-side flexibilities should also be used to avoid the costly redispatch.

Legislation /Regulation

If TSO/DSO revenues and the corresponding network fees are determined via cost-plus regulation, no changes to the legislative framework may be required for taking the costs of the flexibilities into account. Where incentive regulation is in place, as in Germany, the additional investment needed for the flexibilities may lead to reduced net profits of the TSO or DSO, which would be a disincentive. Therefore, in a system with incentive regulation, legislation needs to be adapted to mandate the regulator to allow such additional costs in regulated revenues, but also consider savings in operation costs due to the investment, while leaving a positive incentive for the TSO/DSO to invest. Incentives should also be given for the involvement of third-party flexibilities, if they reduce overall system costs, according to the 'energy efficiency first' principle. For example, the implementation of time-dependent grid fees or of redispatch should not reduce the net profits of the TSO/DSO. Independent of revenue regulation principles, legislation should mandate the TSOs/DSOs to include the flexibilities that reduce overall system costs of energy supply and use into the network development and investment planning, and implement the plans. The regulator needs to design details and implement all of these actions.

Dispatch

If the TSOs or DSOs themselves own the flexibility resources installed, they will dispatch them for management of grid congestions as necessary. The same holds for third-party flexibilities they may have contracted.

How relevant and effective is this option for the various types of different types of flexibility resources identified in Chapter 2.1?

This reform option may be very effective for managing network congestions, by directly stimulating TSOs/DSOs to invest in their own flexibility resources, such as grid-integrated batteries, smart transformers, or temperature management of powerlines to enable higher capacity than originally designed. The reform option may be very effective for the proactive use of flexibilities of third parties as well.

3.2.6 Making power prices, grid fees, and possibly even taxes and levies time-dependent (time of use) or even dynamic (real-time pricing)

This reform option will provide an indirect incentive for investment in flexibility resources to electricity consumers/prosumers, especially home or commercial battery storage systems, the batteries of electric vehicles, and commercial and industrial demand response. It makes these actors see the fluctuations of wholesale power prices or, in the case of grid fees, network congestions, in the end-user power prices. The differences in prices over time will allow to recover the costs for the investment in batteries or V2G infrastructure, or energy management systems required for demand response, as well as for any operation costs.

Time-of-use pricing means to define several price levels, usually two to three, but with fixed time windows. The highest price would be at times of the day that usually have a high demand or, in a system with high shares of variable renewable energies, a high residual load, i.e., the difference between the current demand and the power generation from renewable energy sources. This can apply to both the electricity retail price and its components, such as electricity and capacity price, grid fees, taxes, and levies. Time windows for the grid fees could be different from those of the electricity from the energy and capacity markets.

Dynamic electricity retail prices are following the wholesale price. Dynamic grid fees, however, may rather have several fixed price levels, but with dynamic time windows that reflect situations of no grid congestions, warning level, and acute congestions (Agora and FfE, 2023).

Preconditions

Smart meters will be needed both for managing most of the demand-side storage and response as flexibilities, and for metering and billing the variable price components with high time resolution. Consumers making use of the time-variable prices need to have an energy management system for their flexible assets that allows them to respond to the prices, or a contract with a specialized provider.

The detailed design and processes to implement the time-of-use or dynamic electricity price components may need considerable effort.

Legislation and/or regulations may be needed to make the offer of time-of-use or dynamic price components mandatory for power suppliers, TSOs, or DSOs.

Advantages

Since the economic incentive for the investment and operation of flexibility resources is provided by electricity prices, this is considered as a market-based instrument. In principle, this should be a cost-efficient way of allocation of resources.

To the extent that the instrument is effective in stimulating the market integration of demand-side flexibilities that are cheaper than the expansion of grids or flexible power plants, this will contribute to reducing the overall costs for ensuring the security of electricity supply.

There is a good chance that these resources will be cheaper, since the basic devices, such as batteries, BEVs, and commercial and industrial equipment, are already in place, and investment is only needed for making use of them as flexibility resources.

Disadvantages

As for all energy pricing instruments, the price signal alone may not be sufficient to overcome organizational barriers and transaction costs for individual consumers to implement the desired actions. Specialized service providers, which could be the energy suppliers or the TSOs/DSOs themselves or independent providers, may be needed to manage the flexibilities for the consumers and reduce transaction costs or hassle.

Role of actors

The electricity retailers and TSOs/DSOs need to offer the time-variable electricity prices and grid fees. Metering providers (DSOs or, in Germany, also competing metering providers) need to install smart meters. The consumers/prosumers need to decide on whether they switch to a time-of-use or dynamic price contract instead of the fixed price contract. If they switch, they need to have an energy management system for their flexible assets that allows them to respond to the prices, or a contract with a specialized provider.

Legislation /Regulation

Legislation and/or regulations may be needed to make 1) the provision of smart meters, and 2) the offer of time-of-use or dynamic price components mandatory for power suppliers, TSOs, or DSOs, and metering providers.

Dispatch

The consumer/prosumer will be responsible for the dispatch of the flexibility in response to the price signal. She or he can use an own energy management system or the services of a specialized provider.

How relevant and effective is this option for the various types of different types of flexibility resources identified in Chapter 2.1?

At the scoping workshop organized with selected GJETC members for this study, participants noted that it is important to bring market signals to demand response and storage on the demand side. This is exactly the aim of this reform option. Depending on its detailed design and implementation, it may be very effective for stimulating these demand-side flexibility resources.

More specifically, time-variable electricity retail prices aim to support the balance between supply and demand in the whole system. However, they are blind for network congestions within a wholesale market bidding zone. Therefore, they may increase the need for expanding the network capacity when the amount of flexible demand-side resources grows a lot in the medium to long term. This may at least partly be offset by simultaneously introducing time-variable grid fees, which address network congestions (Agora and FfE, 2023).

3.3 Analysis of applicability for the selected options in Japan

3.3.1 Analysis of the six reform options and concrete policy instruments implementing them

Reform option 1: uniform capacity instruments with uniform price

- **Which concrete instruments pertaining to this option already exist in Japan?**

Japan started capacity market auctions in 2020.

Background

- Before the retail electricity market was liberalized in 2016, existing major electric utilities were able to recover the power generation investment cost under the regulated tariffs based on the full cost method.
- However, after the full liberalization, it became necessary to recover the power generation investment cost through the wholesale electricity market (kWh market), but some power plants are not necessarily able to properly recover costs.
- At the same time, in recent years, with the increase of FIT power plants, renewable power plants with relatively low marginal costs have entered the wholesale electricity market.
- This has resulted in a decline in wholesale electricity market prices. Declines in the wholesale market prices benefit consumers in the short term. However, power generation plants often face a challenge in covering the costs of maintaining their power sources.
- To ensure an adequate supply capacity in the medium to long term, a capacity market (kW market) has been introduced to guarantee the necessary supply capacity in advance, instead of relying solely on the ‘energy-only’ wholesale electricity market (kWh market).

Key features

- OCCTO (Organization for Cross-regional Coordination of Transmission Operators, JAPAN) holds capacity market auctions four years ahead of actual supply and demand.
- Prior to the auction, OCCTO performs an assessment of the need for the amount of capacity that should be opened to tender. The auction is usually organized for all capacity that is needed to meet demand in the year concerned.
- The contracted price is, in principle, the highest bid price among the successful bids for power supplies, and the contracted price is a uniform price.
- The capacity market targets the existing and new power sources.
- Fossil fuels account for more than 70% of the capacity market's bidding power sources, with LNG at 42.6%, coal at 23.7%, oil at 7.5%, nuclear 4.6%, hydro with pumped storage 13.7%, other hydro 7.7%, and other renewables 0.2% in the 2022 auction.
- The capacity market in Japan offers power suppliers contracts for only one year.
- Retail suppliers pay for the cost of capacity contribution, because retail electricity utilities need to meet their obligation of ensuring supply capacity.

- **Are further instruments of this type of option currently planned to be implemented?**

No.

- **Is there a political and/or scientific discussion about the need for further instruments of this type of option?**

1. The current capacity market scheme offers power suppliers contracts for only one year. Therefore, it may not be a sufficient measure for new power plants or other flexibility resources that will recover fixed costs over a long period of time. Currently, in the capacity market, there is a trend that thermal power plants with lower generation costs tend to secure more bids.

2. Existing power sources (constructed before 2010) will be subject to transitional measures that reduce capacity revenue until 2029. In response to the goal of achieving a carbon-neutral society by 2050 while ensuring stable supply, actions are planned. Beginning with the auction for supply and demand in 2025, steps will be taken to limit the operation of inefficient coal-fired power plants. Specifically, if coal-fired plants have less than 42% design efficiency and exceed a 50% capacity factor, their contracted capacity will be reduced by 20%. These actions could potentially increase the share of decarbonized power sources in the future. Therefore, Japan's capacity market may reduce the incentives for power generators to maintain power plants.

3. In the guidelines for capacity markets, it has been clarified that including depreciation costs is not considered reasonable. As a result, Japan's capacity market may not be able to adequately recover the costs of newly installed power sources.

- **Assessment of the usefulness of existing, planned, or discussed instruments**

Under the capacity market it is possible to secure the supply capacity needed in the future in advance. In the capacity market, auctions are usually held three to four years in advance of actual supply and demand. This enables power generation companies and other market participants to make capital investments and maintain power generation and other facilities with a certain predictability of investment returns because they no longer solely rely on electricity sales revenue in the wholesale power market. For retail electricity providers, it becomes easier to procure the 'supply capacity', ensuring electricity is available when needed in the future. This leads to more stable business operations.

Reform option 2: Systemic investment framework / Uniform capacity instruments with differentiated conditions for new and existing assets

This type of capacity market is not implemented in Japan. In the capacity market in Japan, different types of existing and new assets compete in the same auction, and there will be a uniform price and same contract duration between them, which is reform option 1 as presented above. For supporting investment in new decarbonized power capacity, Japan has adopted reform option 3, for the reasons discussed in that section.

Reform option 3: Specific capacity instruments using capacity auctions with differentiated products

- **Which concrete instruments pertaining to this option already exist in Japan?**

Japan has started the **Long-term decarbonized power source auctions** in January 2024.

Background

- Even if a capacity market is introduced, the prospect of long-term investment recovery is uncertain owing to the full liberalization and one-year capacity contracts, and there are concerns that power source investments, which require long construction periods and large amounts of investment, will stagnate.
- Therefore, from the perspective of securing power source investment, it is necessary to introduce a system to secure long-term fixed income for new power source investments.
- Furthermore, in order to achieve carbon neutrality in 2050, it is also necessary to invest in new and replacement of decarbonized power sources as well as to replace the balancing power of thermal power with decarbonized power sources.

Key features

- OCCTO holds long term decarbonized power source auctions. Unlike in the capacity market for existing resources (option 1), considering the construction lead time, this auction allows for each power plant to determine the start of operation individually.
- The auction will target the new installation and replacement of decarbonized resources like renewables, hydrogen/ammonia, storage batteries, pumped-storage, nuclear, as well as the renovation of existing thermal plants into decarbonized ones.
- The minimum bidding capacity for each project in general is 100,000 kW, the minimum capacity for thermal power generation (renovated to hydrogen or ammonia single/mixed combustion) is 50,000 kW, and the minimum capacity for storage battery and pumped storage power generation is 10,000 kW. Successful bidders receive a fixed cost (construction cost, operation and maintenance cost, capital cost, etc) for 20 years.

- This auction adopts a multi-price system for each winning power sources. Here, the pricing is specific to each power generation or storage facilitiy. The winning bids will be selected at different prices across the types of flexiblity resources. In other words, bids for power generation projects are accepted starting with the lowest yen per kilowatt (kW), and each bid price is considered the winning price.
- Same as in the capacity market, retail suppliers pay for the cost of capacity contribution, because retail electricity utilities need to meet their obligation of ensuring supply capacity.
- As of FY2023, 4 million kW will be solicited as a decarbonized power source. Out of the total 4 million kW, a maximum of 1 million kW is designated for the renovation of existing thermal power plants including hydrogen or ammonia co-firing, and biomass-only combustion. (In the case of co-firing, it targets the kW equivalent to decarbonization, based on the shares of each fuel) Energy storage batteries and pumped storage also have a combined maximum limit of 1 million kW. If there are only a few successful bids for other types of decarbonized power sources, the above limits (1 million kW) can be increased.
- This auction also solicits a total of 6 million kW of LNG power sources from FY2023 to 2025, but they need to upgrade and switch to a carbon-free power source by 2050.

- **Are further instruments of this type of option currently planned to be implemented?**

No.

- **Is there a political and/or scientific discussion about the need for further instruments of this type of option?**

If all profits obtained from other markets are recognized within this system, there's a possibility that the profits of power generation companies could rise without limits. Japan's system requires a refund of profits earned in other markets. To be specific, 90% of the profits earned in other markets will be refunded later, but there will be no compensation for losses. This measure may create the risk of reducing investment incentives for power generation companies.

- **Assessment of the usefulness of existing, planned, or discussed instruments**

Power generation companies and other participants offering distributed resources through aggregation can obtain capacity income at a fixed cost level over a long period of time. As a result, this system offers participants predictability in long-term income while recouping the substantial initial investment. This system is, therefore, more appropriate for stimulating new investments than the capacity market with uniform prices for all assets.

In this system, unlike the capacity market with uniform price, the rules do not uniformly request a starting operational period. Instead, considering the construction lead time for each power source allows for flexibility in determining the start of operations. This opens up the possibility for various decarbonized power sources to participate in bidding.

Reform option 4: Other specific capacity instruments for flexibilities

Reform option 4, which include specific capacity payments, does not exist and is only marginally discussed in policy discourse in Japan. When introducing the capacity market in Japan, capacity mechanisms introduced in other countries were referred to. For example, the capacity market (centralized) in PJM and U.K, the capacity market (decentralized) in France, the strategic reserve in Germany, and capacity payments in Spain were investigated but Japan finally adopted the capacity market (centralized) (METI, 2022). Capacity payments were not adopted because it is a type of subsidy which may impair efficient power use using market mechanisms, and may not be able to secure the necessary power supply capacity.

As mentioned above, there is also the balancing power market in Japan. However, the balancing power market does not aim at promoting the investment in flexibility resources, rather at utilizing existing flexibility resources.

Reform option 5: Allowing the future costs of flexibilities in the regulated tariffs of TSOs and DSOs

Reform option 5 is not explicitly discussed in the policy discourse in Japan. Regarding the regulated tariffs of TSOs and DSOs, the revenue cap system began in Japan in 2023 (TEPCO, 2023). Under this system, TSOs/DSOs create a business plan that clearly defines the goals to be achieved within a five-year regulatory period. The revenue forecast, in which a TSO/DSO estimates the costs necessary to implement the plan, is approved by the government. The wheeling fee can be set flexibly within the approved revenue forecast. Therefore, it is possible for TSOs/DSOs to include the cost of flexibility investment in this plan. However, many companies focus on strengthening the aging infrastructure, strengthen resilience, facilitating the massive introduction of renewables. They do not focus on expanding the flexibility resources. If the government or the regulator wanted to change this, they would have to create the corresponding laws or regulations. However, this has not been explicitly discussed in Japan so far.

Reform option 6: Making power prices, grid fees, and possibly even taxes and levies time-dependent (time of use) or even dynamic (real-time pricing)

Time-of-use pricing and dynamic pricing are generally aimed at maximizing profits for retailers and reducing costs for customers. As part of their own management efforts, retail electricity providers may offer time-of-day pricing or dynamic pricing menus in Japan. However, there is no political and scientific discussion in Japan in the context of an obligation for making power prices, grid fees, and possibly even taxes and levies time-dependent (time of use) or even dynamic (real-time pricing).

Apart from the six reform options discussed here, no other important instruments to stimulate investment in flexibility resources are in place or under discussion in Japan.

3.3.2 Comparative Analysis of the Six Reform Options and Instruments

Among the existing, planned, or discussed reform options and concrete instruments, the long-term decarbonized power source auction is considered most effective to stimulate investment in decarbonized flexible power plants in Japan. This system also has the potential to facilitate grid-scale batteries above 10,000 kW per project.

Long term decarbonized power source auction

Considering the goals of reaching carbon neutrality in 2050, it is becoming difficult to promote investment in decarbonized power sources through free market competition alone. Therefore, there is a need for a system in which the government systematically procures the decarbonized power sources. Japan has introduced capacity markets and long-term decarbonized power auctions as mechanisms to encourage investment in these resources.

The capacity market was introduced in 2020, but there are issues such as only single-year contracts being allowed, which may not provide incentives for operators to make new investments. In addition, in the future, there is a strong possibility that thermal power sources, which have provided flexibility due to the large-scale introduction of renewable energy, will be largely phased out in Japan. This has led to the introduction of the long-term decarbonized power source auction scheme in addition to the capacity market, with the aim of promoting investment in decarbonized power sources that can provide reliable flexibility.

Although this system already has institutional issues such as the need to refund profits earned in other markets, it is an important system as a new decarbonized power source investment. This auction scheme covers large scale batteries but excludes demand response and distributed batteries on the demand side.

3.4 Analysis of applicability for the selected options in Germany

3.4.1 EU legislation as the framework for German market design

In the EU, the legislation for the electricity markets is laid down in the Electricity Directive 2019/944 and the Electricity (or EMD) Regulation 2019/943, along with further regulations on the cooperation of national regulators (ACER regulation 2019/942) and the Regulation to improve the Union's protection against market manipulation in the wholesale energy market (REMIT Regulation No 1227/2011).

The EU legislation of electricity markets (Article 21 and 22 of Regulation(EU) 2019/943) allows the introduction of capacity markets (reform options 1 to 3), but requires an assessment of the need for their introduction, the so-called European resource adequacy assessment (ERAA). If an ERAA is showing an expected shortage of capacity without a capacity market, the European Commission may allow its introduction.

Other specific capacity instruments (option 4) may also be possible, but may be subject to EU subsidy regulations and the corresponding allowance procedures.

The Electricity Directive and Regulation (Article 32 of Directive (EU) 2019/944) also require network operators to consider energy efficiency and demand response and flexibilities in general as an alternative to network expansions, and they now also require network regulators to consider these in revenue cap regulation, see below under 'Flexibilities'. This corresponds to our reform option 5. It has been further strengthened by the requirements of Article 27 of the

Energy Efficiency Directive 2023/1791 to apply the ‘energy efficiency first’ principle in network regulation and planning.

In the recently agreed revision, in the future, consumers will have the right of choice between fixed electricity tariffs (minimum term of 1 year) and dynamic tariffs, see below. This will boost the provision of dynamic tariffs (our reform option 6).

Recent changes

In March 2023, the European Commission proposed changes to the electricity market design and, after several months of negotiations, the European Parliament, Council, and Commission reached a draft agreement on 14 December 2023. The aim of the reform of the electricity market design is, on the one hand, to better integrate renewables and make them more competitive. On the other hand, consumers are to be protected from crisis-related price fluctuations. Specific reforms include Direct Price Support Schemes for renewables (double-sided CfDs), Capacity Remuneration Mechanisms (CRMs), and Power Purchase Agreements (PPAs), consumer protection, definition of a future electricity price crises and allowed measures against them, and energy sharing, as well as regulations regarding day-ahead, intraday, and forward markets, flexibility provisions, and derogations. We will focus on changes that support the use of flexibility resources.

Capacity remuneration mechanisms (CRMs)

There are some changes in the existing provisions on CRMs (laid down in Articles 21, 22, 64 and 69 of Electricity Regulation 2019/943). CRMs correspond to the reform options 1, 2, and 3 discussed in this study. Furthermore, the definition in Art 2 (22) now reads: “‘capacity mechanism’ means a measure to ensure the achievement of the necessary level of resource adequacy by remunerating resources for their availability, excluding measures relating to ancillary services or congestion management”. According to Art. 19e of the 2023 compromise text, in addition, Member States that apply a capacity mechanism “shall consider to make the necessary adaptations in the design of the capacity mechanisms to promote the participation of non-fossil flexibility such as demand side response and storage, without prejudice to the possibility for those Member States to use the non-fossil flexibility support schemes mentioned in this paragraph”; the latter are mentioned below. Capacity mechanisms shall be approved by the Commission for no longer than 10 years (Art 21). The Commission shall produce a report on how the procedure to install capacity mechanisms could be shortened and simplified (Art. 69).

Consumer Protection

In addition to the simplified feed-in of renewables, consumer protection also motivated significant changes. The Parliament, Council, and Commission agreed on five key points here. Consumers will have the right to install smart meter devices to use energy in a more targeted and transparent manner. Related to this is the right of choice between fixed electricity tariffs (minimum term of 1 year) and dynamic tariffs in the future. This is very relevant for flexibilities, and corresponds to our reform option 6.

Energy Sharing

Energy Sharing (Article 15a of the compromise text) introduces a new decentralized platform for sharing renewable energies beyond large energy corporations, where electricity and storage capacities within a bidding zone can be traded. Participants can include small businesses (if not their main source of income), public institutions, and households, which do not necessarily have to provide electricity themselves. While the main aim is to further boost renewable energies, the instrument may also support the use of flexibility resources, particularly storage, within the communities and in their relations to the rest of the market or the TSO/DSO. It was mentioned in chapter 3.1 but not included in our six reform options.

Flexibilities

With regard to flexibility, an EU-wide analysis of the need for flexibility, such as electricity storage and DR, will need to be carried out. Member States are obligated to estimate the needs for flexibility for at least the next 5 to 10 years and update these reports every two years (Art. 19c of the 2023 compromise text). The European Union Agency for the Cooperation of Energy Regulators (ACER) shall issue a report analyzing them and providing recommendations on issues of cross- border relevance. Furthermore, according to Art. 19d, Member States will establish one single indicative objective at national level for 'non-fossil' flexibility (which are the *other flexibility resources* according to the terminology for this report) allowing for different types or resources, with a focus on the specific contributions by demand response and energy storage. Member States may then design support schemes with direct payments for new non-fossil flexibility resources to achieve their objectives (Art. 19e and f). These would be equivalent to the reform option 4 discussed in this study. In addition to national efforts, the European Commission may draw up a Union strategy on demand response and energy storage that is consistent with the Union's 2030 targets for energy and climate (Art. 19d). These provisions are a response to criticism in the ACER report (2023), which calls for greater expansion of flexibility in all EU countries.

Spot markets should also converge 30 minutes before real-time by 2026. This should enable renewables to be better integrated into peak loads. Another adjustment resulting from ACER's criticism is that Member States may request system operators to offer peak-shaving products during times of electricity price crisis, which would allow market participants who reduce their consumption at times of high load and prices to be remunerated. The peak hour is defined to concern the residual load from generation other than renewable energies (Art. 2 (72)). This will be an instrument corresponding to our reform option number 4.

Also, Art. 7 (b) requires that TSOs and DSOs do not require smart meters but also accept data from dedicated measurement devices for the settlement of demand response of flexibility services, if a consumer does not yet have a smart meter. These devices will need to be defined by Member States. This instrument, too, is an example of reform option 4.

Article 18 more explicitly clarifies the following: Network tariffs should incentivize transmission and distribution system operators to use flexibility services through further developing innovative solutions to optimize the existing grid and to procure flexibility services, in particular demand response or storage. This corresponds to our reform option number 5.

3.4.2 Analysis of the six reform options and concrete policy instruments implementing them as well as other important instruments in Germany

Reform option 1 and 2: uniform capacity instruments with uniform price

Reform options 1 and 2 are not (yet) existing and were only marginally discussed in the political and scientific discourse in Germany until recently. The reason for this is that they may primarily be needed to maintain the economic viability of operating existing fossil-fuel or nuclear power plants. Germany, on the other hand, has phased out nuclear power in 2023 and has decided on a coal exit by 2035/38 and 'ideally' already by 2030. In various modeling scenarios, the implementation of a capacity market in Germany under a coal exit by 2030 has been analyzed. The result indicates that while certain elements would be advantageous for the German electricity market design, a uniform implementation of a capacity market like in option 1 and 2 is not favored. This is why there are few discussions in the political discourse regarding reform options one and two.

The expert commission for the monitoring of the energy transition, f.i., appears to be against the introduction of individual small-scale capacity market mechanisms (our reform option 4) to support new capacities (Löschel et al., 2023). Instead, they propose the development of instruments that, on the one hand, integrate many capacity and flexibility options and, on the other hand, only take effect when investment incentives for flexibility via the "Energy only market" (EOM) and the ancillary services markets are not sufficient (Löschel et al., 2023, p.251). However, they do not seem to be in favor of including existing capacities in such a uniform capacity instrument. So, they discuss a sub-option of a uniform capacity instrument for new capacities.

The Platform for a Climate-Neutral Electricity System (PKNS), which the German government has set up to develop further reforms, recently discussed several capacity instruments, including decentralized and centralized capacity markets.

The Monopoly Commission suggested a combination of decentralized and centralized capacity markets, which seems to concern power plants. The type of centralized capacity market remains unclear. Energy suppliers or large consumers themselves should cover base demand through purchasing certified firm capacity. This is called the decentralized market. It is a different concept from the reform options 1 and 2 discussed here, although it could also cover both existing and new assets. An advantage that the Commission sees is that this may inherently include demand-side flexibility and storage. The government would then only need to procure additional needs through centralized tenders, i.e. a 'classical' capacity market.

Although the PKNS discussed these options, they still seem to focus on other instruments because it is generally assumed that EOMs, including reform options, can guarantee security of supply (BMWK, 2023, p.8).

- **Assessment of the usefulness of existing, planned, or discussed instruments**

As said above, there is very limited need to maintain the economic viability of operating existing fossil-fuel power plants in Germany. Therefore, the two reform options 1 and 2 do not a priori seem to be very relevant for Germany.

Yet, the concept of a decentralized capacity market may become relevant and useful in the future in a system based on close to 100% renewable energy in electricity generation. It may be a way to integrate variable and controllable renewable power plants, storage, and other demand-side flexibilities in securing and trading firm capacity.
In addition, the German government decided on 5 February 2024 to install a capacity market from 2028 onwards. No detail is known yet; the aim is to develop this by the summer of 2024. We assume that it will mostly focus on new capacities, hence our reform option 3, but it may also be open for existing gas-fired capacity, which would combine it with option 1.

Reform option 3: Specific capacity instruments using capacity auctions with differentiated products

- **Which concrete instruments pertaining to this option already exist in Germany?**

No such instrument is in place in Germany.

- **Are further instruments of this type of option currently planned to be implemented?**

On 5 February 2024, the German federal government decided to create a capacity market by 2028. We assume that it will mostly focus on new capacities and will be a form of our reform option 3.

- **Is there a political and/or scientific discussion about the need for further instruments of this type of option?**

In the case that a systematic procurement of capacities will be needed, the expert commission (Löschel et al., 2023) and PKNS seem to favor this option, as discussed above.

- **Assessment of the usefulness of existing, planned, or discussed instruments**

This reform option may be useful for new controllable generation capacities and cheaper than specific instruments (option 4), due to the competitive auctions. It could, therefore, replace particularly the planned power plant strategy and possibly the CHP law. However, under EU legislation it may take several years to be introduced, which may be too late to cover the urgent needs, although the procedure shall be accelerated under the recent revision of the EU electricity market regulation, as discussed in chapter 3.4.1. Since the costs of flexible biomass power plants may continue to be higher than those of gas power plants for some time, this option may not be useful for them, but they would rather remain under the renewable energy law (EEG).

According to Art. 19e of the recent revision of the EU electricity market regulation, the government will have to consider making the design for the capacity market to start in 2028 in an appropriate way, so that this reform option would also support investment for demand-side storage (new HSS/ISS or making existing storage such as HSS and BEV available for flexibility through the investment in metering and energy management infrastructure) and demand response. But we estimate that the latter would also need option 6 in addition, to enable the cost-effective operation of the resources (Eicke et al., 2024, share this assessment).

Reform option 4: Other specific capacity instruments for flexibilities

- **Which concrete instruments pertaining to this option already exist in Germany?**

There are already many such instruments in Germany (Löschel et al., 2023, pp. 64 to 69). They include the following.

Renewable Energy Law (EEG)

The EEG currently includes provisions for auctions for biomass power plants (around 6 GW until 2030) and green hydrogen power plants (8.8 GW until 2030, see below under the planned 'power plant strategy`). The law is also the basis for 'innovation auctions', which concern utility-scale PV with battery storage to shift the feed-in from times of high PV generation and low wholesale power prices to evening or night times of low generation and high prices. In addition, there will be electrolysis capacity auctions for ca. 5 GW until 2030, and these assets may be used to provide flexibility as well.

CHP law

New combined heat and power (CHP) plants may receive a payment of feed-in premiums (FIP) for up to 30,000 hours of operation. For capacities below 500 kW and above 50 MW, the level of the FIP is fixed in the law. Between 500 kW and 50 MW, there will be auctions of up to 1,4 GW by 2030. All capacity numbers here concern electric power output.

Power plant reserves according to §§13d to h EnWG

- Grid reserve power plants according to §§13b and d EnWG; existing power plants that would be closed for market reasons are kept available to avoid redispatch, so they are mainly located in Southern Germany; 7.0 GW in winter 2022/23, and 5.4 GW in winter 2023/24;
- New power plants of 1.2 GW in Southern Germany were secured via auctions for 10 years, and are called special network-technical assets;
- In order to facilitate the phase-out of lignite power plants, some of these existing plants were moved from the market to a 'security standby' reserve with special payments (§13g EnWG). This began in 2016 with 2.7 GW, of which 1.5 GW remain today and will be permanently closed by 2029 in a staged roadmap;
- The strategic capacity reserve to balance supply and demand (§13e EnWG). Although it is created by an auction, we can classify it as a specific capacity instrument, since it is not a full-fledged capacity market based on a comprehensive adequacy assessment (Weltenergierat 2022, p.96f.);
    - Germany has had this strategic capacity reserve outside the electricity market since winter 2020/2021;
    - Reserve for exceptional shortage situations defined in the Capacity Reserve Ordinance (according to §13h EnWG);
    - The reserve amounts to a maximum of 2 gigawatts (GW) and is open to generation plants, controllable loads and storage facilities;
    - Allocation by auction with a uniform price procedure, price cap: €100,000/MW/year;
    - Can be used as a grid reserve if at locations suitable for the grid;
    - First provision period (until the end of September 2022) only reached 1,056 MW capacity of existing gas power plants in the North of Germany (Löschel et al., 2023);
    - Adjustments for the second provision period (until the end of September 2024) by the Federal Network Agency in order to achieve the intended capacity of 2 GW.

These power plants may normally not participate in the market. However, during the recent energy price crisis, the grid reserve and strategic reserve were allowed to return to the market between 2022 and 2024. Around 4.8 GW of capacity used this option.

Demand Response

From 2016 to 2022, there was an Ordinance on curtailable loads, which remunerated very large industrial consumers for demand response. Costs were included in grid fees. Although deemed useful by Löschel et al. (2023), it expired in 2022.

Storage for grid operations purpose

In Germany, there are already two pilot projects - also known as grid boosters - which, with reference to Section 11a and 11b EnWG, enable grid operators to install and operate battery storage systems for grid operation purposes (BMWK, Stromspeicherstrategie, 2023, p. 18).

In addition, there is an exemption of batteries from grid fees and levies/taxes.

Balancing power markets

In addition to flexible power plants, also storage and demand response are allowed to participate in the balancing power markets. It is unlikely that this alone is sufficient for investment in new capacity, except maybe for demand response. However, existing storage and demand response can be aggregated to participate.

- **Are further instruments of this type of option currently planned to be implemented?**

At least the following two instruments are under development.

The ‘power plant strategy’

The most prominent instrument currently under preparation is the ‘power plant strategy’. It was announced by BMWK already in early 2022 and is now expected to start implementation in 2024. It mostly concerns auctions for new flexible power plants to replace coal power plants. Originally, they were planned with a total capacity of up to ca. 24 GW by 2030. This included 1) green hydrogen power plants connected to early H2 pipelines (4.4 GW to be auctioned by 2030; §39p EEG) or with PV or wind and electrolysis on-site (4.4 GW as well; §39o EEG), however, on 5 February 2024, the government apparently decided that these were too costly and will not be implemented; 2) natural gas-fired ‘H2 ready’ power plants (10 GW confirmed on February 5, to be auctioned between 2024 and 2027) that will need to convert to hydrogen by 2040; plus 3) 6 GW of biomass and storage, which were not mentioned in the cabinet’s decision of 5 February, so their fate is unclear. From 2028 onwards, any further new capacity needed would be procured through the new capacity market mechanism (cf. option 3 above).

The ‘national energy storage strategy’

In December 2023, the BMWK published a ‘national energy storage strategy’, discussing 18 fields of action and measures for sustained expansion dynamics and optimal system integration. Sixteen measures are related to reform option four. The two remaining are discussed in reform option five and six. The sixteen measures related to reform option 4 include improvements to the ‘innovation auctions’ under the EEG, acceleration and cost transparency for grid connections, financial incentives for local communities, easier participation of batteries in balancing power markets and creating markets for other ancillary services, subsidies for battery factories, a regulatory framework for vehicle-to-grid use of BEVs, the analysis of barriers to various storage technologies and the improvement of the economic framework for their use as flexibilities, an analysis of the future need for storage in the system, improved deployment forecasts and storage statistics, and a few others. A grid fee exemption for small-scale batteries is also discussed but faces problems regarding the smart meters and billing procedures needed.

- **Is there a political and/or scientific discussion about the need for further instruments of this type of option?**

The Platform for a Climate-Neutral Electricity System (PKNS) recently discussed that an instrument that would be located somewhere in between an EOM and a full capacity market could be a duty for suppliers to hedge against the price spikes of peaking power plants, which would provide an additional revenue for the latter. This would build on a new provision in the EU Electricity Regulation.

The expert commission (Löschel et al., 2023) deplores that there is no systemic framework for demand response and aggregation of demand-side flexibilities as yet.

- **Assessment of the usefulness of existing, planned, or discussed instruments**

Given the need to achieve speed in promoting flexibility resources because of the target to achieve 80% of renewables in power supply by 2030 already, there may be no alternative for Germany to enhancing the specific capacity instruments of this type until the new capacity mechanism takes effect, planned for 2028. The reason for this is that in the EU framework, it may take years to install a capacity market even of option 3, which may take until 2028. Also, specific capacity instruments may allow a quick reaction to changes in market conditions as well as specific support for emerging technologies.

Reform option 5: Allowing the future costs of flexibilities in the regulated tariffs of TSOs and DSOs

- **Which concrete instruments pertaining to this option already exist in Germany?**

In Germany, revenue regulation is an ‘incentive regulation’ based on economic efficiency benchmarking. Therefore, the scheme needs special allowances through legislation or from the regulator for extraordinary investments, like it is done for transmission and distribution grid reinforcement due to renewables expansion, but not so far for storage, demand response, or even demand-side energy efficiency programs.

- **Are further instruments of this type of option currently planned to be implemented?**

The German government will need to create such incentives to TSOs and DSOs due to recent EU electricity market reform. As mentioned above, Art. 18 now states that network tariffs (and revenues) should incentivize TSOs and DSOs to use or procure flexibility services, in particular demand response or storage.

In addition, Article 27 of the recent revision of the Energy Efficiency Directive (2023/1791) requires energy regulators to apply the energy efficiency first principle in their tasks, including decisions on network tariffs. It also requires Member States to ensure that gas and electricity transmission and distribution system operators apply the ‘energy efficiency first’ principle, in accordance with Article 3 of the Directive, in their network planning, network development and investment decisions. This includes both energy efficiency and demand-side flexibility. Such a requirement will obviously also need to include an allowance of the respective costs of flexibilities in the regulated tariffs.

From the perspective of the BMWK, at least some large-scale electricity storage projects in the transmission network may be useful. There are two "grid booster" pilot plants that are to be connected to the grid in 2025, as well as two other projects that have been applied for by the grid operators in the 2023 grid development plan. Experience from these projects will also be used to evaluate the existing legal framework (BMWK, S.18f, 2023)

- **Is there a political and/or scientific discussion about the need for further instruments of this type of option?**

Several publications and initiatives have called for modifications to the incentive regulation scheme to better include the costs of flexibility resources (e.g., dena, 2019; Umpfenbach et al., 2021; Öko-Institut, 2023). The problem to be overcome is that the revenue is fixed for 5-year regulation periods in advance, so that during this period, any additional investment of TSOs/DSOs in own flexibilities or in grid reinforcement to connect storage facilities (Deuchert et al., 2023), or any procurement of flexibility, would reduce the profit margin of the TSOs/DSOs. Several proposals in general or regarding specific types of flexibility assets or activities were made.

- **Assessment of the usefulness of existing, planned, or discussed instruments**

From a societal perspective, it would often be cheaper to install and use flexibility resources than expanding the network, even if such expansion may not be completely avoided but delayed. This can be found out through applying integrated resource planning or the 'energy efficiency first' principle, using benefit-cost analysis. Therefore, the current network regulation in Germany should urgently be enhanced to make such cost-effectie flexibility options also more cost-effective for TSOs and DSOs than grid expansion. However, potential conflicts with the unbundling rules need to be taken into account and handled in a pragmatic way. Outside the scope of this study, such an enhanced incentive regulation should also include activities of system operators to improve energy end-use efficiency, if they are more cost-effective than grid expansions, which they may be able to avoid or defer.

Reform option 6: Making power prices, grid fees, and possibly even taxes and levies time-dependent (time of use) or even dynamic (real-time pricing)

- **Which concrete instruments pertaining to this option already exist in Germany?**

In the Law on the Restart of the Digitalization of the Energy Transition, it is stated that from 2025 dynamic prices must be offered, if smart meters are available. This law also aims to boost the installations of smart meters.

In addition, time-variable grid fees will have to be offered from 2025 to owners of heat pumps and BEVs under the Regulation according to §14a EnWG, as mentioned under other reform options below.

As soon as electricity prices or grid fees are made time-dependent, the value added tax (currently 19%) will also become time-dependent.

- **Are further instruments of this type of option currently planned to be implemented?**

We are not aware of further plans by the German federal government at this stage. Probably, its stance is to first monitor the effectiveness and impacts of the new regulations on dynamic prices and time-variable grid fees mentioned above.

- **Is there a political and/or scientific discussion about the need for further instruments of this type of option?**

The working group AG2 of the Platform for Climate-Neutral Power Systems advocates for the immediate introduction of dynamic electricity prices and network tariffs (PKNS, 2023a).

In line with AG2, the expert commission on the energy transition (Löschel et al., 2023) demands a faster rollout of smart meters. It also discusses dynamic grid fees and making taxes and levies dynamic in the same way.

Stute and Kühnbach (2023) analyzed the impact of multiple dynamic electricity price offers. They found that in this case, even though dynamic tariffs lead to increased peak demand at the level of individual households, peak loads are spread more widely within a grid area as the result of households choosing different tariffs based on economic considerations, which could reduce the need for grid expansion (Stute and Kühnbach, 2023).

- **Assessment of the usefulness of existing, planned, or discussed instruments**

This type of reform can be considered very important for stimulating DR and demand-side storage, including heat pumps and BEV. It may even make investment incentives unnecessary, while the latter would not be fully effective without dynamic prices and grid tariffs. However, widespread implementation of time-dependent price components requires greater availability of digital infrastructure, particularly smart meters but also digital identities and a national or better EU-wide register of machine identities, and a consistent regulatory framework. The coming years provide an opportunity to test and establish business models, communication pathways, and interoperability solutions.

According to dena (2023), in order to fully harness the potential of dynamic power prices to reduce the overall system cost, the potential of HSS would not be sufficient. A large-scale flexible operation of heat pumps and BEV would also be necessary.

Also, it seems that it is important to introduce dynamic power prices and grid fees at the same time. With dynamic power prices alone, the need and cost for expanding the grid may even rise. Whereas, Agora/FfE (2023) found that the need for expanding the distribution network can be reduced by 45 % in an anticipated system of 2035 based on close to 100% renewable energies, if dynamic grid fees (time of use with dynamic time windows) are used instead of fixed grid fees or time of use fees with fixed time windows. However, according to another study (Eicke et al., 2024), currently (2024) time of use grid fees would be sufficient to also reduce network costs. Even without these, dynamic electricity prices would slightly reduce network costs in 2024. However, in the medium term, this study agrees that grid fees should be made dynamic too, with dynamic time windows.

Other important instruments in Germany

- **Which concrete instruments pertaining to this option already exist in Germany?**

Controllable consumption devices

On 27 November 2023, the BNetzA stipulated a change to the catalogue of controllable consumption devices according to Section 14a EnWG (BMWK, 2023, p.12f). DSOs are now allowed to curtail the combined load of heat pumps and BEVs to 4.1 kW per home in times of local grid congestions. The amendments will also allow consumers subject to this regulation to benefit from reduced grid fees in the future. In 2025, it will become mandatory for DSO to introduce time-variable grid fees as a choice for consumers, which should provide better incentives for grid-friendly behaviour.

- **Are further instruments of this type of option currently planned to be implemented?**

According to EU legislation, renewable energy communities and energy sharing need to be enabled by the Member States. Most experts expect that the German national legislation will need some enhancement to comply with EU requirements. Many, including experte commission (2023), expect that such communities will also use flexibilities to optimize their operations.

- **Is there a political and/or scientific discussion about the need for further instruments of this type of option?**

As mentioned above, the Platform for Climate-Neutral Power Systems discussed a decentralized capacity market, and the Monopoly Commission suggested its introduction.

- **Assessment of the usefulness of existing, planned, or discussed instruments**

While the allowance for DSOs to curtail the combined load of heat pumps and BEVs to 4.1 kW per home may be a pragmatic approach in the short term, it may be more appropriate to perform a systemic analysis at each voltage level of a DSO area and provide economic incentives for system-serving behaviour. This may be an instrument receiving higher acceptance by consumers.

Renewable energy communities and energy sharing may rather be useful to accelerate expansion of renewable energies than to stimulate the investment in and use of flexibility resources, but may improve their acceptance with those who are participating. However, care needs to be taken that it will not increase the prices and grid fees for non-participants.

A decentralized capacity market may take quite some time to develop, but may become useful in an electricity system supplied with almost 100% of renewable energies.

3.4.3 Comparative analysis of reform options and instruments

As discussed above, analysis finds that it would often be cheaper to install and use other flexibility resources (and energy end-use efficiency) than building flexible power plants and/or expanding the network. Therefore, the first step should be to apply integrated resource planning or the ‘energy efficiency first’ principle as required by EU legislation, using benefit-cost analysis of large-scale and small scale energy storage, as well as heat storage coupled with CHP and heat pumps, and BEVs, and demand response, but also smart grid technologies, in comparison to expanding supply-side resources. This should be done at all levels of adequacy assessments for generation capacity as well as TSO and DSO network planning. It will allow to determine the amounts of power demand as well as different generation, transport, and flexibility resources that would form a least-cost system during future years until a decarbonized system is reached. The least-cost system will include some additional reserve capacity of various types that may be needed for a secure and resilient system.

Therefore, in order to minimize the need for investment in new decarbonized thermal and T&D network upgrades, by maximizing the utilization of cost-effective DR, batteries and other demand-side flexibility resources, it will also be necessary to explore and use a wide range of policy frameworks along the six types of reform options discussed above. In Germany, incentives for investment could either be provided directly via instruments of reform options 3 and 4. However, in political debate or implementation, these are focused so far on flexible power plants rather than demand-side flexibility resources. For the latter, corresponding specific instruments would need to added, or if a capacity market of option 3 were installed, it would need to be designed to achieve priority access for demand-side resources. Still, the capacity investment incentives under reform options 3 and 4 may remain the most important instruments for flexible power plants.

For the demand-side resources, the time-dependent power prices, grid fees, and possibly taxes and levies under reform option 6, will be very important instruments, providing indirect incentives for investment in demand-side flexibility resources. These and particularly grid-integrated batteries and smart grids would also benefit from a reform of the revenue regulation of TSOs and DSOs to better allow them integration of the flexibility costs into network tariffs (reform option 5), instead of grid expansion.

4 Comparison and policy recommendations

4.1 Comparison between both countries

In this chapter, we will compare the usefulness of the types of flexibility resources (chapter 4.1.1) and the extent, to which the six important reform options to simulate investments in flexible low-carbon power plants and other flexibility resources are already implemented, planned, or discussed in Japan and Germany.

4.1.1 Comparing the usefulness of different types of flexibility resources

In the following table, we have drawn together the information on the usefulness of selected important types of flexible low-carbon power plants and other flexibility resources for the three main use cases of flexibility, i.e., portfolio optimization in the market, balancing, and grid congestion management.

Tab. 4-1 Comparison of the usefulness of different types of flexibility resources

Types of flexibility resources	Usefulness in Germany for the main use cases	Usefulness in Japan for the main use cases
Flexible low-carbon power plants		
Power plants using 100% green or blue hydrogen or ammonia or other derivatives (gas turbines, combined-cycle power plants)	portfolio optimization: high balancing: high congestion management: medium	portfolio optimization: high balancing: high congestion management: high
Gas power plants ready to be converted to 100% green or blue hydrogen or ammonia or other derivatives	Same as for 100% clean hydrogen plants.	portfolio optimization: high balancing: high congestion management: high
Flexible use of biomass power plants	Similar to clean hydrogen power plants. More distributed, so higher for congestion management, but somewhat lower for portfolio optimization due to shorter storage periods	portfolio optimization: high balancing: high congestion management: high
Other flexibility resources		
Demand response (in general, other subtypes than demand-side storage resources listed below; includes industrial demand response in production facilities and all kinds of cold storage)	portfolio optimization: medium (end-user side) balancing (mostly with aggregation): medium congestion management: high	portfolio optimization: high balancing: medium congestion management: medium
Grid-integrated batteries (to store green power)	portfolio optimization and balancing: due to the unbundling, batteries owned and operated by	portfolio optimization: high balancing: high congestion management: high

Types of flexibility resources	Usefulness in Germany for the main use cases	Usefulness in Japan for the main use cases
	TSOs or DSOs may not participate; medium for other operators congestion management: locally high	
Building-integrated batteries (to store green power)	portfolio optimization: medium balancing (with aggregation): medium congestion management: medium overall, but high at the local/substation level	portfolio optimization: high balancing: high congestion management: high
Battery electric vehicles (using low-carbon power)	portfolio optimization: medium (on end-user side but also for system with adequate incentives); for several hours or a few days balancing (with aggregation): medium congestion management: medium overall, but high at the local/substation level	portfolio optimization: high balancing: medium congestion management: medium
Electrolysis (using low-carbon power)	portfolio optimization: high balancing: high congestion management: medium to high	portfolio optimization: medium balancing: medium congestion management: medium
Small-scale CHP or heat pumps and other electric heat generators in connection to heat storage	portfolio optimization: medium to high balancing (with aggregation): medium congestion management: medium to high, especially at the local/substation level	portfolio optimization: medium balancing: medium congestion management: medium

A precondition for all demand-side flexibility resources is the availability of smart meters or at least digital meters with an energy management system.

From table 4.1., we can see the following similarities and differences.

In Germany, demand for flexibility is increasing rapidly due to expansion of PV and wind (flexibility demand from local to system level) and deployment of BEVs and heat pumps (substation to local level), but at the same time, building-integrated batteries, BEVs and heat pumps offer a very high potential for demand-side flexibility, although it needs aggregation (cf. chapter 2.3.3). This is relevant already the short to medium term.

In Japan, the deployment of PV is fast but the deployment of the other distributed energy resources such as wind and BEVs is slower, so the potential of demand-side flexibility aggregating a variety of resources may only unfold at a later stage.

4.1.2 Comparing the use and relevance of reform options

In the following, we first compare, which of the six important reform options discussed in chapter 3 are already existing or planned in both countries.

Tab. 4-2 Comparison of existing and planned instruments in Japan and Germany

Existing and planned instruments under the six reform options	Japan	Germany
Option 1: Uniform capacity instruments with uniform prices	**Existing** Capacity market exists since 2020	**Not yet implemented** However, this may be introduced from 2028 as a segment of the capacity market the government wants to develop
Option 2: Uniform capacity instruments with differentiated conditions for new and existing assets but uniform price for each class	**Not implemented** Not implemented and not planned, since Japan combines options 1 and 3 instead	**Not implemented** The reasons are the same as for option 1. It is also unclear if this will be part of the new capacity market from 2028
Option 3: Specific capacity instruments using capacity auctions with differentiated products, specific by type of asset: e.g., uniform auction for new assets with type-specific caps or multipliers leading to multiple prices; separate auctions by type	**Existing** Japan started long term decarbonized power source auction since January 2024 to replace thermal power-based balancing power plants with decarbonized ones and to update existing decarbonized power plants such as hydro, pump storage and so on	**Not yet implemented but planned** With the announcement of the German government's power plant strategy on February 5th, the introduction of a capacity market in 2028 was also announced. It may be of the option 3 type, or a combination with option 1 The German government plans to discuss an initial concept for this with the European Commission in mid-2024
Option 4: Other specific capacity instruments. Examples: fixed payments per kW/kWh of demand response; government grants for batteries or V2G systems	**Not implemented**	**Existing** There are already many such instruments: 1. Biomass auctions in Renewable Energy Law (EEG) 2. CHP law

Existing and planned instruments under the six reform options	Japan	Germany
		3. Power plant reserves according to §§13d to h EnWG 4. Demand Response 5. Storage for grid operations purpose 6. Balancing power markets 7. The 'power plant strategy' 8. The 'national energy storage strategy'
Option 5: Allowing for costs of flexibilities in revenue regulation (TSO; DSO)	**Not explicitly implemented** In 2023 a revenue cap system regarding the tariffs of TSO and DSO was introduced Within a five-year business plan, it is possible for TSOs and DSOs to include investment costs of flexibilities, as long as approved by the government. However, investment focus is mostly set on other factors.	**Not explicitly implemented but soon required by EU legislation** Revenue regulation is taking the form of "incentive regulation" Scheme needs special allowance for extraordinary investments These schemes already exist for renewables but not for storage, demand side energy efficiency and demand response Recent changes of the EU electricity market reform of Art 18 require that Germany will need to create incentives for TSO and DSO to use or procure flexibility services like DR and storage Changes in Article 27 and 3 of the Energy Efficiency Directive require energy regulators to apply the energy efficiency first principle in their network planning, network development and investment decisions.
Option 6: Time of use or dynamic (real-time pricing) price components for final customers: applied to power prices, grid fees, or taxes	**Partially implemented** Some retail electricity providers may offer dynamic pricing menus' to maximize profits and reduce costs for consumers.	**Partially implemented** Law on the Restart of the Digitalization of the Energy Transition states that from 2025

Existing and planned instruments under the six reform options	Japan	Germany
	However, there is no political and scientific debate of an obligation for dynamic pricing in power prices, grid fees or taxes.	dynamic prices must be offered, if smart meters are available Time-variable grid fees will have to be offered from 2025 to owners of heat pumps and BEVs under the Regulation according to §14a EnWG We are not aware of further plans by the German federal government at this stage

In the second comparison table, four categories are used to classify the relevance of instruments in the public and academic discussion about the further development of the electricity market design beyond current plans. These categories are: not discussed, marginally discussed, frequently discussed, and highly discussed.

Tab. 4-3 Comparison of discussed and needed reform options in Japan and Germany

Discussed/needed reform options and concrete instruments to fill gaps	Japan	Germany
Option 1:	**Frequently Discussed** There are issues such as only one-year contracts being allowed, which may be hindering new investment. This led to the discussion of long-term decarbonized power source auctions that guarantee fixed income over the long term.	**Until January 2024, Marginally discussed** due to the very limited need to maintain an economic viability of operating existing fossil-fuel power plants There are some discussions e.g., in the PKNS on centralized and decentralized capacity markets. However, Usefulness may be low since existing nuclear and coal power plants shall be replaced anyway. **Now, frequently discussed** due to the need to clarify the design of the capacity market that shall be introduced by 2028
Option 2:	**Not discussed**	**Marginally discussed**
Option 3:	**Not explicitly discussed** at present, since experiences have to	**Highly discussed** due to the need to clarify the design of the capacity market

Discussed/needed reform options and concrete instruments to fill gaps	Japan	Germany
	be made with the recently introduced scheme There are challenges such as 90% refund of other market profits, which may hinder new investment, so it may be reviewed in the future.	that shall be introduced by 2028 In the case that a more systematic procurement of capacities will be needed, the expert commission (2023) and PKNS seem to favor this option
Option 4:	Only **marginally discussed** Japan selected option 3 instead	**Highly Discussed** PKNS: discussed an instrument in between an EOM and a full capacity market that could be a duty for suppliers to hedge against the price spikes of peaking power plants, which would provide an additional revenue for the latter expert commission (2023) deplores that there is no systemic framework for demand response and aggregation of demand-side flexibilities as yet
Option 5:	**Not explicitly discussed** Revenue cap system introduced in 2023 implicitly allows to include costs of flexibilities for TSOs/DSOs	**Highly discussed** (e.g., dena, 2019; Umpfenbach et al., 2021; Öko-Institut, 2023) Instrument is needed to make cost-effective flexibility options also more cost-effective for TSOs and DSOs The Problem to be overcome is that revenues are fixed for 5 years for TSO and DSOs. A modification to the incentive regulation scheme is needed to better include the costs of flexibilities
Option 6:	**Not discussed** i.e., there is no discussion on making the offer of dynamic prices or network tariffs mandatory	**Highly Discussed** Considered as a very important instrument in the short run (PKNS)

Discussed/needed reform options and concrete instruments to fill gaps	Japan	Germany
		for stimulating DR and demand-side storage, including heat pumps and BEV requires greater availability of Smart Meters and an EU wide regulatory framework importance of simultaneous introduction of dynamic power prices and at least time of use grid fees

In addition to these instruments, a decentralized capacity market is discussed in Germany in the PKNS working group 2. Such a market may become relevant and useful with close to 100% electricity from renewable energies, to integrate variable and controllable renewable power plants, storage, and other demand-side flexibilities.

As we can find in the comparison tables, Japan mainly relies on capacity markets while until January 2024, Germany preferred other specific capacity instruments. A reason for this preference may be that the European Commission needs to permit the design of a national capacity market in a Member State, which was taking several years in the few examples to date, such as Belgium. With the recent amendment to EU legislation, installation of a capacity market will become easier, and the German government decided on 5 February 2024 to create a capacity market for new assets (option 3) from 2028. Therefore, the instruments to directly support investments in flexibility resources that are used in both countries may converge over the next years.

For other reform options that support the investment in flexibility resources and their operation by TSOs and DSOs (option 5) or the use of existing decentralized storage and DR for flexibility purposes through price incentives (option 6), the discussion in Germany is recently getting strong, because the need for such new instruments is high already in the short to medium term. In Japan, this is not (yet) discussed in the context of procuring the flexibility.

4.2 Policy recommendations

4.2.1 Recommendations for Japan

Background

- Electricity industry in Japan has more focused on competition since full liberalization in 2016.
- However, in recent years, as carbon neutral become important policy issue, the expansion of renewables is expected to accelerate further.
- For instance, as of 2019, the renewables only accounted for 18% of the power generation mix but the 6th Strategic Energy Plan released in 2021 aims for power generation mix of 36-

38% renewables by 2030. In the electricity sector, the share of renewables will increase up to 50-60% by 2050.
- Conversely, with the increase of FIT power plants with low marginal cost into wholesale market, the capacity of thermal power plants, which has traditionally functioned as balancing power sources, is decreasing.
- This highlights the need to secure the balancing capacity, particularly for decarbonized power sources.

Recommendations

- Within the framework of free competition, it is not necessarily possible to systematically procure the necessary capacity in the medium-long term.
- Therefore, government support is crucial to facilitate the investment of decarbonized power sources.
- Japan has already initiated measures such as capacity market and long-term decarbonized power source auction.
- These policies are expected to systematically secure the decarbonized balancing power sources required towards carbon neutral.
- However, these policies (particularly the long-term decarbonized power source auction) have only just started, and it would be useful to review them in the future.

Japan is also expected to learn from the experience of Option 5 and Option 6, which are actively discussed in Germany as a mechanism to encourage the investment in demand side flexibility.

4.2.2 Recommendations for Germany

Background

- In Germany, the target is to already achieve 80% of power generation from renewable energy sources by 2030. In 2023, this share exceeded 50% for the first time, reaching 56%. The additional capacity will predominantly be PV and wind energy.
- Therefore, the need to add flexibility resources to the electricity system will increase already during the next few years.
- At the same time, the coal phase out is planned for 2038 by the latest, and ìdeally`by 2030 already.
- In addition, there are policy targets to achieve 15 million BEV, 6 million heat pumps, and 10 GW of electrolyzers by 2030, and the number of HSS is increasing rapidly.
- These demand-side storage systems and electrolyzers are providing new opportunities for using them as alternatives to new low-carbon flexible power plants.

Recommendations

- The first step should be to apply the ‘energy efficiency first’ principle, using benefit-cost analysis to assess the least-cost potential of
    - large-scale and small scale energy storage; heat storage coupled with CHP and heat pumps; BEVs; demand response; smart grid technologies; electrolyzers
    - in comparison to expanding supply-side resources, such as gas power plants

    - for generation capacity as well as TSO and DSO network planning.

- For the capacity market planned from 2028 (probably reform option 3), we recommend to give priority to least-cost demand-side flexibility resources over new power plants; for the latter, to prioritize CHP plants that would be replacing coal-fired CHP plants, also in auctions up to 2028.
- It will also be interesting to take a closer look at the Long-term Decarbonized Power Source Auctions in Japan to see if something can be learned for the design of the new German capacity market, e.g., regarding the cap on revenues from other markets
- It may also be necessary to create other specific capacity instruments (reform option 4) for demand-side flexibility resources for the period until the capacity market is fully operating, and it will be crucial to accelerate the roll-out of smart meters.
- In addition, the government should make power prices, grid fees, and possibly taxes and levies time-dependent (reform option 6).
- It is also necessary to reform the revenue regulation of TSOs and DSOs to better allow them integration of flexibility costs into network tariffs (reform option 5), instead of grid expansion.

4.2.3 Recommendations in general

The situation in Japan and Germany differs in various aspects of the framework conditions, which leads to differing recommendations regarding some points. Japan already implemented a capacity mechanism for new assets at the beginning of this year and is closely monitoring their effectiveness. In Germany and the EU, meanwhile, there is an intensive debate about possible reforms to the European and German electricity market design. In the last six months, new provisions in EU electricity market design that will support investment in flexibility resources have been agreed, and numerous papers with further proposals for change have been published.

However, two of the above recommendations are relevant for both countries and beyond. Firstly, the adoption of the ‘energy efficiency first’ principle is important for both Japan and Germany. At EU level, this principle was included properly into Article 3 and 27 of the energy efficiency directive 2023/1791 on 20 September 2023. The application of the ‘energy efficiency first’ principle also plays a central role in Japan's energy strategy.

In both countries, it should be systematically investigated whether demand-side and grid-integrated storage and demand response mechanisms can replace or postpone the construction of new power plants and the expansion of grid infrastructure.

Secondly, another requirement that affects both countries equally is the creation of a level playing field. This can be achieved, for example, through competitive auctions that promote competition between newly emerging flexibility resources and low-carbon power plants.

In addition, the introduction of dynamic electricity pricing and grid tariffs as well as adjustments to the revenue regulations for transmission system operators (TSOs) and distribution system operators (DSOs) are essential.

To summarize, although the framework conditions may differ from country to country, the development of the electricity market design and the effective integration of flexibility will be crucial to achieving a climate-neutral electricity system in the future.

5 Conclusion and Outlook

This study analyses the different electricity market designs and the existing and proposed reform options to support decarbonization through the increased use of flexibility resources. In the first chapter, current challenges for electricity market design that arise from the power sector transition towards higher shares of variable renewable energies are discussed. Based on this analysis and on the results of a scoping workshop, the study topic is narrowed down for both countries. The focus of the analysis was on reform options that strengthen investment in flexibility resources. These can be either flexible low-carbon power plants or other flexibility resources notably on the demand side, such as demand response and distributed storage. Although transformation needs are emerging in other aspects of electricity markets, they are not equally relevant for both countries.

The main reasons why investments in flexibility were identified as relevant in both countries is to 1) reduce the pressure and costs of further grid expansion, 2) support the expansion of renewables by 3) improving their integration into the markets, and 4) minimizing the overall system cost.

The central difference in the market design in both countries is that Japan has implemented a capacity market and Germany, as a country embedded in the EU, until now works with an 'energy only market' (EOM).

Following the identification of similarities and differences in the existing market design, six reform options to directly or indirectly stimulate investments in flexibility resources were analysed in more detail on this basis with regard to their advantages and disadvantages, role of actors, dispatch procedures and legislation and regulation.

- **Option 1** is characterized as being a uniform capacity instrument with consistent prices across the board, for both new and existing assets. This option is implemented in Japan but so far rarely discussed in Germany. With the announced changes to the electricity market design, Germany is also set to implement a capacity market in future, mainly for new assets. However, it remains an open question if this instrument mainly goes in the direction of Option 2 or 3.
- **Option 2** comprises uniform capacity instruments, but with distinct conditions for new and existing assets while maintaining a uniform price for each class. This option is not discussed in Japan and neither in Germany.
- **Option 3** also includes the implementation of specific capacity instruments through capacity auctions, but introducing differentiation based on asset type, such as uniform auctions for new assets with type-specific caps or multipliers leading to diverse prices, and separate auctions by type. Option 3 is frequently discussed in Japan, as they started long term decarbonized power source auction in January 2024. The goal was to replace thermal power-based balancing power plants with decarbonized ones and to update existing decarbonized power plants such as pumped storage hydro. Although option 3 is not yet implemented in Germany, it is frequently discussed and might be the way to implement the future capacity market planned from 2028.
- **Option 4** is a broad category of other specific capacity instruments, including examples like fixed payments per kW/kWh for demand response or government grants for batteries and

V2G systems. While Option 4 is only marginally discussed and not implemented in Japan, there are several already implemented or planned instruments in Germany. Two examples are the “Biomass auctions in Renewable Energy Law (EEG)” and the “power plant strategy”.

- **Option 5** focuses on explicitly allowing the costs of flexibilities operated or incentivized by system operators in the revenue regulation for both Transmission System Operators (TSO) and Distribution System Operators (DSO). This option is not discussed in Japan, but for TSOs and DSOs it is possible to include investment costs of flexibilities, as long as approved by the government. While the current situation is similar on the German side, the recent EU electricity market reform mandates Germany to establish such incentives, specifically under ‘incentive regulation’, to encourage TSOs and DSOs to adopt flexibility services such as Demand Response (DR) and storage, extending beyond the existing frameworks for renewables. Moreover, amendments in Article 27 and 3 of the Energy Efficiency Directive emphasize the application of the energy efficiency first principle, compelling energy regulators to prioritize energy efficiency in their network planning, development, and investment decisions. Hence this option will be relevant in Germany in the future.
- Lastly, **Option 6** aims to provide price incentives through the adoption of time-of-use or dynamic (e.g., real-time pricing) components for final customers, which may be applied to power prices, grid fees, or taxes. Again, this option seems to be of lower relevance on the Japanese side today, while on the German side dynamic prices must be offered from 2025, if smart meters are available, and time-variable grid fees will have to be offered from 2025 to owners of heat pumps and BEVs under the Regulation according to §14a EnWG.

From a policy perspective, in Japan, the electricity industry has shifted its focus towards competition since the full liberalization in 2016. However, the increasing emphasis on carbon neutrality as a policy priority in recent years is expected to drive the accelerated expansion of renewables. Despite this positive shift, the rise of Feed-in-Tariff (FIT) power plants with low marginal costs entering the wholesale market is reducing the capacity of traditional thermal power plants, which historically served as balancing power sources. This underscores the critical need to secure balancing capacity, especially for decarbonized power sources. In the current framework of free competition, systematically procuring the necessary capacity is challenging. Therefore, government support is deemed crucial to facilitate the required investments. Japan has already implemented measures such as capacity markets and long-term auctions for decarbonized power sources, aiming to systematically secure the balancing power sources essential for achieving carbon neutrality.

From a policy perspective, for the German side the insights derived from this study propose a strategic roadmap for Germany's energy landscape. The initial step involves applying the” energy efficiency first” principle, employing benefit-cost analysis to evaluate the cost-effectiveness of various energy storage solutions, including both large and small-scale options, as well as innovative technologies such as heat storage coupled with Combined Heat and Power (CHP), heat pumps, Battery Electric Vehicles (BEVs), demand response, smart grid technologies, and electrolyzers. This evaluation should be conducted in direct comparison to the expansion of supply-side resources, spanning both generation capacity such as hydrogen-ready gas power plants and the planning of Transmission System Operator (TSO) and Distribution System Operator (DSO) networks.

Looking ahead to the envisioned capacity market set for 2028 (involving reform options 3 or a potential mix with option 1), the emphasis should be placed on prioritizing the integration of least-cost demand-side flexibility resources over the establishment of new power plants. For the latter, a specific focus on auctioning CHP plants as replacements for coal-fired counterparts is recommended, particularly in auctions leading up to 2028.

To bridge the transition until the full operation of the capacity market, it is advisable to develop additional specific capacity instruments (as suggested by reform option 4) tailored to demand-side flexibility resources. Simultaneously, expediting the deployment of smart meters is essential.

Further enhancements could be achieved by introducing time-dependent elements into power prices, grid fees, and potentially taxes and levies (as proposed by reform option 6). Lastly, a crucial aspect of reform involves adjusting the revenue regulation of TSOs and DSOs to facilitate the integration of flexibility costs into network tariffs, steering away from an exclusive focus on grid expansion (as suggested by reform option 5). This comprehensive approach aligns with the evolving energy landscape and positions Germany to navigate the challenges of the future energy market effectively.

In conclusion, the comparison of electricity market design policies in Japan and Germany reveals distinct approaches to fostering investments in flexibilities. Both nations exhibit a commitment to renewable energy integration and system flexibility, yet to date they employ diverse instruments to achieve these goals.

However, it may be that the reform options used by both countries might somewhat converge in the future. Germany now wants to develop a capacity market mostly for new assets by 2028. The country may take a closer look at the Long-term Decarbonized Power Source Auctions in Japan to see if something can be learned for the design of the new German capacity market, e.g., regarding the cap on revenues from other markets. Japan may learn from Germany's experiences in the implementation of option 6 and/or other instruments to stimulate the use of distributed storage like BEVs and heat pumps, in case there will be a need and a potential to use these in the long term.

Future research should focus on experiences with all these innovative instruments in both Japan and Germany as well as many other countries, to further adapt and improve their design and implementation.

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