Overview of the design of a combined capacity market

Briefing paper

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Executive Summary

Background

The issue of financing dispatchable capacities in the electricity market of the future was discussed within the framework of the Platform for a Climate-Neutral Electricity System. While there was unanimous agreement that the energy-only market would be fundamentally capable of incentivising new investments in controllable capacities, there was also agreement that the necessary confidence in the market has suffered in recent years and that it is necessary to improve the investment framework for dispatchable capacities. The German federal government has announced its intention to introduce a technology-neutral capacity mechanism, which will be operational from 2028. The discussion has now shifted to the question of which capacity mechanism concept would be the most appropriate to introduce.

In theoretical research and international practice, there are various market design options in this context, including explicit capacity remuneration mechanisms. These mechanisms are designed with the aim of efficiently guaranteeing security of supply by incentivising sufficiently flexible power plants on the basis of capacity payments.

One possible model is the "combined capacity market (CCM)," which combines elements of a centralised and a decentralised capacity market. If designed correctly, it has the potential to combine the advantages of both approaches while minimising their disadvantages.

The concept of the combined capacity market (CCM)

The CCM is comprised of two distinct components: a centralised segment and a decentralised segment.

- **Centralised segment (CCM-C)**: In this segment, tenders for new, additional capacities are centrally organised. Capacity providers compete for capacity payments, which are intended to offer investment security through long-term contracts. The capacities are then transferred to the CCM-D.
- **Decentralised segment (CCM-D)**: In this segment, suppliers – specifically the balance responsible parties (BRPs) – are obliged to purchase capacity certificates for peak load situations. An alternative option is for suppliers to reduce their load by using their own

flexibilities, which does not necessitate the acquisition of certificates. In this manner, they contribute to the security of supply while simultaneously reducing the extent of their obligation through self-fulfilment. Certificates are offered by certified capacity providers according to the contribution of their power plants and generation units to security of supply. Certificates for new capacities in the CCM-C are included.

The strength of the combined capacity market lies in the fact that it combines the advantages of a decentralised and centralised approach if designed correctly: it enables the optimal integration of decentralised flexibility options and decentralised knowledge of the development of electricity demand. Concurrently, it provides sufficient investment security for new capacities that are particularly capital-intensive and for which there is a maturity mismatch (approx. 15 years of refinancing security are needed, while the futures market only trades liquidly approx. three years in advance). The combination of centralised and decentralised elements strengthens competition between the various flexibility options and capacity providers. The decentralised segment of the CCM renders it particularly amenable to innovation and adaptable to the uncertain developments of the energy transition, particularly with regard to demand. This makes the CCM especially compatible with the energy transition. Another advantage is that in contrast to a centralised capacity market, which would require a new levy to be introduced, the levy in the CCM would only apply to the central segment and could be significantly reduced by selling the certificates generated there. A new levy would not be required for the decentralised segment as it would largely support itself. The costs would be incurred directly by the BRPs and, at least in part, passed on to electricity customers.

Central design elements

Auction of capital-intensive new builds and decentralised certificates

In the proposed CCM model, the decentralised segment comes into effect after a tender for new generation units that are particularly capital-intensive (or possibly also for extensive modernisations) in the central segment. The successful bidders in the tender will be awarded long-term contracts for capacity payments, which will refinance their investments. The tender in the CCM-C is held five years prior to the beginning of the commitment period and is conducted on an annual basis as long as there is a need for more new builds. Subsequently, the certificates awarded to the new generation units are marketed by a government-appointed agency (CCM-administrator) in the CCM-D certificate auction. Furthermore, certified existing plants may also offer their certificates in the CCM-D auction. This auction occurs four years prior to the beginning of the commitment period, which marks the inception of continuous trading in certificates. This trading permits suppliers to respond flexibly to fluctuations in expected consumption (more specifically, their individual load during periods of system peak load). Furthermore, new suppliers who are certified after the initial auction are permitted to offer certificates on the market via trading. The certificates are valid for a specified commitment period, which is typically one year. New certificates are issued on an annual basis, and suppliers have to comply with their obligation according to the development of their load. Installations that have already received a certificate for the previous year can be recertified in a simplified procedure. The interplay between the auction of new plant capacities, the certificate auction, retrospective certification and continuous trading enables an efficient allocation of security of supply certificates.

Determining the system dimensions

The CCM assigns the responsibility of determining the quantity of new capital-intensive generation units to be put out to tender (CCM-C) to a central authority. Simulation calculations are used to this end. In contrast, the quantity of certificates to be held in the decentralised segment is determined by the market, which is a key strength of the CCM. The amount of capacity needed is derived directly from the specification of the suppliers' obligation and their (decentralised) expectations of the number of certificates they need. In general, suppliers and their customers are the parties best suited to estimating their electricity demand at times of peak load from a system perspective, to projecting future electricity demand, and to assessing the cost-effectiveness of reducing the obligation via flexibility measures rather than purchasing certificates ("self-fulfilment"). This results in a more accurate mechanism and provides an inherent incentive for all consumers to minimise their load during periods of peak system demand.

The quantity of capital-intensive new units to be put out to tender in the CCM-C is determined by means of simulation calculations of the optimal development of the energy supply system. This enables the anticipated quantity of new units to be calculated in an efficient manner. The CCM-C tenders are typically issued on an annual basis for future commitment periods. In the event that the simulations indicate that there is no additional demand for new capital-intensive units, particularly if a significant number of new units have already been procured via the CCM-C tender in previous rounds, the CCM-C tender is cancelled for that year, and certificate trading occurs only within the CCM-C.

In the context of the CCM-D, the key parameter for the design is the system peak load of the commitment period, which determines the demand for certificates in the CCM-D. The load of a supplier at the time of the system peak load (i.e. its peak load contribution) is the variable from which the amount of the individual obligation is derived. The total quantity of certificates required is thus determined by the sum of the individual peak load contributions. It is not uncommon for these load contributions to deviate from the individual peak loads as the former can frequently occur at disparate times from the latter, which are typically considered the most relevant for system design. Determining the system dimensions based on the individual peak loads would result in substantial oversizing, leading to increased costs. The incentive inherent in the CCM-D for consumers to minimise their own load at the time of the system peak load has a cost-reducing effect as the controllable capacities needed to cover the load are reduced.

The CCM thus unites the advantages of two distinct approaches: on the one hand, there is the secure expansion of new capital-intensive units with long refinancing periods through central tenders, the scope of which is determined centrally. Conversely, the requisite volume of certificates is determined on the market, thereby ensuring load coverage at the lowest possible cost. This is achieved through the integration of decentralised knowledge and the option of self-provision with its own flexibilities, combined with a high degree of adaptability over time.

Participants

In addition to the BRPs or indirect suppliers, who are considered "obligated parties," the participants in the CCM are capacity providers, such as power plants, storage facilities, and, where applicable, demand-side flexibilities. The capacity providers can offer their capacities in accordance with the contribution of their respective units to security of supply. The contribution in question is determined centrally for the CCM-C and for the CCM-D (outside of self-fulfilment) by means of de-rating. It should be noted that participation in the capacity market is voluntary for all capacities. Conversely, BRPs/suppliers are obliged to participate in order to guarantee security of supply.

Products

In the CCM, remuneration for available capacity is based on the unit "de-rated MW". De-rating is the relationship between the capacity contribution to security of supply and the technical rated power of the controllable capacities. The certificates are valid for one year, which corresponds to one commitment period. In the CCM-C, new units are granted an annual capacity payment, determined through competitive bidding, for a fixed period (e.g. 15 years). Concurrently, the new units awarded these payments are obliged to surrender their capacity certificates to the CCM-administrator for the duration of the contract. The CCM-administrator is responsible for auctioning the capacity certificates for the specified compliance period. The revenue generated is used to refinance the CCM-C.

Claw-back mechanism

In the case of the CCM-C, the introduction of a claw-back mechanism is unavoidable due to the necessity of complying with European legal requirements under state aid law. One potential implementation option for this, which has previously been employed in other capacity mechanisms, is a reliability option. In practical terms, this means that units that are awarded a contract in the auction and thus receive a capacity payment are obliged to give the CCM-administrator the positive difference between the short-term electricity market price ("spot market price") and a set price threshold ("strike price" of the option). Furthermore, the revenue generated from this source is used to refinance the CCM-C. It is imperative that the strike price is not set at an unduly low level as this could have the unintended consequence of jeopardising the efficient dispatch of plants on the electricity market.

It remains open whether a similar reliability option will be required for the CCM-D. The matter is still being examined.

Monitoring of compliance control

The compliance control, which involves monitoring the suppliers' and capacity providers' compliance with their obligations, is conducted by the CCM-administrator. For capacity providers, a purely financial obligation is also a potential avenue for consideration, although its feasibility still requires further examination. In any case, the commissioning of new units is a crucial factor in ensuring the compliance of obligations.

Existing funding mechanisms

Plants that already receive subsidies, such as those from the German Renewable Energy Sources Act (EEG), the German Combined Heat and Power Act (KWKG) or from the tenders as part of the power plant strategy, are integrated in the CCM as follows: Their contribution to security of supply is taken into account in the certificate system by the CCM-administrator, which adds certificates to the extent of the contribution to the CCM-D. The units will continue to receive the same level of subsidy. To avoid double funding, no further funding will be provided by the CCM.

1 Introduction

The issue of securing investments in controllable capacities to ensure security of supply has recently been the subject of much public discussion. Discussions held within the Platform for a Climate-Neutral Electricity System (PKNS) have indicated that a number of stakeholders perceive potential benefits in supplementing wholesale electricity trading with a market mechanism for financing controllable capacities. There are a number of potential market design options that could be considered, both in theory and, at least in part, in practice.

One such option is that of explicit capacity remuneration mechanisms. The aim of a capacity mechanism is to ensure the security of supply in an efficient manner by providing incentives for sufficient quantities of flexible units. Depending on the specific requirements, these can be designed on the basis of various basic models. The best-known models include a centralised capacity market, as in Belgium, Poland, the UK and parts of North America, and a decentralised capacity market, as implemented in principle in France. A combined capacity market (CCM), which combines decentralised and centralised capacity markets, is also conceivable. In practice, it seems that the CCM is most likely to be found in the French model, where the decentralised capacity market was supplemented by centralised auctions of new plant capacities after it was introduced.

There is considerable scope for flexibility in designing capacity markets, including combined capacity markets. The aim of a CCM is to strike a balance between the benefits of centralised and decentralised capacity markets while avoiding the drawbacks of each model. It would be beneficial if the centralised segment in the CCM (CCM-C) could offer the necessary investment security for the expansion of new capacities through long-term contracts. It would be beneficial if the decentralised segment in the CCM (CCM-D) could enable the optimal integration of innovative decentralised flexibility options (e.g. load flexibility) and decentralised knowledge about the development of demand. In this brief paper, we aim to provide an overview of a potential, suitable form of the basic design of such a CCM. The paper presents the current state of discussions on the concept of the CCM. The concept is to be developed further on the basis of discussions with stakeholders and will inevitably need to be fleshed out in more detail.

The capacity market as an important component of a secure, sustainable and affordable electricity system

The main aim of introducing a capacity market is to secure the technology mix needed in a decarbonised electricity system in order to guarantee security of supply in a climate-neutral, efficient and affordable manner. To this end, a capacity market should create a stable framework for the necessary new investments in dispatchable capacities or the provision and, if necessary, upgrading of existing capacities. In the paper "Electricity market design of the future," the Federal Ministry for Economic Affairs and Climate Action observed that market participants have expressed reservations about the current market design, citing concerns about the risks of the transformation and the lack of sufficient incentives for corresponding investments. In a capacity market, suitable framework conditions can be created, meaning that it could provide an effective solution in this regard. For technologies with high fixed costs and relatively short deployment times, it may be helpful to consider framework conditions that allow for longer contract terms and more time between formation of the contract and the compliance period. This would help to ensure that investments are incentivised and existing uncertainties are overcome. It would be beneficial to explore ways of strengthening market-based development for decentralised and innovative flexibility options.

In order to be compatible with the energy transition, it is important that the capacity market takes into account the developments and uncertainties of the energy transition and technological progress and is open to innovation and connectivity. It is also important to ensure that the effective guarantee of security of supply is maintained. One way to achieve this would be to enable an efficient technology mix through competition between power plants, storage facilities and flexible loads, which would contribute to a cost-effective electricity system. On the other hand, in order to ensure the continued security of the supply system, it would be prudent to consider the potential impact of changes in generation and consumption patterns, including the possibility of increased consumption due to the electrification of additional sectors and the flexibility of new consumers.

The CCM offers a potential solution for limiting the implementation costs associated with integrating a diverse range of flexibility options in the capacity mechanism. At the same time, it has the potential of guaranteeing security of supply in a more cost-effective and resilient manner, particularly in the face of unforeseen developments and forecasting errors. It is thought that the CCM, by combining a long-term hedging mechanism for new investments with the development of decentralised knowledge on the demand side, is more suitable in this regard than centralised capacity markets developed in the past, which do not inherently address the challenges of the energy transition.

2 Combined capacity market – an overview

Figure 1 shows the CCM at a glance. A CCM consists of a centralised segment (CCM-C) and a decentralised segment (CCM-D). The centralised segment includes auctions for new capacities and, where applicable, extensive retrofits, in which capacity providers compete for capacity payments. Long-term contracts are intended to provide the necessary investment security for the addition of new capacity.[1] In principle, the decentralised segment works by obliging electricity consumers or their suppliers to purchase sufficient capacity certificates for situations of system peak load[2], i.e. to act as capacity consumers. Such capacity certificates are offered by suppliers of certified capacities and traded via a certificate market. This segment is intended to enable the optimum integration of decentralised flexibility options (e.g. load flexibility), innovative flexibilities and decentralised knowledge about the development of demand. Controllable capacities that are incentivised via the CCM-C are allocated certificates. These in turn are made available within the scope of certificate trading in the CCM-D in order to obtain the correct information about the total supply of controllable capacities.

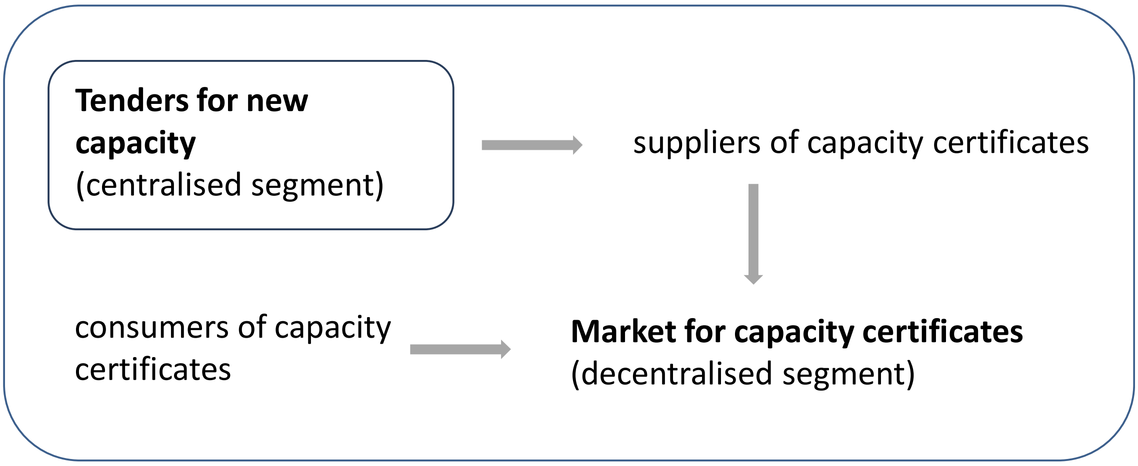

Figure 1 : Simplified operation of centralised and decentralised segments in the CCM

The CCM-D in the CCM is founded upon the principles of balancing group responsibility as they are currently operational within the electricity system. In accordance with this system, the balance responsible parties (BRPs), typically electricity distributors or suppliers, are required to submit schedules to the transmission system operators (TSOs) for each quarter of an hour of the following day. It is the responsibility of the BRPs to ensure that their balancing group is in a state of equilibrium; that is to say, the demand must be met by a corresponding feed-in or purchase. The transmission system operators (TSOs) oversee the balance of each balancing group and physically equalise the sum of all deviations (i.e. the control area balance) through the use of balancing energy. The imbalance settlement system provides substantial financial incentives for balance responsible parties (BRPs) to ensure sufficient quantities of electricity in their balancing group through ex ante procurement, particularly in situations in which there is a risk of shortages in the electricity system.

[1] In contrast to the CCM approach presented here, in which the CCM-S offers long-term contracts for the new capacities, the Monopolies Commission's proposal for a CCM only provides for short-term contracts (one-year contracts), including for the central segment.

[2] The term "situations of system peak load" is used here and in the following to mean that the BRPs must cover their own peak load with capacity certificates in situations with the potentially highest system load or system residual load. Whether the design-relevant time windows should be selected based on the system peak load or system *peak* residual load still needs to be clarified in the further discussion and the existing advantages and disadvantages of both approaches still need to be assessed. For the sake of simplicity, the term "system peak load" will be used consistently in the following.

The introduction of a CCM requires that BRPs in the decentralised segment explicitly secure their peak load within "design-relevant" time slots with capacity certificates. A central body appointed by the government determines the design-relevant time windows in accordance with pre-defined rules. These windows typically correspond to the periods of the expected system peak loads in the underlying delivery year. As the precise individual peak load of the obligated parties is not known in advance, they estimate their obligation based on forecasts and make adjustments as necessary over time. This obligation guarantees the availability of sufficient controllable capacities within the system, thereby enabling balancing groups to fulfil their balancing obligations. From the perspective of the BRPs/suppliers, this approach serves to reinforce their accountability for the security of supply to the customers they serve. Conversely, they have the opportunity to leverage customer relationships and supplier expertise for the benefit of the customers.

This expansion of balancing group responsibility is shown in Figure 2. The green elements show how the current system functions without a capacity market (in a highly simplified form). The yellow elements would be introduced upon implementation of a CCM. The central segment with the auction of new capacities is shown in blue.

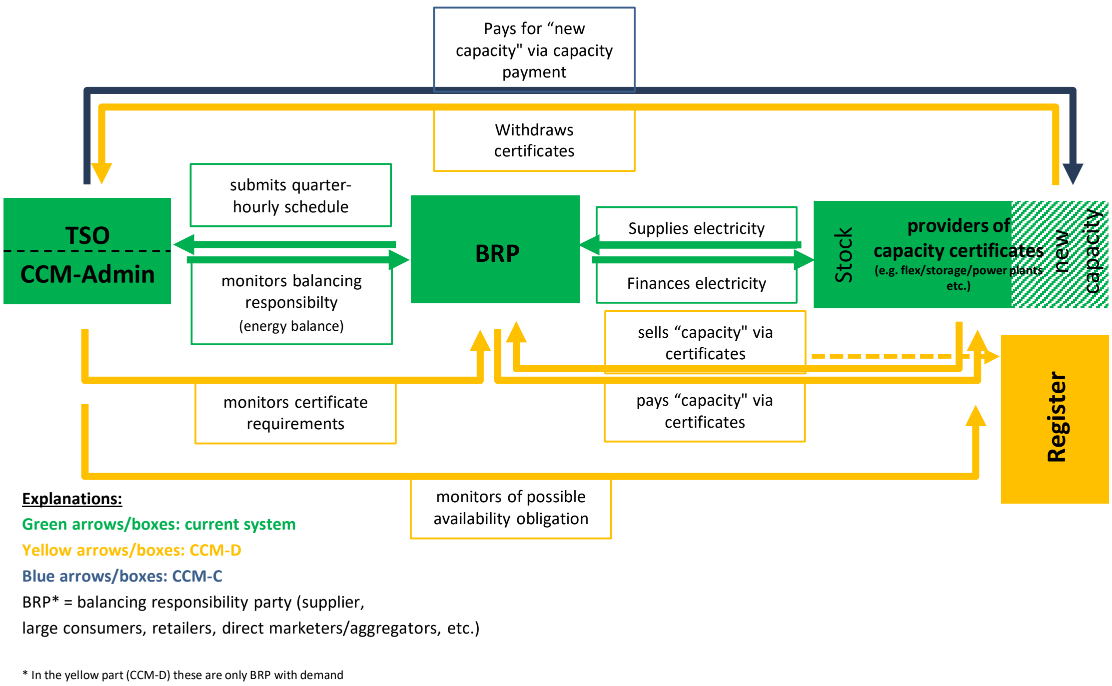

Figure 2 How the CCM functions (with today's system shown in simplified form)

In particular, dispatchable capacities, notably flexible loads, can facilitate compliance with the BRP's obligations by reducing the peak load contributions of "their" BRP by strategically using flexibility. This, in turn, alleviates the obligation of the BRP and thus its necessity to procure capacities (a process known as "self-fulfilment"). This can be advantageous not only for the BRP, but also for some controllable capacities as the cost of certification can be waived without simultaneously having to forego the contribution of these flexible units to covering the BRP's peak load contribution.

Power plants, storage facilities and any load flexibilities that are not used for self-fulfilment are certified by a central authority within the CCM-D and receive capacity certificates based on their expected contribution to the "design-relevant" situation. These can then be sold on the electricity exchange or over the counter to the BRP. Certified capacity providers are obliged to ensure that their unit is available at the time of the system peak load. Furthermore, capacities created through the central new build auctions also generate certificates. The above-mentioned data is then made available to the CCM-D certificate trading system, thus ensuring the accuracy of information pertaining to the total supply of dispatchable capacities.

Each certificate is valid for a fixed period, corresponding to the duration of a compliance period, which is typically one year. The transfer of certificates to another actor is duly recorded in a central register. When the delivery period ends, a compliance check is conducted on this basis, accompanied by financial settlement (see Chapter 3.5). This may be conducted by a government-appointed body, referred to hereafter as the CCM administrator. The CCM administrator performs an ex-post comparison of the number of certificates associated with each BRP, as recorded in the register, and the actual measured peak load contribution within the "design-relevant" time slot. Any shortfalls are subject to penalties (see chapter 3.5). Furthermore, the CCM administrator oversees the compliance of capacity providers subject to the availability obligation. It is necessary to examine further whether the proof of availability in scarcity situations should be physically demonstrated or whether a financial incentive mechanism is also sufficient.

Practical experience gathered with the decentralised capacity market in France demonstrates that the trading of certificates between capacity providers and obligated BRPs typically only occurs with short lead times of one to three years, with long-term contracts being an exception. It thus follows that the longer-term hedging requirements of investors in new units with long amortisation and refinancing periods cannot be met via the decentralised capacity market.[3] Consequently, the CCM incorporates a central component in the form of a tender for new units (shown in blue in Figure 2). The capacity providers who were awarded contracts as part of the tender for new units will receive longer-term contracts with a state-mandated counterparty. In return, the contracted plants are obliged to certify their capacity and transfer the capacity certificates to the CCM administrator, who is responsible for marketing the certificates on behalf of the CCM in the CCM. In a manner analogous to a futures contract, the tender for new units enables long-term hedging of revenues from the sale of certificates.

3 Combined capacity market - design issues

Chapter 2 offered a preliminary account of the manner in which the CCM under consideration operates. Nevertheless, the practical implementation of such a mechanism gives rise to a multitude of intricate design issues, which this chapter will address, at least in part. The European legal framework[4] provides guidelines for some of these design issues, while greater flexibility is permitted for others. The existing centralised capacity markets in Belgium[5] and the

[3] Based on the experience gathered with the existing decentralised capacity market in France, conclusions can be drawn about the design of a capacity mechanism in Germany and have also been incorporated in the present design proposal for the CCM. At the same time, it should be noted that the market situation in France differs considerably from the situation in Germany, for example with regard to the dominant role of nuclear energy or the high market concentration, with the result that the experiences gathered there have a limited transferability.

[4] In particular, the EU Electricity Market Regulation and the European Commission's Guidelines on State Aid for Climate, Environmental Protection and Energy.

[5] The CCM in Belgium serves as a good reference for the design of the elements of centralised procurement within the CCM. At the same time, the Belgian centralised capacity market still has to prove its effectiveness: although several procurement auctions have already taken place, the first compliance period has yet to begin.

decentralised markets in France[6], for example, can provide important points of reference for certain elements of the CCM.

3.1 Interaction of the segments and determining their dimensions

Sequences and interactions

It is essential that the centralised and decentralised segments of the CCM adhere to a specific temporal choreography in a steady state, as shown in Figure 3. This also necessitates the presence of certain interactions between the segments. It should be noted that the introduction of CCM-C and CCM-D within the framework of CCM does not necessarily have to occur simultaneously. It is conceivable that invitations to tender can be made in the CCM-C while the CCM-D is still in the process of being established (see below).[7]

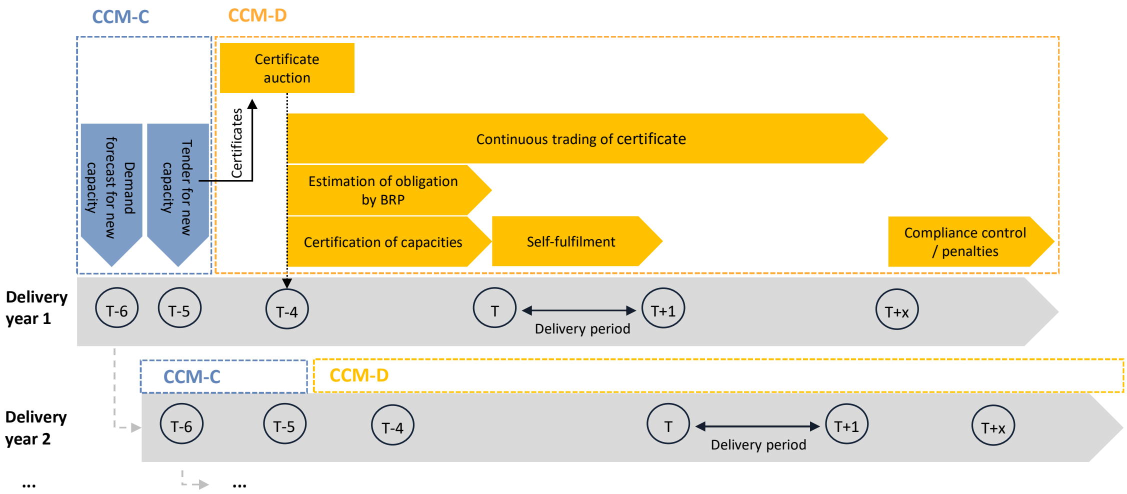

Figure 3 : Sequences of the CCM

In the CCM model under consideration, the decentralised segment is preceded by a central tender for new units (i.e. CCM-C). As part of the CCM-C, the CCM administrator initially performs a simulation of the efficient development of the electricity supply system to estimate the likely efficient demand for new capacity (see below). This demand is then tendered with sufficient lead time before the actual delivery period (in this case, five years in advance) – with respect to new capacity, this is their first delivery period. The successful bidders in the auction receive long-term contracts for capacity payments to refinance their investments

Furthermore, suppliers who have been awarded a contract in the tender for new units are also certified. As the central mechanism for securing and refinancing their investment is the CCM-C for the awarded new units, the CCM administrator auctions off the certificates of the awarded new units in the CCM certificate auction and uses the proceeds generated to partially refinance the costs of the CCM-C.

[6] See also footnote 3.

[7] It should be noted that the legal basis for the CCM-C and CCM-D will probably have to be created at the same time due to the requirements of European and state aid law. However, it is conceivable (subject to the approval of the EU Commission) that 1-2 years more time could be scheduled for the actual implementation of the CCM-D than for the CCM-C.

Furthermore, existing installations that have already been certified have the option of offering their certificates for sale at the CCM-D certificate auction. For these installations, certificate trading is not confined to this auction; rather, continuous trading in certificates (on or outside of the electricity exchange) occurs after this auction. In principle, the trading and re-certification of additional capacities is possible until the delivery period commences. In order to mitigate the risks associated with uncertainty with regard to the projected individual demand for certificates (for instance, due to electricity customers switching suppliers), it may be feasible to consider extending trading activities beyond the end of the delivery period. This enables obligated parties in possession of surplus certificates to transfer them to BRPs that have insufficient quantities of certificates. Nevertheless, additional new certificates cannot be created after the delivery period has commenced.

As shown in Figure 3, a "run" of the CCM encompasses the duration of a single compliance period, which typically spans one year. However, the CCM is not designed for a single run; rather, it is intended for the long term. Consequently, multiple runs may occur, either consecutively or concurrently. For instance, the CCM for delivery year 2 (and so on) commences simultaneously with the CCM for delivery year 1, one year after its inception.

Determining the dimensions of the centralised segment

Determining the dimensions of the centralised segment entails determining the demand, i.e. determining the amount of (new) capacity required to achieve a certain reliability standard. In the CCM-C, a simulation of the optimal development of the energy supply system is initially conducted to ascertain the quantity of new capacity to be tendered (including extensive retrofits in the CCM-C, if applicable) in order to determine the probable optimum demand for new units with a corresponding lead time (here T-6; see Figure 3). The optimum approach is to utilise a stochastic investment model, which is a market equilibrium model that incorporates the decision-making processes associated with the addition and removal of individual plants.[8] The equilibrium of the investment model reflects the optimum system development and the requisite new construction requirements. This process yields the optimum demand that should be contracted via the CCM-C.[9] If the parameters of the investment model are determined in accordance with the requisite specifications, the targeted security of supply level can be achieved through this methodology.[10]

Once the demand for new units has been determined, the question then arises as to which new capacity should be put out to tender in the CCM-C. In the event that particular attention is to be paid to avoiding possible over-subsidisation or to efficient design, it may be prudent to set the tender volume rather conservatively. Such an approach would not necessarily entail an inherent risk to security of supply as the downstream CCM-D can also provide an incentive for investment in additional new capacity. This is because in the event that the number of capacity certificates

[8] In the CCM analysed here, the CCM-C is upstream of the CCM-D and begins with determining the need for new capacities. In contrast, in the Monopolies Commission's CCM approach, the decentralised segment is upstream of the centralised segment. An upstream centralised determination of demand is therefore not provided for in the Monopolies Commission's approach.

[9] In practice, modelling simplifications and assumptions are unavoidable. For example, it also makes sense to model different scenarios for the development of the energy system in order to depict uncertain developments with regard to electricity consumption, interconnector capacities or the availability of hydrogen.

[10] This statement applies in the same way as it does when determining the dimensions of the capacity requirements of a CCM. Here, too, calculations are used to determine a capacity requirement that mathematically ensures a certain security of supply level. In contrast to the centralised capacity market, the calculation with the investment model requires the calculation over a longer period of time (in the centralised capacity market, this is only one year / one shortage period).

in circulation in the CCM-C is insufficient to fulfil all obligations, the price of certificates will increase. Such an increase in price could theoretically prompt further investment, potentially from investors with a greater aversion to risk or technologies with shorter refinancing cycles. This also implies that in the event of an erroneous estimation of the necessity for new construction in the CCM-C, the CCM-D can address any resulting discrepancies by providing incentives for further new units. This constitutes a significant advantage of the CCM, which is designed to guarantee the security of supply in the most effective and efficient manner possible.

Consideration of the power plant strategy (PPS)

In general, there are several potential avenues for integrating the power plant strategy (PPS) with a prospective CCM. Nevertheless, it seems reasonable to posit that the PPS tenders will at the very least be carried out before the CCM is introduced. In the event that the PPS volume is already available prior to the inaugural tender for new units within the CCM-C, or alternatively, if the respective contracts have already been made, it would be necessary to specify the PPS capacities exogenously within the investment model, as previously discussed. Furthermore, the capacities from the PPS would have to be treated in the same manner as plants that have already been subsidised in other locations (see below).

It should be noted that the introduction of the CCM-C and CCM-D within the framework of the CCM does not necessarily have to occur simultaneously. It is conceivable that tenders are already issued in the CCM-C while the CCM (e.g. the certificate register) is still being established. It is sufficient for the installations and units in the CCM-C to recognise that they will not receive additional revenue from the subsequent CCM.

Determining the dimensions of the decentralised segment

The system peak load of the delivery period represents the design-relevant variable, i.e. the situation that determines the need, for which the dimensions of the CCM-D are determined overall. The load of a BRP at this juncture is, in turn, the variable from which the volume of the individual obligation is derived. However, the system peak load for a given year is not known in advance. What is usually known, however, is the approximate time period in which it occurs, e.g. in winter between November and March. It can be reasonably assumed that within this specified window, there will be a day (or an hour) in which the system peak load situation will occur. In order to be able to estimate the relevant day (or hour) ex ante, the French decentralised capacity market[11] allows the TSO to define 15 days during the delivery year (11 days in the January-February-March period and 4 days in the November-December period). The TSO publicly declares each day relevant to the obligation that is one day prior to the obligation beginning. The obligation must be fulfilled from 7:00 to 15:00 and from 18:00 to 20:00 on these days. The individual load of the BRPs on these days determines the number of certificates that a BRP must provide. The TSO employs its own optimisation algorithm to ascertain these days.

Accordingly, the BRPs are unable to ascertain the extent of their obligation to provide certificates in advance as they are not privy to the precise load within the delivery period in question. Nevertheless, the BRPs are in a position to use ex ante load forecasting in order to estimate their obligation. One advantage of the CCM-D design is that the obligation is estimated in a decentralised manner by the BRPs, who are therefore able to make an estimate that is informed by their relevant expertise.

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[11] The French model offers initial starting points for practical implementation. The extent to which other implementation variants are conceivable and possibly advantageous has not yet been investigated.

In general, it is not possible to rule out the possibility that the individual load peaks of the individual BRPs will occur on different days over the 15 days that are relevant to the obligation, given the approach that has been taken in the French system. For example, one BRP may experience its peak load on the first day relevant to the obligation, while another may do so on the second relevant day. Consequently, there is a possibility that the collective obligations of the BRPs will exceed the peak load of the system, resulting in overdetermined dimensions. Nevertheless, the probability of oversizing is considerably reduced in comparison to the alternative scenario in which the individual peak load (irrespective of a pre-defined time window) is employed as the measurement variable.

3.2 Participants

Balance responsible parties and capacity providers

In a CCM, participants are essentially BRPs with physical demand (i.e. not BRPs of pure trading, generation and difference balancing groups). They are either obligated parties or buyers of certificates, while capacity providers are suppliers of certificates (or indirectly so, in the context of self-fulfilment). In accordance with the stipulations set forth in the EU's Regulation on the Internal Market for Electricity (referred to hereafter as the Electricity Market Regulation), the participation of all technically capable capacities that can contribute to the assurance of security of supply must be permitted. Furthermore, foreign capacities must be permitted to participate. In addition to the BRPs and the capacity providers, the CCM administrator is also a stakeholder and is involved in determining the dimensions, in tendering or auctioning, and in the monitoring of the CCM, among other activities.

In terms of the definition of capacity providers, these can be power plants. In light of the impending transformation of the electricity system, it is anticipated that new power plants will be primarily gas-fired (and potentially bioenergy plants), with a gradual transition to CO_2-neutral fuels, such as hydrogen and biofuels, as outlined in the following section. In addition to power plants, storage facilities and demand response can also be considered as capacity providers. Nevertheless, facilities that are currently subsidised under existing support schemes (see below) or that are excluded from the CCM due to emission limits prescribed by EU law[12] (this particularly applies to coal-fired power plants) are not permitted to participate. From the perspective of state aid law, the exclusion of units that already receive support elsewhere is necessary in order to ensure the legally required avoidance of overcompensation.

Capacities that engage directly in certificate trading and do not participate based on self-fulfilment must undergo the certification process. It is imperative that certified units are not included in self-fulfilment, and thus require appropriate labelling to avoid any potential for double counting. As part of the certification process, a range of administrative and technical data is documented, including the location of the unit, the grid operator with which it is connected, and the emission factors associated with it. Additionally, the output of the unit is subject to review, with measurements or explicit tests serving as the primary means of assessment. In cases in which batteries are involved, the certification process also encompasses an evaluation of their storage capacity or exit capacity. While such an assessment is relatively straightforward for power plants and batteries, it presents a more significant challenge for load flexibility (in part due to the need

[12] Emission Performance Standard in accordance with the Electricity Market Regulation: CO_2 emission limits for new units: < 550 g CO_2/kWh_{el} , existing units: < 550 g CO_2/kWh_{el} or an annual average of < 350 kg CO_2/kW_{el}

for a robust baseline determination), which is why the option of self-fulfilment is particularly crucial in this context.

A significant challenge arises when certifying new units as the certification process commences before the unit in question has been completed. As a result, a physical inspection cannot be conducted until the unit has been completed. Consequently, the inspection could be restricted to the specifications set forth by the manufacturer. Additionally, the certification of new capacity would be subject to the condition that, if the construction of the facility depends on being awarded in the new capacity auction, certification would only be granted on the condition of a successful award in the CCM-C.[13]

Contribution of capacity to security of supply (de-rating)

As part of the certification process, capacity providers are also subject to a de-rating procedure. The de-rating factor is a quantitative measure that accounts for the varying contributions of different systems to security of supply, taking into account their specific technical characteristics. The specific de-rating factor is employed to provide a quantitative expression of the statistical contribution of different capacities/capacity types to security of supply in relation to the installed output of the capacity. For the sake of simplicity, this factor can be summarised for technology groups (e.g. for all open gas turbines). It should be noted that the contribution to security of supply is not exclusively unit-related; rather, it is also contingent upon the characteristics of the electricity system as a whole. These include the composition of other capacities and the demand for electricity. For example, the de-rating factor of batteries is also contingent upon the total number of batteries within the system. The de-rating factor is inversely proportional to the number of batteries in the system. Furthermore, the de-rating factor of the batteries is contingent upon the duration of the scarcity periods, which in turn is influenced by the broader system dynamics, including renewable energy profiles and load profiles. Such discrepancies are incorporated into the de-rating process. In the context of a CCM, both segments, namely CCM-C and CCM-D, necessitate the application of de-rating factors in order to ascertain the contribution of a technology to scarcity situations within the specified period. To ensure consistency, it is recommended that the de-rating factors are determined for both CCM-C and CCM-D on the same database using the same models. However, different calculation methods may be employed for the two segments. In the event that new delivery periods or tendering rounds are required, the de-rating factors may be updated accordingly.

3.3 Products

“De-rated MW” and period of validity

The EU Electricity Market Regulation already stipulates that the availability of capacity is to be considered as part of capacity remuneration mechanisms. The product that is procured in a capacity market is therefore generally de-rated capacity; the capacity must be available at the expected times of scarcity. The unit on which a capacity market and thus a certificate is based is “de-rated MW”; this applies to both the centralised segment (tender) and the decentralised segment. Capacity providers enter into an availability obligation as required by the Electricity Market Regulation. It must first be examined whether availability must also be physically proven in scarcity situations or whether a financial incentive mechanism is also sufficient (see below).

[13] Alternatively, other approaches are also conceivable, but these need to be examined further.

The certificates have a fixed validity. In the CCM-D, this corresponds to the duration of a commitment period, which is usually one year in other capacity markets. In order to reduce the effort involved in certification and the associated costs, it may make sense to enable simplified or accelerated re-certification after initial certification. This limits the certification effort both on the part of the capacity providers and on the part of the CCM administrator.

For capacity providers, certification and the opportunity to sell certificates are accompanied by availability obligations for the respective commitment period. In France, the period in which capacity providers must be available comprises the obligation-relevant days of the capacity providers. These include the obligation-relevant days of the BRP (see above) and up to 10 additional days of the year, which are also announced one day in advance.

The aim of CCM-C is to hedge the longer-term investment risks of new units. Accordingly, CCM-C issues longer-term contracts, e.g. for 15 years. For the term of the contract, the new units receive the capacity payment (EUR/MW/a) specified in the tender for new units. At the same time, the new units awarded this payment surrender their capacity certificates to the CCM administrator during the term of the contract. This also includes the obligation to undergo annual recertification as described above for the CCM-D in order to prove that they can continue to contribute to security of supply with their plant. The CCM administrator markets the capacity certificates for the respective compliance period in the CCM-D certificate auction, as in the case of otherwise subsidised or excluded plants. In addition, the availability requirements associated with the capacity certificates, which can lead to penalties in the event of non-compliance, apply to the awarded new units for the entire term of the contract (see chapter 3.5).

Claw-back mechanism by a reliability option

In the case of CCM-C, the introduction of a claw-back mechanism appears to be an inevitable consequence of state aid law. It is less clear whether a similar claw-back mechanism is also necessary or economically sensible for CCM-D in terms of state aid law.

One potential implementation option for such a mechanism is a reliability option that is not dependent on the generation in question. This would entail that, in the event of the electricity market price in the spot market exceeding a certain threshold (strike price), capacity providers would be obliged to pay the difference between the electricity market price and the strike price to the CCM administrator, irrespective of whether they produce electricity in that particular situation. Provided that the strike price exceeds the marginal costs of the capacity providers, they will continue to have an incentive to generate electricity during periods when the spot price exceeds the marginal costs. Concurrently, the capacity providers would incorporate the levy into their bid, thereby mitigating risk by transforming uncertain cash flows from uncertain price peaks into secure cash flows. In the implementation of the reliability option in the Belgian centralised capacity market, the day-ahead market serves as the reference price, with the strike price being recalibrated on an annual basis. T he strike price is set at a level that is at least as high as the marginal costs.[14]

3.4 Geographic allocation

In considering the CCM, a key question is whether it should encompass mechanisms for geographic allocation. This is a topic that is frequently discussed in the context of capacity

[14] While there is a strike price for all larger generation facilities in Belgium, there are exceptions for demand response.

mechanisms for the German electricity system with a view to addressing system requirements, e.g. in relation to the availability of sufficient redispatch capacity.

Two principal approaches may be considered with regard to geographic allocation:

- Regional quotaquota), which is defined, for example, under transmission adequacy aspects and for which a certain share of the total demand must be covered by capacities from a certain region.
- Competitive bonus (or bonus-malus system) in which, for example, installations in the south receive a bonus (= discount on the submitted bid) during the bidding process as part of clearing (alternatively, installations in the north receive a malus).

The implementation of regional control via explicit access requirements, i.e. the exclusion of plants in certain regions or at certain grid interconnection points from tendering (or, alternatively, the admission of plants in certain regions only), would entail considerable disadvantages from a competition point of view and would fail to adequately address the current situation of the North-South bottlenecks within Germany.

The implementation of geographic allocation is of particular significance for the CCM-C as it serves as a primary instrument for incentivising the development of new units and the associated locations. It should be noted that both of the above-mentioned options also apply to the CCM-C (see below). The optimum approach is contingent upon the aim of geographic allocation. If the aim is to ensure a minimum level of capacity in a given region – e.g. because the technically necessary amount cannot be achieved otherwise or can only be achieved at a significant cost disadvantage – then the specification of regional quotas is the preferred approach. This is the case, for example, if the aim of geographic alloication is to procure a quantity of additional redispatch capacity that is demonstrably required in a specific region. Conversely, if there is a cost advantage in allocating additional capacity in a specific region from an overall system perspective, but this allocation is not technically necessary (e.g. because there are alternative procurement options), the bonus/malus approach described above is more favourable. In any case, the incorporation of additional objectives beyond the mere assurance of supply in a capacity mechanism necessitates a thorough examination under the auspices of state aid law.

Although geographic allocation is primarily relevant in the CCM-C, it could also be implemented in the CCM-D. It is similarly conceivable that a regional core share (or a regional quota) could be implemented. This would entail associating a certificate with its geographic orgination (e.g. distinction between certificates from South and North”) and a quota (e.g. 40%) would have to be fulfilled with certificates with corresponding origins in order to fulfil the obligation. However, this approach is not without the risk of ineffectiveness as the requirement of a regional quota can only be applied to the certificates, but the obligation of the BRP can also be fulfilled implicitly through self-fulfilment. It is evident that this self-fulfilment cannot be regionalised. There is an alternative or workaround option in this regard.

Another topic that is frequently discussed in connection with geograpic allocation and is also likely to be raised in the context of the approval of the CCM under state aid law is the division of the German bidding zone into several bidding zones, the boundaries of which run along heavily loaded grid elements. The question of whether such a division of bidding zones is advantageous, disadvantageous, or otherwise legally or implicitly problematic falls outside the scope of this paper. It is also important to consider that a bidding zone division would have an impact on the design of the CCM. Furthermore, the necessity for the above-mentioned instruments for regional control could be obviated after a division of the bidding zone. Furthermore, the dimensioning of the CCM would be affected as this is typically conducted at the bidding zone level. In order to determine the optimum capacity of the CCM-C, the “efficient amount of new capacity,” as previously described, is calculated for a given bidding zone, in accordance with the stipulations set forth in the Electricity Market Regulation. In the context of the CCM, the obligation of the BRP is to be fulfilled by the issuance of certificates from units located within the bidding zone of the balancing group in question. It should be noted, however, that contributions from other bidding zones are also possible in general, and not only in the context of the CCM. In the case of contributions from other bidding zones, it is imperative that no differentiation is made between German and foreign bidding zones, in accordance with the requirements of European law. These considerations demonstrate that a bidding zone division also has implications for the impact of a CCM (the same would also apply to a centralised capacity market and a decentralised capacity market).

3.5 Organisation of the CCM

Centralised segment

In regard to the tender for new units (CCM-C), it is imperative to ascertain and resolve a multitude of design-related concerns in advance. Such issues include, for example, the format and procedure of the auction, the regulations governing prices, and the introduction of price ceilings.

With regard to the auction format and the auction process, Belgium has elected to utilise a “single-round sealed bid” auction in its centralised capacity market. In this format, bidders are required to submit their bids without knowledge of the bids submitted by other participants. Subsequently, the market is cleared in a single round by the auctioneer. It should be noted, however, that the number of bidding rounds is not necessarily limited to one. The centralised capacity market in the UK, for instance, employs a multi-round bidding process. The selection of an appropriate auction format is a crucial decision that entails weighing the advantages and disadvantages inherent to each format. These considerations extend to aspects such as strategic incentives for bidders, the avoidance of collusive behaviour, and the overall complexity of the format. This aspect requires further examination during the subsequent design process.

Additionally, there are various potential configurations for the price rules, though these must align with the above-mentioned auction formats. In essence, there are two models: “pay-as-bid” (PAB) and “pay-as-cleared” (PAC). In a PAB system, the price paid by each successful bidder is equal to the amount they bid. In contrast, the pay-as-cleared (PAC) model entails that all successful bidders receive the same price, which is the price of the last bid required to cover demand. The former has been implemented in the Belgian capacity market, whereas the latter has been implemented in the UK’s CCM. In theory, the results of PAB and PAC should be similar. In the case of PAC, participants are automatically awarded the most expensive accepted bid (or the most favourable bid that is no longer awarded). In the context of PAB, participants are motivated to estimate the price of the highest accepted bid and submit a bid at this price.

In addition to the price regulations, it is necessary to define a reservation price. The reservation price is the maximum remuneration that can be achieved for a bid in the tender for new builds (CCM-C). By establishing a maximum remuneration, the potential for exploiting market power by submitting unsuitable bids is mitigated. In the Belgian CCM, the global auction price cap is calculated by multiplying the cost of new entry (CONE) by a factor. In particular, the net CONE is employed, i.e. the CONE minus the anticipated market revenues from the energy-only market (EOM) and balancing energy marketing, and so forth. The value of the correction factor is contingent on the inherent uncertainties associated with the estimation of the net CONE, both in terms of the costs of the various technologies and the determination of other market revenues. The price cap for the inaugural auction in Belgium was set at EUR 75/kW/year, which equates to the net CONE of EUR 50/kW/year multiplied by a correction factor of 1.50.

Decentralised segment

It is also necessary to define the numerous design issues relating to the market structure in the CCM-D. As shown in Figure 3, the CCM-D commences with a certificate auction. It is also necessary to provide advance clarification in response to questions about the format and process of the auction, and the rules governing the determination of prices. Subsequent to the certificate auction, continuous trading in certificates ensues. This may occur on the electricity exchange (in France via EPEX SPOT) or over the counter (OTC). Continuous trading occurs beyond the delivery period, extending up to the compliance check. This mitigates the risks associated with uncertainty regarding the projected individual demand for certificates.

Secondary trading

From a legal standpoint, a capacity market established under the Electricity Market Regulation must provide for the possibility of transferring capacity obligations between duly authorised capacity providers. From the perspective of the CCM, the question of secondary trading arises in relation to both the CCM-C and the CCM-D. In the CCM-C, the question arises as to whether there should be a mechanism for secondary trading, whereby capacity providers awarded payments can transfer their obligations associated with the award to a third party, provided that this third party can fulfil at least the same requirements that the original capacity provider had to fulfil in the CCM-C. It would be prudent to provide for such secondary trading in the CCM-C.

In the case of the CCM-D, the question arises as to whether explicit secondary trading is required or whether this is rendered obsolete by continuous certificate trading. In the event of unavailability, a capacity provider may fulfil its obligation by providing proof of purchased capacity certificates. Nevertheless, in order to ascertain the total amount of capacity that should have been available in the relevant time window, it would be necessary to offset the purchases of certificates by capacity providers against their capacity certificates, as recorded in the certificate register.

Compliance control

Subsequent to the conclusion of the delivery period, a compliance verification is conducted (for further details, see Figure 3). On the one hand, the CCM administrator verifies whether the BRP has fulfilled its obligation. All certificates are recorded in a central register, which contains the relevant information pertaining to their transfer, holders, and so forth. The CCM administrator then compares the obligation of each BRP based on the actual peak load contribution within the design-relevant time window (e.g. the obligation-relevant days of the BRPs in France) with the number of certificates held by each BRP as recorded in the register. Should there be a discrepancy between the obligation and the inventory of certificates, a financial settlement will be necessary (see below). In the French decentralised capacity market, the compliance check is conducted with a relatively substantial time lag relative to the delivery period (T+3). However, an earlier compliance check could also be feasible, for instance, at the conclusion of the subsequent year when the final balancing group statements are accessible.

As previously outlined, with respect to certified capacity providers, it is necessary to determine whether the demonstration of technical availability is always a requirement, even in situations of scarcity, or whether a financial incentive mechanism is an adequate alternative.

A separate compliance check is not required by the CCM-C, as this is instead conducted via the CCM-D through the obligation of new units to submit their certificates to the CCM-D. An additional option would be to consider whether new units should be required to pay a higher financial compensation for breaches of contract than other capacity providers.

The level of financial compensation and the design of the settlement are of critical importance with regard to the incentive effect in the CCM-D. In terms of the design of the settlement system, there are a number of theoretical possibilities, with some overlap with the design of the imbalance settlement with regard to BRPs' imbalances per market time unit (MTU). For instance, it is unclear whether there should only be penalties for BRPs not fulfilling their capacity obligation, or whether there should also be compensations in case of over-fulfilment, namely the issuance of a greater number of certificates than required. In this context, the question also arises as to whether the compensation system should be designed symmetrically or asymmetrically. That is to say, should upward and downward deviations be penalised equally or differently?

Refinancing

The refinancing of costs in the CCM is associated with the CCM-C. In addition to monitoring and administrative costs, the CCM-D is largely self-supporting as the costs are borne directly by the BRPs and subsequently passed on to electricity customers. In contrast, at CCM-C, the costs associated with the new capacities are borne by the CCM administrator, necessitating the refinancing of these expenses.

In the case of the CCM-C, the subsidised new units are required to surrender their certificates to the CCM administrator for auctioning off in the CCM. This enables the CCM-C to be partially refinanced. Nevertheless, there is a possibility that the costs associated with the tender for new units in the CCM may have to be partially refinanced outside the CCM-D. In theory, there are a number of potential options for the allocation or transfer of costs. In general, the European Commission's state aid guidelines require cost-shifting based on the polluter pays principle. It is conceivable that a levy on consumers could be implemented, with the level of the levy fluctuating in accordance with a system variable such as the wholesale electricity price or the residual load.. In this manner, scarcity signals could be conveyed to consumers, thereby creating incentives for those who are able to adjust their consumption patterns in response to such signals. It is similarly conceivable that the surcharge could be levied solely on those hours of the CCM deemed to be "design-relevant," thereby providing an additional incentive to minimise load during these hours. Nevertheless, as only the CCM-C share requires refinancing in the CCM-D, the resulting distortion or burden on consumers through a levy appears to be limited overall.

3.6 Further questions

Installations receiving support from existing subsidy schemes

As previously stated, installations and units receiving support from existing subsidy schemes are not eligible for funding under the CCM.[15] This is also due to the requirement under European Union law that aid must be proportionate. Furthermore, the cumulation of aid must be avoided to prevent over-subsidisation. For example, plants that receive subsidies under the Renewable Energy Sources Act (EEG) or the Combined Heat and Power Act (KWKG) would be excluded from the CCM. Installations and units that already receive a capacity payment under the PPS would also not be eligible for subsidies under the CCM.

The contribution of the excluded plants to security of supply is nevertheless taken into account in the CCM. One potential solution would be for the CCM-D administration to include certificates in the scope of the de-rated capacity of these plants in the CCM-D, e.g. as part of the certificate auction. This approach would allow an efficient allocation of these certificates while simultaneously generating revenue to finance the CCM-C.

Dealing with reserves

In light of the players involved in the CCM, another pertinent question is how to handle reserves in order to guarantee the stability of the electricity market, particularly in times of crisis, and to ascertain their compatibility with the CCM. It would appear that in principle, reserves and a CCM could exist in parallel. For example, the CCM is principally orientated towards ensuring resource adequacy, whereas the grid reserve is designed to guarantee transmission adequacy, specifically the ability to ramp up and alleviate grid congestion. The disparate foci of the CCM and reserves may therefore be seen to justify their co-existence. Nevertheless, it is not possible to exclude the possibility of interactions between a CCM and the reserve. In the event that the CCM incorporates a local element (see the section on regional control above), this may serve to diminish the necessity for grid reserve.

In considering the role of reserves in the context of the CCM, it is important to note that installations designated as reserves do not receive any certificates. This is because it can be assumed that they will not be required in the scarcity situations relevant to the design of the CCM. Furthermore, they cannot be counted towards self-fulfilment and thus require appropriate labelling to indicate that they are excluded.

Requirements for gas-based energy generation

As previously stated, a number of technologies can be regarded as capacity providers. In the context of power plants, these are likely to be natural gas power plants, with the potential for bioenergy plants to also be included. In the case of natural gas, however, the Commission's state aid guidelines call for a commitment to gas-based energy generation to be avoided. This can be achieved by implementing measures such as the imposition of binding obligations on the recipient of aid to utilise decarbonisation technologies or to substitute natural gas with renewable or low-carbon gases. Furthermore, the EU electricity market reform explicitly states that Member States are permitted to set emission limits for participation in capacity mechanisms in a manner that allows only flexible, non-fossil technologies to be considered as technology options.

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[15] Theoretically, it would be conceivable for plants to leave the old subsidy regime and switch to the CCM instead. However, in view of the associated increase in complexity, this does not seem advisable.

In order to facilitate practical implementation, it is recommended that existing instruments for the reduction of greenhouse gases should also be included. In particular, this pertains to the EU ETS, which, as the principal instrument, should provide incentives for the utilisation of decarbonisation technologies or the substitution of natural gas with renewable or low-carbon gases.

In addition to the EU ETS, the prerequisites must be created to ensure that a potential transition is also technically feasible. On the one hand, with regard to hydrogen this entails establishing the necessary infrastructure (H2 grid, etc.) by central authorities. On the other hand, plant operators must retrofit their facilities to make the conversion technically feasible. For natural gas-based generation plants, an obligation could be introduced requiring operators to in advance demonstrate how they plan to technically achieve this. However, it is not necessary to call for a concrete timeline for this type of retrofit, as the retrofit will be incentivized by the price signals of the EU ETS, as described above.

4 Combined capacity market - a comparison of costs and benefits

One criticism of the CCM that is frequently made is that the decentralised segment and its interconnection with the central tenders would markedly enhance the intricacy of the novel system in comparison to a pure centralised capacity market. The implementation costs of a CCM would therefore be significantly higher than those of a centralised capacity market. This prompts the question of the cost-benefit ratio of the CCM, particularly in comparison to the centralised capacity market, which is often perceived as a well-established and conceptually straightforward alternative. This section examines the cost-benefit question in greater depth and concludes that the one-off cost of introducing the CCM is offset by relevant simplifications and decisive advantages elsewhere. With regard to the compatibility of the energy transition and the necessity for technology neutrality – that is to say, the fundamental requirement to integrate flexible loads and storage in addition to power plants – the CCM has decisive advantages that make it preferable to a CCM.

The evaluation of costs and benefits is conducted from three distinct perspectives: Firstly, with regard to the *compliance costs*, i.e. the costs of developing the various flexibility options (flexible loads, power plants, storage). Secondly, the question of *error costs* must be addressed, namely the susceptibility to risk of incorrectly determined parameters and the learning capability of the capacity market. Thirdly, the *programme costs* must be considered, i.e. the costs of implementing the capacity market.

It is crucial to consider these factors not only in the context of the current situation or past experiences, but also in light of the evolving electricity system that will emerge as a result of the energy transition. In this prospective system, demand flexibility will assume a significant role alongside power plants based on wind and solar energy, dispatchable power plants and storage systems. This is applicable to both highly heterogeneous electricity applications (e.g. in industry) and to standardised, albeit in some cases markedly decentralised, forms of electricity consumption that may also be significantly influenced by customer preferences (e.g. e-mobility, heat pumps, etc.). In addition to ensuring the sufficient capacity of dispatchable power plants, it is imperative to guarantee security of supply in this system by employing a diverse and expanding range of flexibility options on the demand and storage side. It seems probable that a considerable number of new business areas will emerge, accompanied by a high level of innovation, particularly in the field of flexibility options. In the context of a capacity market, this gives rise to particularly high demands in relation to the definition of pre-qualification characteristics and certification procedures.

Compliance costs: The extant evidence from other EU countries indicates that the existing centralised capacity markets have, thus far, been capable of offering only incomplete solutions for the integration of different flexibility options in an efficient and non-discriminatory manner. In contrast, the CCM provides the potential for capacity contributions from a range of sources, including certified capacity contributions from dispatchable power plants, storage facilities and demand flexibility, and the self-provision of capacity contributions that are not subject to further prequalification or individual certification. This could enable the coverage of peak load through a combination of these sources. In contrast to the centralised capacity market, in which only capacities that depend on predefined products and pre-qualifications can contribute to the proof of security of supply, the possibility of self-provision significantly increases the number and variety of security of supply options. In light of the growing number of innovative and/or decentralised flexibility options, such as e-mobility and heat pumps, the importance of self-provision is becoming increasingly evident. This results in a reduction in the costs associated with ensuring security of supply. Furthermore, the CCM-D provides an inherent incentive for consumers to use the available or economically accessible flexibility through self-provision. The reduction in the respective contribution to the system peak load also has the effect of reducing the supplier's individual costs in the CCM-D.

Error costs: Furthermore, practical experience gathered in other countries in this context demonstrates that existing capacity market models have not yet fully addressed the challenges associated with the transformation of the electricity system. It is evident that existing capacity markets require regular and, in some cases, considerable adjustments to adapt the regulations to the evolving landscape of the electricity system. However, in order to ensure investment security, it is necessary to implement a robust, self-stabilising and adaptive system that is capable of reacting dynamically and transparently to any incorrectly determined parameters. In contrast to the centralised capacity market, the decentralised element of the decentralised capacity market enables systematic learning effects via the resulting prices and corresponding adjustments. For example, the CCM makes it easier to identify capacity market miscalculations than a centralised capacity market due to the intercommunication between the two market segments. This results in a tendency towards self-stabilising behaviour or the facilitation of more expedient readjustments, thereby contributing to enhanced fault tolerance in the context of forecast inaccuracies. Furthermore, the risk of other incorrectly determined parameters (e.g. in the product definition and prequalification of flexibility options) should also be reduced in the CCM in comparison to the centralised capacity market due to this feedback mechanism. In particular, the risk of incorrectly assessing the security of supply contributions of flexibility options or of double counting is reduced if flexibility is taken into account in both determining the demand at the system level and in individual certification. It can be reasonably deduced that the overall error costs in the CCM will be significantly lower than in the centralised capacity market.

Programme costs: The above-mentioned fundamental advantages of the CCM are, however, initially offset by the increased implementation costs in some areas. This is due to the need to introduce certificate trading, compliance monitoring and implementing a system of financial settlement for all obligated parties on the demand side within the CCM-D. Nevertheless, as the corresponding transactions are largely based on existing data and information flows (especially in balancing group management, in which all suppliers are already active) and there is already extensive and positive experience with the corresponding IT systems and the relevant regulations for a comparable number of players (EU ETS, balancing group management), the implementation costs in this area of the programme costs are estimated to be relatively low compared to the above-mentioned benefits. Furthermore, it is important to consider that the administrative burden associated with certifying and monitoring compliance options in the CCM (and thus the programme costs on the supply side) can be significantly reduced compared to the centralised capacity market. This is due to the possibility of self-fulfilment.as there is no requirement for certification, availability checks, and so forth for the flexibility options employed in self-fulfilment. As a result, a more level playing field is created for all participants in the portfolio of security of supply options, without the necessity of further regulatory requirements and bureaucracy. Furthermore, the T-1 auction, which is typically conducted in the centralised capacity market, is no longer a necessary component of the CCM, as the CCM-D serves this function. The net result of these two opposing trends in terms of programme costs depends crucially on the extent to which the determination of parameters and the certification costs can be avoided by using flexibility options in the area of demand and potentially storage or micro-flexibilities via self-generation.

In other areas, the costs associated with the CCM are comparable to those of the centralised capacity market. This applies to the overall determination of capacity needs (in the CCM for the assessment of the centralised segment, at centralised capacity market for the assessment of overall demand), and to the prequalification and certification of the plants participating in the central auctions.

From this comprehensive and holistic assessment of the three facets of the costs and benefits discussed in the context of the future electricity system – compliance costs, failure costs and programme costs – the CCM is considered the preferred option.