Working Paper

Cross-border coordination in interconnected power systems

Economic considerations on allocating decision-making competencies in the European Union

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1 Introduction

The European Union (EU) represents a supranational association of currently 28 European countries with the purpose of promoting the national prosperity levels by means of economic and political cooperation.[1] The creation of an internal market is an essential means of achieving this aim. Reducing trade barriers, the internal market is supposed to help reap the benefits from international division of labour. Against this background, the member states have transferred certain decision-making competences to the EU and its institutions, implying restrictions of the national sovereignties in the corresponding policy areas. “Completing” the internal market remains one of the European Commission’s (EC) primary objectives. In many policy areas this means a further convergence of national regulations, which is pushed forward by more extensive standardisation requirements if necessary. At the same time, the question of which concrete competences should be assigned to the supranational level has not substantially lost importance since the signing of the Treaty of Rome in 1957 establishing the European Economic Community (the EU’s predecessor organisation). Recent developments and events, the most striking one being “Brexit”, clearly demonstrate the crucial importance of the allocation of decision-making powers for the continued success of the EU. Acknowledging that the heated debate on the issue indicates potential shortcomings, the EC itself officially placed this topic high on the agenda by publishing its “White Paper on the Future of Europe” in March 2017. The White Paper presents several scenarios for the EU’s future organisation and orientation, whose differences are largely related to variations regarding the allocation of competences between the member states and the EU. Although the EC’s initiative aims first and foremost at the union’s overall governance structure and policy focus, it can be argued that the allocation of responsibilities for individual sectors and specific detailed questions is ultimately not less important. This certainly applies to the electricity sector, which is a key industry for modern economies like the EU.

In this working paper we compare different alternatives for the allocation of decision-making competences in the European power sector. We focus on the provision of generation capacity, which represents a crucial matter due to its large share in the overall costs of electricity supply. The aim of our analysis is to identify governance structures that, on the one hand, allow to reap the benefits of international coordination without, on the other hand, neglecting national preferences or leading to undesirable distributional effects. In particular, we examine the following questions: What are the potential benefits of a coordinated provision of generation capacity in an interconnected power system? How can these benefits be achieved? What are the general advantages and disadvantages

[1] This working paper is based on the research paper “Cross-border coordination as a prerequisite for efficient sector coupling in interconnected power systems” which was prepared as part of TU Berlin – WIP’s research activities in the project “Kopernikus ‘ENavi’, a navigation system for the energy transition”, funded by the German Federal Ministry of Education and Research (BMBF). The analysis incorporates previous work by TU Berlin – WIP carried out within the framework of the project “Effiziente Koordination in einem auf Erneuerbaren Energien basierenden europäischen Elektrizitätsversorgungssystem (EK-E4S)”, which was funded by the German Federal Ministry for Economic Affairs and Energy (BMWi); apart from the authors of this paper, Daniel Weber and Alexander Weber delivered substantial contributions in this context.

of centralised and decentralised decision-making? How does the current institutional framework in the European power sector perform in the light of these insights? Which reform options are available and seem reasonable? With these questions in mind, we start off by drawing conclusions from observations made in a simplified industry model environment. The simplification includes that for most parts of the analysis we deal with a very basic set of actors between which responsibilities are distributed, namely: (i) the supranational level (EU), (ii) the national level (member states) and sometimes (iii) the level of market actors (mostly generators). Such an approach certainly does not deliver a suitable basis for immediate assessments of currently applied policies on a very detailed level; however, as indicated before, the aim of this analysis is rather to attain a better understanding of the big picture.

The analysis presented in this working paper is based on qualitative economic considerations. We apply insights from a broad range of economic fields, including (New) Institutional Economics (NIE), industrial economics, welfare economics, finance theory, game theory, public choice and fiscal federalism; different new institutional economic theories form the centrepiece of our approach's theoretical foundation. When comparing different governance solutions we mainly focus on their impact on costs. Apart from costs that are directly related to the use of resources in the electricity supply process, we also take transaction costs into account. While overall welfare effects generally play a prominent role in this context, in view of the research subject, the analysis furthermore has a special focus on the distribution of rents, mostly among states, but also between generators and consumers. Besides the cost efficiency objective, we assess how variations in governance models may affect environmental objectives and security of supply. These objectives, on the one hand, can be interpreted as necessary conditions, which must be achieved at least cost. On the other hand, it seems reasonable to acknowledge the obvious trade-offs between the objectives.[2]

In the following section 2, we present a selection of general economic considerations concerning the topic of this working paper, which serve as a basis for our assessments throughout the subsequent steps of the analysis. This includes, firstly, a discussion of the fundamental mechanisms of international cooperation on power supply and the importance of the prevailing framework conditions. Secondly, we provide an overview of selected market design topics to which we refer later on. Section 3 contains a conceptual discussion of governance models for the provision of power plants in a union of states. Analysing models with extreme solutions for the distribution of competences as a first step, our major aim in this section is to identify suitable components of a governance model with a well-differentiated allocation of powers and tasks. In section 4, we check the status quo in Europe for consistency with our findings and point out needs for improvement, before concluding with a summary of the main insights from our analysis in the final section 5.

[2] Due to the inherent conflict of objectives, the problems discussed ultimately rather resemble a multi-objective optimisation than a constrained cost optimisation.

2 Basic considerations

2.1 Framework conditions for international cooperations on the provision of power generation capacity

International cooperation is an important issue in interconnected power systems like the one in the Europe. First of all, a coordinated approach to the provision and operation of power plants offers large cost-saving potential compared to stand-alone actions by each country. Secondly, investment and operational decisions made in one country possibly affect the situation in connected countries (directly or indirectly). In the case of commercially linked power markets, this includes effects on domestic electricity production, market prices and rent distribution, which might not always be desirable from the perspectives of each country involved. Since technical interdependencies exist regardless of trade agreements, decisions in neighbouring countries might have significant implications for a power system, even if there is no commercial connection. As the occurrence and size of (positive or negative) effects highly depends on the initial situations in the countries involved, it is important to take the prevailing conditions for cooperation into account when assessing the favourability of coordinated solutions. It seems logical that, in principle, all these aspects should be considered when pursuing a goal like the “completion” of the internal energy market. In the following subsections, we elaborate on some general potential benefits and drawbacks of cooperation on the provision of generation capacity in the European power sector, which will be essential for the subsequent steps of the analysis.

2.1.1 Potential benefits of a coordinated provision

The magnitude of benefits that international cooperation offers depends on the initial situation in the electricity sectors of the countries concerned, including their respective national power systems, institutional frameworks and policy agendas. It could be argued that the potential benefits of coordination are, in general, even more obvious in the power sector than in some other areas, which can be explained by the following aspects:

- **Security of supply (provision of highly reliable plants):** Electricity is a good with peculiar characteristics, one of the most striking ones being that demand must always be matched by a simultaneous production of the required power volumes (including the infeed from electricity storage systems and taking account of possible adjustments on the demand side)[3]. A system’s guaranteed capacity, therefore, has to be sufficiently high to cover peak demand. As the load varies considerably over time and very high volumes are reached only rarely, some plants (usually the ones with high variable costs) typically function as reserve plants with a low

[3] At this point in time, existing storage systems in Europe can only cover a small share of the aggregate load. Even though storing electricity might play an important role in replacing conventional plants in the future, in the following we do not explicitly distinguish between electricity generation in power plants and infeed from storage as it would increase the complexity without substantially affecting our main lines of argument and thus the findings. Furthermore, it is worth mentioning that, in principle, electricity demand can also be adjusted to a certain degree. Although in many power systems around the world the possibilities to make adjustments on the demand side have been improved over recent years − mostly due to increased regulatory efforts – short-term flexibility is generally still subject to significant limitations.

utilisation rate. Given the fact that both changes in demand and the availability of power plants are not perfectly correlated across countries, a coordinated provision of plants promises significant cost savings; especially since fewer reserve plants are needed (which go along with particularly capital-intensive investments).[4] Although, for reasons of simplicity, we exclusively discuss resource adequacy issues in the following, it is important to point out that security of supply has several further dimensions, which partly also require coordinated action in an interconnected system (e.g., related to the task of frequency control during operation).[5]

- **RES-E expansion (provision of RES-E plants):** The cost and value of intermittent RES-E (electricity from renewable energy sources) production highly depends on the plants' location. Concerning the deployment of RES-E plants at a large scale, joint action of countries − especially in an interconnected system − is of great importance. Besides the fact that climate protection requires cooperation on an international (and ultimately global) level, a wider distribution of intermittent RES-E plants across a large system leads to more stable generation, since local infeed patterns vary. This is likely to increase production values and reduce the need for reserve plants. Furthermore (and somewhat opposed to the aspect addressed before[6]) cooperating countries may decide to use the best locations for RES-E plants, irrespective of national borders.
- **Operation (plant dispatch):** The fact that electricity, unlike most other goods, can be transported promptly over long distances helps in meeting the challenge of accurately synchronising production with demand. Whenever power plants on the other side of a national border can contribute to satisfying demand at a lower cost than available domestic plants, interconnection and cross-border trade offer the potential to increase resource efficiency. For this, power systems have to be not only physically, but also commercially linked, which means that use is made of existing cross-border capacities to trade electricity volumes between national markets. In this context, the merit-order curves, which rank available plants according to their marginal costs of production, are combined across power systems as far as transmission capacities allow for this.[7]

In the following subsections, we discuss, among other things, obstacles to the realisation of benefits from cooperation in interconnected power systems.

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[4] The particularly high capital intensity of reserve plants is mostly due to their lower utilisation rates which go along with lower fuel costs. The same applies to to intermittent renewables, whose production does not involve any fuel costs. Cf. for instance NEUHOFF / RUESTER / SCHWENEN (2015).

[5] Cf. for instance JOSKOW (2006).

[6] Installing RES-E plants at the most suitable locations with respect to production costs might lead to a higher spatial concentration, which is detrimental to the stability of the aggregate RES-E infeed.

[7] In practice, the merit-order curve is based on the information transmitted to the system operator; usually by means of bids from the generators. In case of strategic bidding behaviour (which, for instance, often appears when generators have market power) the generators' bids might contain mark-ups and, therefore, the merit-order curve might not accurately reflect the plants' marginal costs.

2.1.2 Relevance of the initial situation and heterogeneity between cooperating countries

Among the important factors for an assessment of concrete cooperation opportunities, the grid capacity situation is particularly relevant, since it is responsible for the extent of interdependencies between power systems; this applies both to benefits and to undesired effects. While interconnector lines between the countries play the most obvious role in this context, it is also important to take potential hinterland transport bottlenecks into account. Furthermore, the grid situation determines the suitability of congestion management methods and, related to this, the necessity for active regulatory involvement in the process of selecting sites for new generation projects. Similarly, the suitable design of a country's institutional mechanisms for the provision of power plants depends on the existing domestic power plant fleet (in section 2.2 we will take a more detailed look at some basic mechanisms for the provision of power plants and for congestion management). Different national power plant fleets might sometimes complement each other in some ways and thus be a source of cooperation benefits. On the other hand, a highly advantageous compatibility of generation fleets might not be given in each case. Indeed, the effects resulting from connecting power systems or intensifying existing linkages might sometimes be considered undesirable, which can impede collaborative action (we outline a few possible undesired effects in section 2.1.3).

Apart from the technical system aspects mentioned, national regulations (in particular the electricity sector design) might affect the practicability of cooperations. Sometimes national mechanisms for the provision of generation capacity diverge substantially and have a low degree of compatibility. The same applies to the procedures of system operation; e.g., grid-related differences, such as diverging methods of congestion management, might play a role in this context. The ownership situation of domestic power plants, which we touch upon in the following subsection, is yet another factor that can potentially affect the evaluation of cooperations.

2.1.3 Distributional effects and externalities

Externalities, which sometimes involve distributional effects, occur in interconnected power systems in many forms and for many reasons. As mentioned above, such effects are related to both physical and commercial links.[8] If national markets are linked, generation investment and decommissioning decisions can potentially affect the utilisation rate of plants as well as wholesale market prices across national borders. If the remuneration of generators relies on market revenues, such effects are potentially essential from an investor's point of view. Market price changes also matter to the demand side if they directly or indirectly affect the level of consumer payments; as mentioned above, the ownership situation might play a role in this context. In some countries the generation assets are majority-owned by the state, whereas in other countries private ownership prevails. If entering into cooperation leads to, for instance, higher domestic market prices – such effects are discussed in more

[8] For an exemplary discussion and model-based illustration of distributional effects related to cross-border network extensions cf. GERBAULET / WEBER (2018).

detail in the following section – the assessment from a consumers' perspective might be rather positive in cases in which the plants are public property (because higher consumer payments are, in principle, offset by higher public revenues). An example of cross-border effects that also occur in the absence of market connections is the occurrence of voluminous loop-flows, as was the case with the large-scale development of wind farms in nothern Germany whose production – due to inner-German grid restrictions – interfered with the country's eastern neighbours' grids.[9] Instruments to counter undesired cross-border effects (i.e. negative externalities) include institutional and technical grid congestion management measures, which we will briefly discuss in section 2.2.2.

2.1.4 General advantages and disadvantages of centralising decision-making powers: A differentiated view on the EU's aim of completing the internal energy market

Enshrined in the EU primary law, the full functioning of the internal market represents one of the Union's overarching goals. As will be discussed below (see section 4), it seems to be the EC's general electricity sector strategy to steadily develop the Europeanisation of power markets by enforcing the convergence of national regulations. This approach goes along with a high degree of centralisation in decision-making. On the one hand, the member states are substantially involved in European legislative procedures. On the other hand, the countries did forgo certain decision-making powers by transferring them to European institutions. In consequence, decisions made on the supranational level might not always be in line with individual interests. Since the relevance of this aspect depends on the very topic of centralised decisions, we take a brief look at potentially important factors in the following.

As pointed out above, cooperation offers great benefits in certain areas of electricity supply; in some cases an advanced internal market might be a suitable framework for reaping those benefits. Concerning the operation of generation units, for instance, a high degree of centralisation seems to be beneficial overall (a transnational approach to the dispatch of plants improves the possibilities for using the most cost-efficient production factors available to cover demand; see section 2.1.1). Regarding operation, it seems appropriate to rely on market-based organisation as a convenient way to gather distributed information on current availabilities and costs of the plants. In a market system with multiple supply and demand side actors – which we assume throughout our analysis − the spot market, among the different segments of the wholesale market, is ultimately responsible for dispatch decisions (future and forward markets, by contrast, mainly serve to hedge the positions of supply and demand side actors over the medium and longer term). Ideally, the spot market's marginal cost-oriented selection and pricing mechanisms ensure a dispatch that, in the short run, leads to the lowest possible resource use. A high degree of centralisation might prove helpful in this context, since largely harmonised operational rules throughout the countries are a precondition for an optimisation across borders. Although the described synergy effects rely on the linkage of markets, this does not – for the

[9] Cf. KUNZ (2018).

reasons mentioned in the previous sections − imply that an increase in interconnector capacities, let alone a situation of no bottlenecks at the borders, is desirable.

As mentioned above, there is also a significant potential for synergies in the provision of generation capacity, concerning both intermittent RES-E as well as highly reliable plants that ensure security of supply. In section 2.1.1 we suggested that possible advantages in this area, especially synergies resulting from portfolio effects with respect to the usage of generation capacity and infeed of RES-E plants, partly originate from differences between states. Heterogeneity among countries, however, might also lead to barriers to cooperation and to problems of centralised decision-making. Uniform rules, firstly, might neglect diverging preferences and, secondly, cannot always adequately take different local circumstances into account. If, for instance, the attitudes towards the usage of certain generation technologies diverge substantially between countries, there are good reasons for leaving decisions relating to the generation mix up to each state (as it is generally the case in the EU). Consequently, further central requirements placed on countries in a union of states should not dramatically affect their technological choices. By contrast, it might be very reasonable in some cases to seek consensual agreements on individual contributions to the achievement of common goals; this is especially likely with respect to objectives that necessarily require joint action, such as climate protection.

When assessing institutional solutions, it is important to also take transaction costs into consideration, because they might partly offset or even exceed the achievable benefits of cooperation. Transaction costs go along with, for instance, designing, implementing, monitoring and adapting (new or existing) governance models.[10] Costs of capital, which are associated with financing investments and risk bearing in this context, can also be regarded as transaction costs (in this working paper we do not consistently distinguish between cost categories such as production costs and transaction costs, because a clear classification is not always possible). Furthermore, transaction costs related to the political process of a reform can also be regarded as a relevant aspect for the practicability of measures. To give an example, considerable resistance from national states or from influential lobby groups against centralised decisions might not only reduce the achievable net gains of a measure; sometimes it might go along with alternations of the original concept and thus different effects of the measure than initially intended. Moreover, distributional effects implicated by centralised measures might give rise to laborious negotiations if the countries are involved in the legislative process (or if they can, at least, influence it − if not, undesirable distributional effects might cause further problems, as outlined above). If the countries are involved in decision-making, the amount of transaction costs of reforms is interrelated with the level of heterogeneity in the countries' preferences and objectives. Usually it will be easier to impose new rules when the supranational regulation promotes goals which

[10] Cf. OSTROM (1990), who distinguishes between so-called "transformation costs" and "monitoring and enforcement costs".

are shared by all states. In cases in which central measures that promote coordination do not conflict with individual objectives, there is a very clear case for their implementation.[11]

Up to this point, for simplicity, our discussion on centralised and decentralised decision-making has focussed on the two extreme opposite solutions of i) uniform rules for all member states established on the supranational level and ii) stand-alone actions by each country. Between those two options there is a continuum of conceivable solutions which all involve some form of coordination of national actions. In such differentiated governance models the standardisation of regulations, for instance, might be limited, leaving a certain part of decision-making powers to the national states. Moreover, centralised measures do not necessarily need to apply to each state, but only to a group of countries. Although at certain points of the following sections we refer to the extreme solutions again (especially in section 3.2), the analysis is ultimately targeted at an assessment of differentiated governance models.

2.2 Overview of selected market design topics

As mentioned above, centralised decisions on the supranational level might affect market design choices on the national level; moreover, a great heterogeneity in national market designs might impede international collaboration. In the following we discuss basic concepts for the provision of power plants and for the management of grid congestions, which we will refer to later on in the analysis.

2.2.1 Institutional framework for the provision of power plants

Institutional frameworks for the provision of generation capacity always consist of complex structures of rules, which are often embedded in several different legislations. Designing the institutional framework involves a very large range of interdependent decisions and is therefore a complicated issue. Although seemingly minor design elements may sometimes strongly influence the practical overall functioning of a mechanism, some essential conclusions can usually also be drawn from comparing rough overall concepts. In the following, we take a brief look on two opposite approaches to the provision of generation capacity, the so-called “energy-only-market” (EOM), and capacity remuneration mechanisms (CRM); these two concepts are often considered to be the basic alternatives for the organisational model’s framework. For simplicity reasons, we limit the discussion in this section to the national sector design; i.e., cross-border issues in an interconnected system are only addressed in the subsequent parts of the analysis.

2.2.1.1 The EOM concept

The core idea of the EOM approach is that the provision of generation capacity is based on the interaction of supply and demand side actors on liberal wholesale and retail markets. This means that investment decisions and, virtually, the responsibility for resource adequacy are decentralised and put

[11] For a detailed discussion of the content, cf. HOFFRICHTER / BECKERS (forthcoming).

in the hands of (typically private) market actors. Revenues for generators, in consequence, predominantly arise from sales of energy volumes in an EOM.[12] In the following we assume a setting in which final customers are supplied by load serving entities (LSEs) which buy electricity from generators; the underlying interactions happen on liberal retail and wholesale markets respectively (for a simplified illustration of the basic EOM concept, see Fig. 1).

Briefly assessing the EOM approach, we start by assuming a scenario in which there is effective competition (i.e., no substantial market power) in both the wholesale and the retail market; this assumption coincides with fundamental goals of the EOM concept. Under such circumstances, at least a large share of generators will usually not be able to find counterparties for long-term contracts that would guarantee stable returns and thus a successful amortisation of their investments.[13] The achievable market revenues depend on future power market developments, which are normally subject to great uncertainty. Taking further risks such as costs risks into account, investors face a high uncertainty regarding their possibilities for creating contribution margins. Since private actors in competitive markets have limited abilities to bear risks which they cannot influence or hedge, this uncertainty is reflected in considerable risk premiums, i.e., a high cost of capital.[14] Against the background of a high capital intensity of generation investment, the impact on overall costs of electricity supply is particularly great. In the worst case, the rather inconvenient investment conditions lead to insufficient generation capacity. This calls, in such situations, for centralised measures to guarantee security of supply. However, there is a conflict with the fact that the functioning of the EOM concept fundamentally relies on strong commitments by the regulator to refrain from intervening in market mechanisms. On the one hand, there are several conceivable short-term solutions for adequacy issues that might be sufficiently compatible with the EOM; i.e., a public provision of reserve plants which do not actively participate in markets (this instrument is often referred to as “strategic reserve”). On the other hand, such measures do not contribute to solving the general problems related to the high investment uncertainty.[15]

[12] In this analysis we do not particularly consider further streams of income such as revenues from contracts on the supply of ancillary services (such as control reserve), because their inclusion would not significaantly change the general line of arguments presented in this section.

[13] This general prediction is in line with observations of the behaviour on real power markets that feature fundamental characteristics of the EOM approach. Cf. for instance KEMA (2009) and MAY / JÜRGENS / NEUHOFF (2017).

[14] In this paper, using the term “cost of capital” we refer to all costs that arise from capital provided by the funding parties, including interest payments. This also means that, in contrast to diverging definitions, depreciation is not included.

[15] If apparently EOM-compatible instruments, such as a strategic reserve, are applied in a way that aims at solving problems in the long-run, they are likely to result in extensive centralised planning; cf. HOFFRICHTER / BECKERS / OTT (forthcoming).

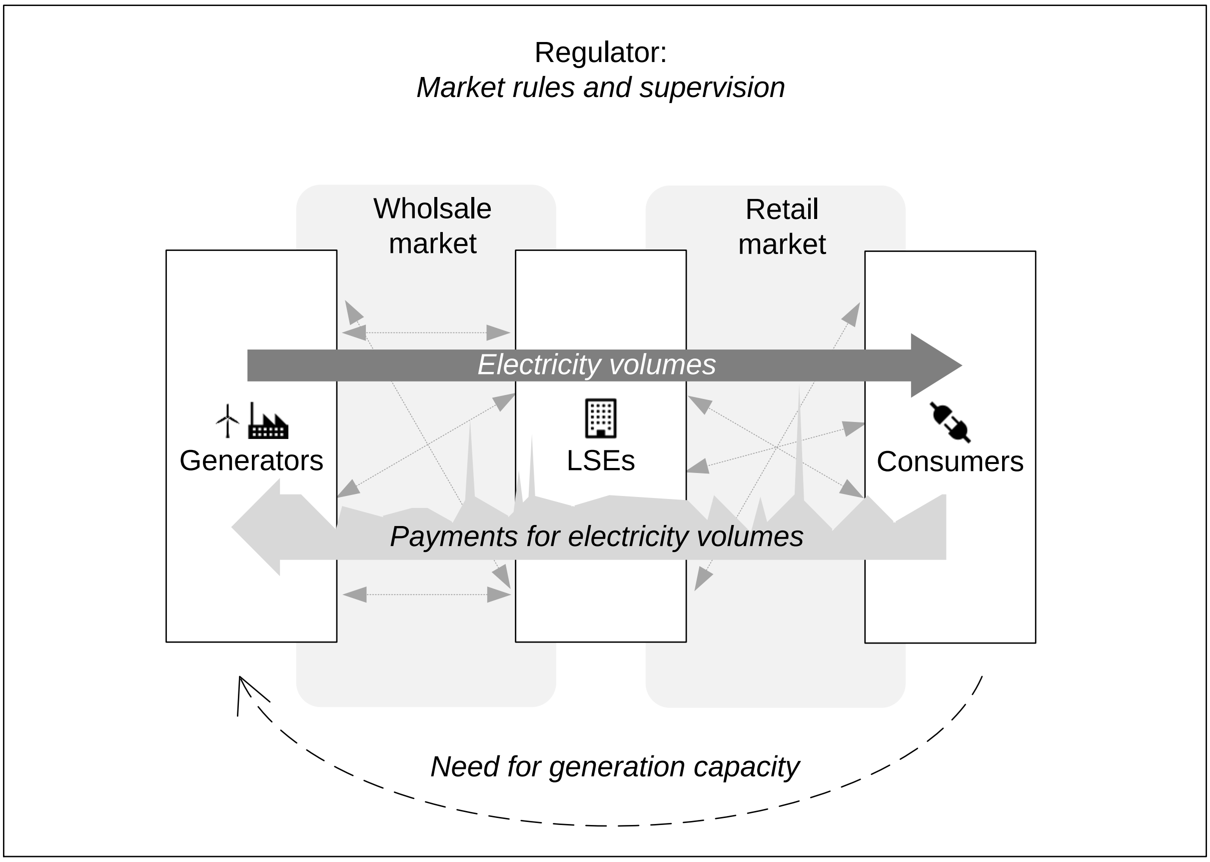

Figure 1: Basic EOM concept.[16]

Apart from the aspects described, it is highly questionable whether the basic mechanisms of the EOM are generally suitable for achieving socially desirable allocation and distributional results. Market mechanisms, in principle, can be of great help in appropriately allocating resources, if the conditions for a decentralised interaction of supply and demand side actors are convenient.[17] On real-life electricity markets, however, there is a wide range of factors that might cause persistent problems regarding the coordination between decision-makers.[18] The result is that evaluations of investment options from a social and from an individual perspective deviate. In accordance with this proposition, there is no indication or even evidence, neither theoretical nor empirical, that market outcomes in an EOM generally converge towards "optimal" results with respect to the provided capacity volumes.[19] Regarding the distribution of rents, it even is highly unlikely that generators receive an appropriate

[16] Own illustration. The lack of stable long-term relationships (vertical integration) between generators, LSEs and consumers in the EOM concept is depicted by the small, dashed arrows in the "Wholesale market" and "Retail market" boxes. The unconventional form of the "Payments for electricity volumes" labeled arrow is supposed to express the uncertainty of revenues for generation investors; for simplicity reasons, the illustration does not take account of risk transformation services that LSEs possibly offer to consumers.

[17] Cf. PÉREZ-ARRIAGA (2001).

[18] Cf. HOFFRICHTER / BECKERS / OTT (forthcoming) for a more detailed description.

[19] Cf. HOFFRICHTER / BECKERS / OTT (forthcoming), NEUHOFF / DE VRIES (2004) and CRAMTON / STOFT (2006). One specific issue in this context, which has received more attention in literature than other problems, is the occurrence of cyclic investment behaviour; cf. FORD (1999, 2002) and HARY / RIOUS / SAGUAN (2016).

level of remuneration. The amount of contribution margins for generation investors in an EOM is determined by the wholesale market's pricing mechanism. The highest marginal costs of all plants selected for dispatch at a certain point in time is set as the uniform remuneration per electricity volume for all operating plants.[20] Since there is no direct connection between the system's marginal production costs and the individual needs for contribution margins, the aggregate remuneration for most plant investors might diverge drastically from the risk adequate level (in both directions).

The expected market outcomes in an EOM also diverge from socially desirable results with respect to technological choices.[21] This applies in particular to the provision of RES-E plants, which can be attributed again to problems regarding the coordination of market actors; among other factors, the neglect of externalities and limited possibilities of generators to appropriate the full value created by their investments play a major role in this context.[22] Proponents of the EOM approach often suggest complementary instruments that aim at the internalisation of external costs, such as emission cap and trade mechanisms which we use as a representative example throughout the remainder of the analysis. Apart from improving the relative investment attractiveness of RES-E, such instruments hardly change the fundamental EOM mechanisms. Unless the emission reduction targets are extremely ambitious, a high uncertainty for investors usually remains. Furthermore, the instruments do not ensure a large-scale development of RES-E plants, since the choice of abatement options is left up to the market. It could generally be argued that this is a positive aspect of the mechanisms, which aims at identifying the most efficient abatement options. However, creating a competitive environment that takes account of all relevant differences between abatement options is very complicated and efficient results, especially in the long-run, are therefore unlikely.[23]

If generators − in contrast to the situation assumed before − do have significant market power, the situation differs significantly. Powerful suppliers are often capable of majorly influencing the terms of supply contracts and consequently able to pass on risks to demand side actors. In this context, many of the typical EOM problems related to investment uncertainty might not occur (or at least not to the same extent). The flipside of settings with limited competition can be seen in the appearance of typical monopoly and oligopoly problems, such as the appropriation of consumer rents by producers. These problems call for regulatory surveillance and potentially intervention, which is why the development of market power contradicts the fundamental ideas of the EOM concept.

2.2.1.2 The CRM concept

In the literature and in the debates on electricity sector design, the term "capacity remuneration mechanism" and similar terms (such as "capacity market" or "capacity instruments") are not used

[20] On a side note, the use of this pricing mechanism is also the reason for the widely discussed "Missing money problem", which is often seen as one of the main problems of the EOM approach. However, compared to the general, persistent problems related to investment uncertainty and the coordination between market actors, the "Missing money problem" seems to be of secondary importance. Cf. HOFFRICHTER / BECKERS / OTT (forthcoming).

[21] Cf. for instance HOFFRICHTER / BECKERS / OTT (forthcoming) and MEUNIER (2013).

[22] Cf. for instance NEUHOFF (2005).

[23] Cf. HOFFRICHTER / BECKERS / OTT (forthcoming), GAWEL ET AL. (2014) und GROSS ET AL. (2012).

consistently; they often refer to specific institutional mechanisms related to power plant investment and operation, substantially differing from case to case. In this working paper, when using the term "CRM", we refer to a broad category of organisational models for the provision of generation capacity which all have certain core characteristics in common (for a simplified illustration of an exemplary CRM concept, see Fig. 2):

- The regulator makes a (more or less detailed) decision on which plants or types of plants should be provided.
- This decision is implemented by (usually private) generators, who build and operate the plants according to the corresponding specifications provided by the regulator (which can be regarded as part of the CRM design); in this context the generators (explicitly or implicitly) enter into contracts with the regulator.
- The successful execution of the tasks is remunerated according to the rules laid down in the regulatory contracts. At least an essential share of the remuneration payments consists of relatively certain revenues that are not subject to great market risks.

More predictable contribution margins for investors possibly lead to substantially lower costs of capital, which is a major rationale for applying a CRM approach. Another potential advantage is that regulatory specifications regarding the use of generation technologies and the amount of capacity prevent discrepancies in the provided plant fleet and policy objectives. However, due to the electricity system's complexity, making reasonable decisions that lead to efficient results can be challenging. Sufficient centralised knowledge is a precondition in this context. This includes adequately sound information on the values and costs of alternative technical solutions regarding the generation mix as well as an advanced understanding of institutional mechanisms that are available as elements of the CRM. The better the regulatory framework is adapted to the needs of investment projects, the lower their costs. Due to the diverging characteristics of different types of generation projects (e.g. with respect to project lead times or the capabilities of operating plants), the individual needs vary considerably. Hence a differentiation of the CRM's requirements and rules to account for different project types can be very beneficial. For designing a properly differentiated instrumental framework, centralised knowledge is particularly important (this explicitly also applies to designing markets on which different technological solutions compete with each other).[24] When designing a CRM, it seems necessary to take account of the fact that part of the relevant knowledge is naturally held by the actors who practically develop generation projects. To incorporate this knowledge it is important to limit the scope of requirements and differentiation of rules to a reasonable level and leave the remaining decisions up to the actors who implement the regulator's targets.

[24] Cf. HOFFRICHTER / BECKERS / OTT (forthcoming).

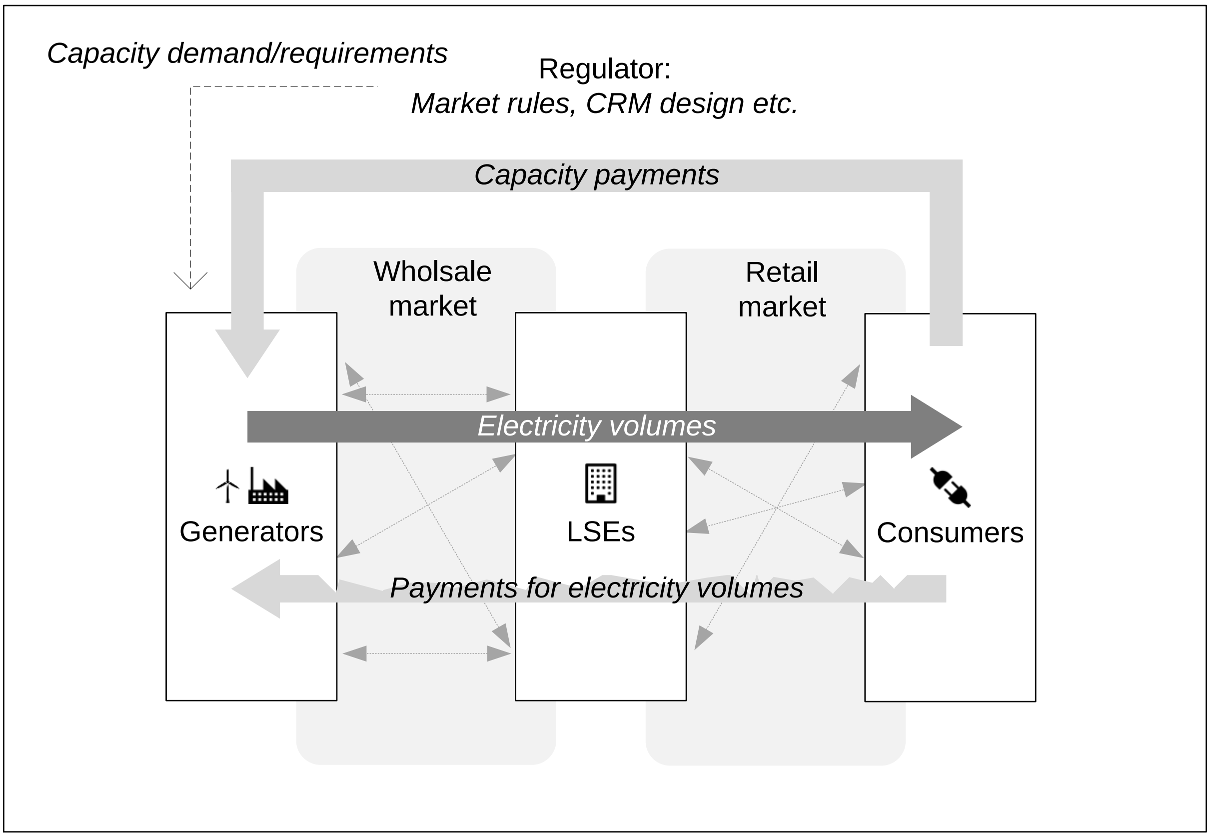

Figure 2: CRM concept (exemplary design).[25]

As pointed out already in section 2.1.4, transaction costs related to the design, implementation, monitoring and adaption of instruments must be included in a comparison of institutional solutions. On the one hand, each institutional framework requires a certain amount of regulatory action, even the most liberal market designs based on the EOM approach. On the other hand, the CRM approach involves a way more active role of the regulator and typically a more complex rulebook. Although the costs incurred in this context will often amount to significant volumes, it seems likely that they can be justified in many cases by the cost savings in generation investment.

2.2.1.3 Comparison of the EOM and the CRM concepts

In principle, the EOM approach seems to fit naturally into the idea of an internal electricity market. However, in combination with liberal wholesale and retail markets, it is a very unusual concept for the provision of durable, capital-intensive specific investments, exhibiting some structural drawbacks that, among other problems, lead to a high cost of capital. A properly designed CRM allows for generation investment at considerably lower costs. To which extent potential benefits can be realised highly depends on the knowledge of the regulator who is planning and administrating the set of instruments.

[25] Own illustration. The simplistic CRM concept depicted here features direct “Capacity payments” flows from consumers to generators; it would also be possible to involve LSEs as intermediaries. The smaller size of the “Payments for electricity volumes” arrow (compared to Figure 1) and the absence of spikes imply a CRM regime which limits the amount of revenues that generators receive for electricity sales.

2.2.2 Approaches to internal and cross-border grid congestion management

2.2.2.1 General issues and possible solutions

A second element of the institutional framework that we will refer to during the subsequent analysis of governance models is the approach to managing grid congestions. This topic has numerous facets and there are plenty of conceivable solutions, which we do not discuss exhaustively in the following. Instead, we focus upon a few selected issues and instruments.

Grid congestion is a common phenomenon in many power systems and most regulators do not in principle aim to completely eliminate it. Grid investment, operation and maintenance go along with significant costs. Besides, power lines, especially the large ones of higher voltage levels, might create negative externalities. Tolerating a certain amount of congestion is therefore often deemed a viable way to avoid excessive grid expansion measures. Existing congestions imply that it is sometimes necessary to depart from the rule of dispatching plants strictly in order of their marginal costs. How exactly this is done in practice depends on the applied procedure. In the following, we briefly outline two approaches, namely redispatch and the implementation of different price zones:

- **Redispatch:** One method of handling the congestion problem is the instrument of redispatch. This means that in a first step, market interactions between supply and demand side actors happen without taking account of transport restrictions. Whenever the market results are not compatible with the grid's transport capability, the production of some plants, in a second step, is replaced by the production of other plants (with higher marginal costs) on the other side of the transport bottleneck. This centralised process is usually managed − more or less manually − by the system operator (on behalf of the regulator) and carried out in a way that it affects market actions as little as possible.
- **Price zones:** Instead of adjusting the dispatch post hoc, it is possible to consider bottlenecks already before or while trade is happening. This can be done by defining different areas between which market prices diverge, whenever relevant congestion issues occur. Consequently, electricity prices decrease in areas with excessive production, while they rise in areas with limited possibilities of importing electricity from low-cost regions. The individual price zones can be determined by the regulator in advance as fixed regions with certain transport capacities in between, or as variable areas depending on current market and grid situations. Available transport capacity can be allocated to market actors, for instance, via explicit auctions. Another option is to consider network constraints during market clearing and adapt the local prices accordingly; the allocation of transmission rights happens implicitly in this case. The basic idea of subdividing market areas can be found in interconnected systems with large price zones that each consist of complete national countries (in such cases, complementary redispatch measures are often necessary). The other extreme would be to allow for different market prices at each node of the power system; this approach is usually referred to as locational marginal pricing (LMP) or nodal pricing.

As mentioned above, redispatch is typically supposed to explicitly not influence the decisions of market actors. This means the measure only solves problems in the short-run and does not contribute to avoiding future congestion issues. Price zones, by contrast, may affect the decisions of investors where to build new power plants, since high price areas generally promise larger revenues. It is, however, important to consider the impact of uncertainty in this context. The amortisation of power plants usually takes many years. The market and grid situations might change substantially over this time. Individual investors can normally not influence these developments at all. This leads to a high uncertainty regarding future regional price differentials, which reduces the impact on plant investors' locational decisions. While, for this reason, the effectiveness of steering signals is unclear, the additional uncertainty regarding achievable contribution margins further increases the cost of capital, when an EOM design is applied. Against this backdrop, some proponents of the LMP concepts suggest that it would be preferable to not confront investors with the risk of locational price changes in the first place.[26]

Ultimately it depends on the distribution of knowledge, whether influencing decentralised investment decisions is the best strategy to reach efficient results (that account for both generation related costs and grid related costs). While the impact of plant locations on grid related costs can be rather assessed by the regulator, plant investors sometimes have better information on generation costs differences. If the latter aspect is of minor important (i.e., the regulator knows the impact of plant locations on generation costs well enough), the regulator could simply decide where new plants should be built. If it is, by contrast, important to incorporate the investors' knowledge, incentive based schemes might be preferable. When a CRM is applied for the provision of power plants, it is relatively easy to complement it by such steering instruments. The compatibility with an EOM is rather questionable, since the regulator's role in making investment decisions increases significantly.

2.2.2.2 Special aspects in an international context

When discussing the topic of congestion management, interconnectors between countries are particularly relevant. Not only might national borders in interconnected power systems potentially coincide with grid bottlenecks; there are additional aspects that potentially matter in this context. These aspects include, inter alia, distributional effects (see section 2.1.3) as well as the impact of interconnections on a country's sovereignty over its national generation mix (we go into this issue in more detail in section 3.2.1.2.3). Furthermore, in case of relevant grid bottlenecks within the power system of a country, problems associated with transport restrictions might be exacerbated by cross-border electricity exchange. If any undesirable effects appear, countries might consider a limitation of the transmission capacity. Although there might often be reasons against taking this step, it can be argued that sometimes it might be a practicable solution to complex problems. There are several ways to impede cross-border effects and it depends on the individual circumstances in each case, which measures are suitable. In some cases adaptions of the institutional framework (e.g. a limitation of commercial flows between countries) can lead to the desired results, whereas in other cases

[26] This can be reached by issuing so-called financial transmissions rights (FTR) to generators. KUNZ / NEUHOFF / ROSELLON (2014), for instance, recommend to hand out FTRs free of charge only in a transition period after the introduction of an LMP approach.

alterations to the technical system are required. Sometimes both institutional and technical measures can solve the problems.[27]

3 Discussion of conceivable governance models for the provision of generation capacity in a union of states

3.1 Overview of the simplified analysis framework and corner solutions of governance models

Our goal in this section is to identify general findings regarding the suitability of governance models for the provision of generation capacity in an interconnected power system. As mentioned in the introduction, we do not refer to the current situation in any real power system. Instead, we detect and discuss interdependencies in a simplified model environment that play a role for determining which decision-making competences should be assigned to the supranational level, the national level or to the decentralised coordination of market actors. Our qualitative model framework features a union of states with (at least partly) interconnected national power systems. While we openly discuss different approaches for the provision of generation capacity − which vary with respect to their compliance with the EC's internal market ideas – we assume throughout the analysis that dispatch decisions are primarily based on the coordination of market actors (which does not preclude any necessary central redispatch measures). In order to systematise governance models for the provision of generation capacity, we start by using two dimensions:

- Centralised vs. decentralised market design; i.e., a uniform market design for all states established on the supranational level vs. decentralised competences to create national market designs
- Planning vs. competition: With these (intentionally simplistic) keywords, we refer to concepts for the provision of power plants that are either based on the EOM or on the CRM approach (as described in section 2.2.1) and thus they are characterised by a different distribution of decision-making powers between the (national or supranational) regulators on the one hand and market actors on the other hand

In a first step, we interpret these dimensions as binary variables, which leads us to the four options for governance models for the provision of generation capacity displayed in table 1 (which are referred to as "corner solutions" hereinafter):

[27] Recalling the example of excessive loop-flows in the power systems of Germany's eastern neighbours (see section 2.1.3), one solution that was discussed extensively was to split the uniform price zone of Austria and Germany into (at least) two parts to better align decentralised trade decisions with the reality of the grid. However, the acute problems were tackled in the end by installing phase shifters at the national borders to physically prevent the unwanted electricity flows. On a side note: It is, in principle, conceivable that the measures taken were partly or even predominantly based on motives other than the loop-flow problem (such as protecting domestic power instustries from competition); in this chapter, we do not discuss this issue in more detail.

	Competition	Planning
Centralised market design	**“Transnational EOM“** *International regulations, such as the competitive framework, are designed on the supranational level; investment decisions are made by individual investors based on market interactions*	**“Supranational CRM“** *Central planning on the supranational level*
Decentralised market design	**“National EOMs“** *National regulators design their own institutions (such as organised markets), which might consequently vary from state to state; investment decisions are made by individual investors based on market interactions*	**“National CRMs“** *Decentralised planning at member state level, including a possible coordination of individual actions by means of international contracts*

Table 1: Corner solutions of governance models for the provision of generation capacity.

In the subsequent section, we start our analysis by taking a look at these extreme corner solutions to carve out the most striking differences. Building on this, we adapt the restrictive assumptions and discuss more differentiated (and thus arguably more realistic) models.

3.2 Advantages and disadvantages of centralised and decentralised governance models

3.2.1 Assessment of corner solution models

In the following section 3.2.1.1 we take a look at the two corner solutions with a centralised market design approach. Afterwards, section 3.2.1.2 deals with the decentralised models. Apart from the two basic decentralised alternatives mentioned before, we discuss several variations of the corner solutions, because there are various conceivable cases which differ considerably with respect to the expected performance of the model.

3.2.1.1 Centralised market design decisions

3.2.1.1.1 Centrally designed competition: “Transnational EOM“

MODEL DESCRIPTION

In the “Transnational EOM” model all relevant decision-making powers related to the provision of generation capacity as well as to grid investment and cross-border power exchange are centralised. However, as far as the provision of generation capacity is concerned, the central planner only uses its authority to establish a competitive framework. The final investment decisions are decentralised and left to the market actors; i.e., generators invest in power plants based on their individual expectations on attainable contribution margins from future sales of electricity volumes.

When examining models based on the EOM approach, it is important to discuss the exact role of the regulator. In the following, we start by assuming a very pure application of the EOM ideas. This means that the regulator's only concern is to ensure effective competition, while regulatory specifications regarding the market actors' tasks are confined to a minimum.[28]

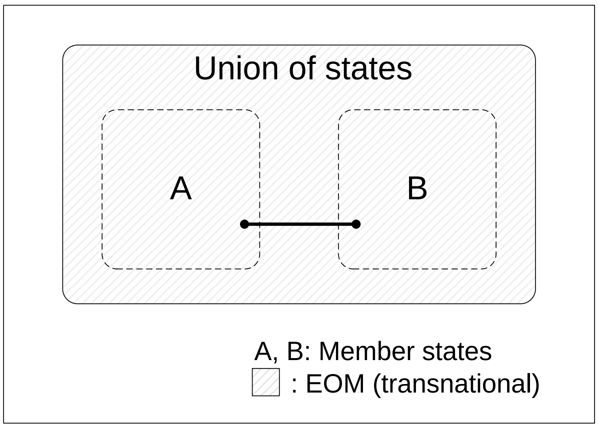

Figure 3: Model setup "Transnational EOM".[29]

MODEL ASSESSMENT

The desired main advantage of the EOM approach is to make full use of all dispersed knowledge and thus render superfluous any extensive regulatory involvement. The idea is that market prices guide generators to reasonable investment decisions with respect to the technologies and locations of power plants. In combination with cross-border trade between the national wholesale markets, which is facilitated by standardised operational procedures, investor decisions should ideally lead to a realisation of large portfolio effects regarding security of supply and RES-E production values. However, the importance of dispersed knowledge depends on the specific decision and situation. Sometimes a great share of the relevant knowledge is only available at a central level, thus there is no case for assigning the respective decisions to market actors in the first place. Generators typically have advantages with respect to knowledge of details on project development and implementation. As far as general questions (regarding, for instance, the provided aggregate generation capacity, the technology mix or the regional distribution of power plants) are concerned, central decision-making often seems more appropriate. But even in cases where decentralised decision-making is potentially conducive to efficiency, it does not always lead to desirable results (see section 2.2). Firstly, it is questionable whether EOM market signals comprise all information that is relevant with respect to costs and benefits from an overall system perspective. Secondly, in the light of an uncertain

[28] In the course of the assessment, we consider additional regulatory measures to take account of emerging issues, which lead to more moderate applications of the EOM concept that feature an advanced scope of centralised regulatory action.

[29] Own illustration. This simplistic depiction outlines the setup of the "Transnational EOM" model. The outer box represents the Union of states. The two boxes inside stand for individual countries (named A and B, respectively), whose electricity systems are connected, which is indicated by the line between the two countries. The country boxes are dashed because of the internationally uniform market design in the "Transnational EOM" model, which is characterised by the striped pattern fill throughout all boxes.

environment, market signals might not be powerful enough to influence investment decisions. And finally, effective coordination between large numbers of decentralised decision-makers in electricity markets is often hampered by transaction costs. This can lead to problems in the following areas (hereafter, the main aspects are presented in a condensed form; see section 2.2 – especially sections 2.2.1.1 and 2.2.2.1 − for more detailed descriptions of the underlying interdependencies):

- **Security of supply:** When applying an EOM approach, the provision of sufficient generation capacity might be endangered by the fact that virtually no actor or group of actors is directly responsible for resource adequacy.[30] The high revenue uncertainty discourages investments in general. Even if generators are, in principle, willing to undertake investments under such circumstances, it will be even harder in a "Transnational EOM" than in a single-country setting to make credible regulatory commitments not to interfere in situations of increasing scarcity and thus allow for high market prices and contribution margins. This would require that neither the supranational regulator nor individual states intervene when security of supply is at stake. In a union of states it is a common phenomenon that countries effectively opt out from mutual agreements as soon as they consider national interests − such as a certain security of supply level − threatened. Since national measures are likely to affect the functioning of the EOM's mechanisms across borders, it is particularly difficult for investors to trust in the credibility of commitments made on a supranational level. Consequently, the incentives to provide generation capacity further decrease. As described in section 2.2.1.1, centrally applied instruments like a strategic reserve could, in principle, serve to effectively tackle acute generation capacity shortages. However, they do not solve the general problems mentioned above. Moreover, the compatibility with the EOM approach is questionable.
- **Technology mix:** In a centrally designed and administrated EOM scheme, individual member states have little influence on which plants are used to serve the load. The disregard of national preferences might lead to certain problems, which we further elaborate on when discussing the "Supranational CRM" model, for which this aspect is particularly important. Apart from this, individual investment decisions in an EOM can generally not be expected to lead to a power plant fleet that serves the load at least cost, due to problems of coordination between decentralised market actors. In particular, this hampers the expansion of new technologies. In case of ambitious climate or other environmental targets in the union of states, somewhat EOM-compatible instruments such as cap and trade mechanisms might at first sight appear to be a suitable means for promoting a shift towards a low carbon generation system. However, the perceived advantage of fully incorporating all decentralised knowledge might not compensate for the drawbacks of the approach. The decision whether certain abatement options should be employed over the following years must be made based on the information available at that respective point in time. It can be assumed that market actors will

[30] As stated in section 2.1.1, in this paper we focus on resource adequacy when discussing security of supply issues.

rarely exclusively possess the bulk of knowledge needed for ranking alternative abatement options. Usually regulators will not be any less capable of assessing whether certain measures form an integral part of the solution. If, for instance, a large-scale development of RES-E plants is considered reasonable, there is no point in exposing RES-E investors to high risks, as is typically the case when the choice of instrument is focussed on EOM compatibility. The implementation of targeted instruments that create appropriate investment conditions for RES-E technologies seems highly preferable.

- **Spatial distribution of plants:** The spatial distribution of plants matters for the cost of electricity supply and system stability. The EOM mechanism itself does not convey any locational signals to generators. Against this background, in a large interconnected system there are, in general, particularly good reasons for an implementation of different price zones, which reflect network constraints. However, zonal or nodal prices are likely to be inadequate to induce decentralised investment decisions that substantially improve efficiency in the long-run; besides, the smaller the market areas are, the higher the danger of market power, which might lead to undesirable distributional effects. Ideally, zonal or nodal price differentials accurately reveal short-term grid constraints. This information, however, is usually insufficient for forecasting long-term price gaps, let alone the optimal distribution of plants across the system. In some cases decentralised investment choices might, in principle, create a need for a more direct regulatory influence on the spatial distribution of plants; on the other hand, such measures tend to contradict the core ideas of the EOM concept.
- **Distribution of rents between generators and consumers:** Rent distribution is a general issue in EOMs, since the market mechanisms by no means consistently lead to risk-adequate investment returns. Furthermore, the cases in which an EOM may function over a longer period usually involve sustained market power on the supply side, which implicates the typical drawbacks from the consumers' perspective. In a large interconnected system, there might also be a number of powerful suppliers (especially if there are different market areas with persistent transport bottlenecks in between). Since such a market environment is very convenient for powerful suppliers, they might aim at influencing the regulator to maintain the current framework. In a "Transnational EOM" with several local incumbents, it would make sense from a supplier's point of view to join forces and (also) represent the common interests collectively. It is not hard to imagine that under such circumstances it might be more difficult for the regulator to implement reforms that are reasonable from the consumers' perspective if they undermine the position of incumbent suppliers.
- **Distribution of rents between member states:** In the "Transnational EOM" model the rents of consumers and producers in individual countries largely depend on investor decisions. They result, for instance, from decisions on the location or on the technology of plants, both of which can not be influenced by member states. Undesired market outcomes might lead to a low acceptance of the applied approach by individual countries. Compensatory measures could generally be a way to resolve conflicts, provided that apparent disadvantages for certain

countries are acknowledged by the regulator or by the other member states. However, as we go on to discuss in the following section, meeting this condition is not easy in all cases.

To sum up, in a "Transnational EOM" the achievement of the underlying objectives is endangered by a range of significant potential problems. While some effective countermeasures are fairly compatible with the EOM approach, in other cases the basic principles of the model − especially the key role of independent investor decisions – are violated. Designing market structures or complementary instruments in order to guide investor decisions towards desirable outcomes could possibly be regarded as a somewhat hybrid solution. On the other hand, it often requires a deep centralised knowledge of the power system, market situations and institutional mechanisms. Under such circumstances more direct centralised planning usually seems preferable.

3.2.1.1.2 Centralised planning: "Supranational CRM"

MODEL DESCRIPTION

Just like in the model discussed before, the relevant decision-making competences are centralised in the "Supranational CRM" model. In this case, however, the supranational regulator uses its authority to make a large share of substantial planning decisions on the development of the power system by itself. Generation assets are provided by investors who receive remuneration payments according to the centrally established requirements, which are generally identical across national borders. In this context, it is usually conducive to efficiency to allocate certain selected risks to generators, but overall, the volume of remuneration payments is less uncertain than in the EOM model. The reasonable level of detail in the centralised system planning depends on the distribution of knowledge between the actors involved and thus varies from case to case (see section 2.2.1.2). This means that central decisions regarding, for instance, the usage of certain generation technologies or the spatial distribution of plants might sometimes be rather general (which leaves the implementing actors with more flexibility) and in other cases more specific (which means a limited scope of action for generators).

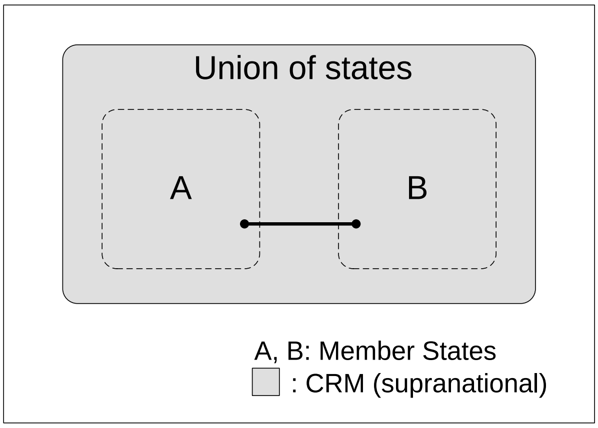

Figure 4: Model setup "Supranational CRM".[31]

MODEL ASSESSMENT

The possibility of performing an integrated system optimisation is a major advantage of centralised system planning. The central regulator can compare the costs of multiple generation and grid scenarios and identify the best solution without having to regard national borders as binding constraints. In this way, it is possible to directly include and realise portfolio effects related to the spatial distribution of power plants across the system. This applies both to security of supply issues and to RES-E infeed (see section 2.1.1). A further advantage with respect to security of supply is that free riding − unlike in decentralised models as we discuss below – is usually not a problem in a centralised CRM.[32]

A potential disadvantage of the "Supranational CRM" model is that a centralised optimisation might not take national differences adequately into account. For one thing, this applies to the design of the CRM's instruments (e.g., RES-E support schemes). The initial situations might differ significantly between the countries and one overarching instrument design might not be suitable in each case. Secondly, central decisions might not be able to meet diverging national preferences, e.g. with respect to the use of certain generation technologies or the desired security of supply levels. Furthermore, decisions on the supranational level often imply a certain distribution of costs and benefits between the countries, which can be the subject of criticism from the member states (see the discussion of the "Transnational EOM" model above). While in an EOM setting, member states might attribute undesired effects to the mechanisms of the chosen model and thus be rather willing to tolerate them up to an extent, adverse effects resulting from decisions by the supranational regulator may be more likely to arouse great resistance from the countries. Although it is generally possible to address such problems with corresponding centralised measures, an exhaustive compensation of all distributional effects within a large system is usually not feasible, because it goes along with significant transaction

[31] Own illustration. The solid grey fill of the boxes – as opposed to the striped pattern in Figure 3 – represents the system-wide CRM.

[32] Security of supply generally shows essential characteristics of a public good. In this context, individual states in an interconnected power system might be incentivised to minimise their own efforts in providing guaranteed generation capacity, if they can rely on other states to carry this burden.

costs.[33] But also a lack of compensation measures might induce substantial transaction costs if it leads to substantial resistance on the member state level against the supranational regulator's decisions.[34]

A crucial factor for the successful application of a "Supranational CRM" model is the knowledge of the central regulator. The more know-how and information the regulator has, the better he can make reasonable decisions with respect to system optimisation, instrument design and taking account of national specifics. Since usually part of the relevant information originally represents decentralised knowledge, the costs of centralising this knowledge can be decisive. In some cases the incorporation and operationalisation of decentralised knowledge will be a major barrier for the successful implementation of a "Supranational CRM" model.

3.2.1.1.3 Cross-cutting aspects and summary

There is a vast range of design options regarding the institutional framework for the provision of generation capacity. The suitability of certain institutional solutions is often not completely obvious beforehand, but partly revealed during practical application. The parallel application of several different approaches might therefore improve the knowledge on mechanisms and interdependencies. Since centralised governance models establish one specific standard, learning effects will typically be rather small and there is little room for institutional innovations. Especially in case of a high uncertainty with respect to the suitable institutional framework, "competition" between regional authorities might lead to lower costs than a repeated process of evaluating and adapting one common design.[35]

The analysis of the "Transnational EOM" model demonstrated various severe problems, which seem to outweigh the potential advantages over the "Supranational CRM" model. As a consequence of this, we do not further consider the "Transnational EOM" model in the remainder of this analysis. The "Supranational CRM" model has several potential advantages. But, firstly, they are subject to meeting certain preconditions and, secondly, there are also some clear disadvantages. Centralised decision-making on a supranational level generally allows for integrated system planning and thus the realisation of optimisation potential in an interconnected power system. Sufficient centralised knowledge is necessarily required for making reasonable planning decisions. The incorporation of dispersed knowledge by designing the right framework for actors who carry out decentralised tasks may be regarded as the key challenge. One potentially important problem in the "Supranational CRM" model is that the approach might fail in adequately taking account of national differences and distributional effects between the countries.

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[33] For a discussion of how external effects (or "spill-overs") can be taken into account using the fiscal federalism approach, cf. OATES (1999).

[34] Member states might, among other options, use their remaining national competences to impede the implementation of centralised decisions. In order to prevent, for instance, the development of new plant projects in its territory, a country could theoretically use (local) spatial planning or environmental instruments. Effective resistance, however, does not necessarily require the existence of national competences. Cf. in this context HIRSCHMAN (1970), who describes how the compulsory character of a collective is determined by the amount of existing "voice and exit options".

[35] Cf. the considerations on "laboratory federalism" in OATES (1999).

3.2.1.2 Decentralised market design decisions

3.2.1.2.1 Outline of the array of decentralised corner solutions

In the following, we discuss decentralised corner solution models, which are all based on the common principle that basically no decision-making powers are transferred to the supranational level. For simplicity we examine a model environment with only two neighbouring countries, whose power systems are physically connected. The national regulators have all relevant competences and may, regarding the national market design, each decide between a national system planning (national CRM) or a national EOM; if an EOM is applied, there are no additional instruments for the provision of capacity in that country. This leads to three possible settings:

(A) Both countries apply a CRM
(B) One country applies a CRM; the other one applies an EOM
(C) Both countries apply an EOM

Besides, we differentiate between settings in which the two countries actively cooperate with respect to electricity supply related decisions and settings with no such cooperation. In the following we assume that cooperating countries enter into more or less formalised interstate agreements for this purpose; especially in cases of good international relations, a coordination of actions sometimes works without explicit contracts. The alternative to active cooperation is that each country basically acts on its own without bilateral consultations. Since cooperation requires a consensus of both countries, there are only two alternative cases:

(0) No cooperation
(1) Cooperation

The combination of market design and coordination options results in six variations, which are displayed in the following table:

	(A) 2 CRMs	**(B) 1 CRM, 1 EOM**	**(C) 2 EOMs**
(0) No cooperation	A.0	B.0	C.0
(1) Cooperation	A.1	B.1	C.1

Table 2: Overview of the examined decentralised corner solution model variations.

In the subsequent sections we discuss the first model variations in more detail than the latter ones, because many interdependencies appear similarly across several model configurations.

3.2.1.2.2 Cross-cutting aspects

Before we take a closer look at the six individual cases, we outline two effects which are possible key reasons to engage in cooperations in the first place. These effects are related to the potential benefits of cooperation, as described in section 2.1.1, and play a certain role in all model variations:

- **Free rider problems:** The less transmission capacity between the two countries is restricted, the more features of a public good (with regard to the overall interconnected system) security of supply exhibits. The possibility to rely on capacity abroad in scarcity situations might compromise the willingness to make own investments in order to guarantee resource adequacy.
- **Realisation of cooperation benefits:** If free rider problems are ruled out but there is no cross-border coordination, both countries would independently build up electricity systems that allow for self-sufficient supply. Aligning national actions in consideration of the opportunities and plans in the respective neighbouring country, by contrast, offers cost-savings with respect to security of supply; the same applies to RES-E production (see section 2.1.1). Bilateral coordination theoretically allows for a system optimisation across national borders. However, as we show in the following sections, problems regarding the distribution of costs and benefits might sometimes limit the amount of achievable gains from decentralised cooperation.

3.2.1.2.3 Examination of variations of decentralised corner solutions

Model variation (A.0): Uncoordinated CRMs

In the case of two independently applied CRMs, the free rider problem described above might appear; i.e., one country might decide to save costs by relying on imports instead of providing sufficient capacity to cover its own load. Such behaviour can be prevented if the other country is able to unilaterally reduce cross-border transmission capacities and thus impede exports. Undesired effects might not only result from deliberate strategic behaviour, but also from a neglect of externalities caused in the neighbouring country. Individual countries might, for instance, not adequately consider loop-flows or − to give a more drastic example − potential damages in case of nuclear accidents, because they first and foremost consider effects on their own national goals (such as effects on national welfare or on internal rent distribution); it is possible in some, but not all, cases to inhibit such effects by taking unilateral actions. Similarly, potential positive cross-border effects (such as contributions to security of supply in the neighbouring country) are typically not fully taken into account if there is no active cooperation.

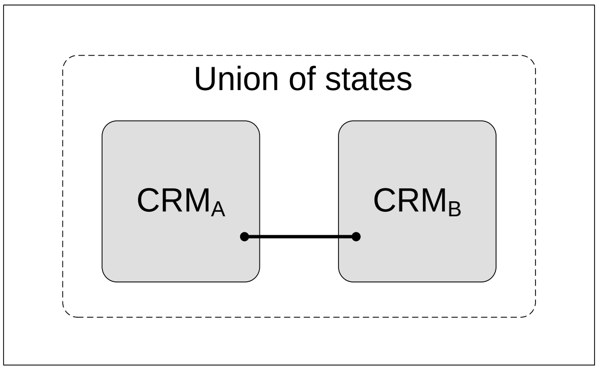

Figure 5: Setup of model variation (A.0): "Uncoordinated CRMs".[36]

If the existing interconnection capacity is used for electricity exchange, the countries partly forfeit their sovereignties over the national generation mixes, which are used to serve the load. Since the national merit-order curves are merged to a certain extent, investment and operational decisions in the respective neighbouring state influence how often certain plants are dispatched (see section 2.1.1). However, the possibility to decide upon the volume of cross-border flows enables the countries to prevent undesired external effects; this means they have the option to ensure that their national preferences are met. Considering the lack of active cooperation, it will be possible to realise portfolio effects (related to security of supply and RES-E infeed) only to a small degree in model variation (A.0). If one of the countries or both decide to restrict the use of existing cross-border capacities, the benefits from system interconnection will further decline.

MODEL VARIATION (A.1): COORDINATED CRMS

Active cooperation of the two countries in order to realise cooperation benefits might include joint planning regarding electricity supply and possibly an alignment of national CRM reglementations. In particular, the cooperation might comprise the following aspects:

- **Requirements on the provision of generation capacity in both states.**
- **Rules for cost and benefits sharing:** In some cases, the implementation of rules for cost and benefits sharing could be considered reasonable. This is particularly likely if generation capacity is distributed disproportionally between the countries (which might, for instance, be the result of cost-driven optimisation decisions). Furthermore, the countries might have an interest in arranging for the compensation of distributional effects that arise from the cooperation. However, the accurate detection and quantification of such effects will often be complicated and thus – especially when taking the corresponding transaction costs into account − not always feasible.[37] The same applies to further effects such as negative

[36] Own illustration. Since the decentralised corner solutions are characterised by national market designs (and an absence of a supranational scheme), the "Union of states" box is dashed now, while the country boxes have solid frames (the same applies to the following figures, which also portray variations of the decentralised corner solutions). CRM_A and CRM_B denote the individual CRMs of the respective countries.

[37] In a multi-country setting the complexity will be even substantially higher.

externalities related to the construction of power plants or positive externalities related to employment effects.

- **Agreements on the use of certain generation technologies.**
- **Implementation of a common CRM:** The countries could possibly also aim at implementing and operating a common CRM scheme, instead of applying two national mechanisms in parallel. In this case, there are numerous decisions to make and issues to solve, which we do not discuss in detail in this working paper.

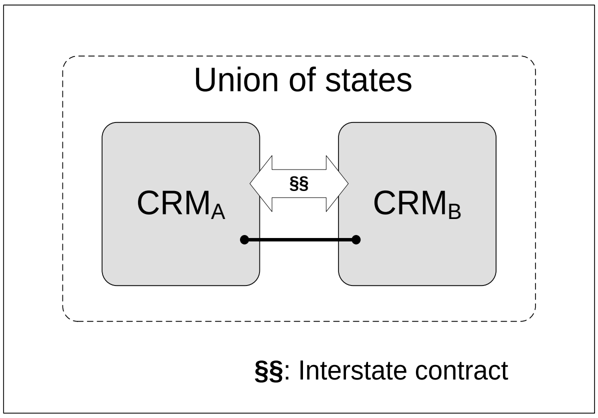

Figure 6: Setup of model variation (A.1): "Coordinated CRMs".

The listed aspects show that an ambitious coordination of national CRMs might go along with considerable transaction costs. Especially if cooperation entails complex effects and a fair distribution of costs and benefits is considered indispensable, the transaction costs might sometimes be prohibitive. Under such circumstances cooperation with respect to only certain aspects, which are not subject to major problems, seems quite feasible, although the amount of achievable cooperation gains decreases accordingly. In other cases the transaction costs might be only moderate. If the cooperating parties are generally on the same side concerning the most important topics of the cooperation initiative, reaching an agreement will usually be significantly easier (see section 2.1.4). Apart from this, mutual trust between the countries is very conducive to cooperation, as it might render unnecessary the inclusion of several aspects into the contract. Similarly, the countries could refrain from aiming at a very detailed and accurate distribution of costs and benefits if they are involved in numerous other economic or political cooperation projects which are based on the common understanding of a long-term welfare increase in both countries.

Model variation (B.0): One CRM and one EOM, no cooperation

If only one country applies a CRM while the other one is using an EOM scheme (without additional instruments that ensure domestic resource adequacy) and there is no active coordination, the appearance of free riding issues is particularly likely. When the typical EOM problems regarding security of supply (see section 2.2.1.1) materialise, they lead to a shortage in national power supply in the EOM country. These deficits also affect the neighbouring CRM country, since the national electricity systems and power markets are interlinked. If the CRM country does not want to restrict the cross-border transmission capacity, it has to consider the additional demand from the EOM country when dimensioning its own provision targets. It is theoretically conceivable that these interdependencies could be exploited by the EOM country in order to avoid costs of providing generation capacity domestically. Regarding any further aspects, the mechanisms are similar to model variation (A.0).

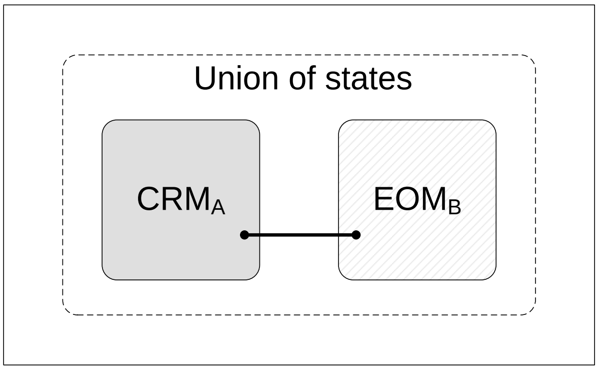

Figure 7: Setup of model variation (B.0): "One CRM and one EOM, no cooperation".

MODEL VARIATION (B.1): ACTIVE COOPERATION IN A SETTING WITH ONE CRM AND ONE EOM

International agreements on the provision of generation capacity are hardly conceivable in model variation (B.1). Such commitments are incompatible with a pure EOM scheme and will usually contradict the intentions of the EOM country. One way to realise cooperation benefits could be to open the CRM to plants situated in the EOM country. This could be especially reasonable if production conditions in the EOM country are favourable and allow plants to be built and operated at lower cost. When considering such a decision, it is important to be aware of the current and future cross-border capacity situation (as well as the situation regarding relevant hinterland transmission capacities). In case of restrictions to the capacities and availabilities of interconnectors (and hinterland capacities), plants abroad might not deliver the same contributions to achieving national goals as plants located on domestic territory.[38] Apart from cost advantages with respect to the provision of power plants, positive cooperation effects could arise from an increased level of competition in generation (for a schematic illustration of the model variation (B.1), see Fig. 8).

[38] Cf. HOFFRICHTER / BECKERS (forthcoming).

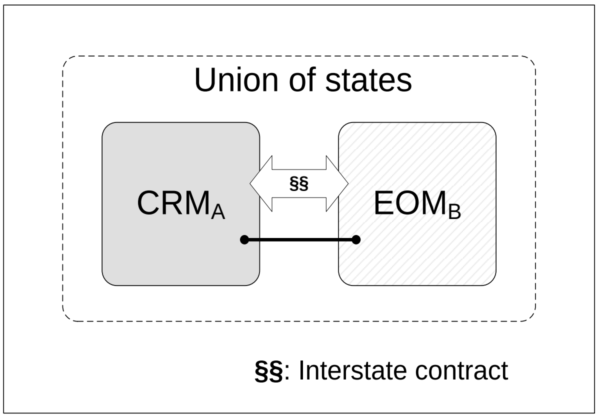

Figure 8: Setup of model variation (B.1): "Active cooperation in a setting with one CRM and one EOM".

Financing power plants abroad (instead of on domestic territory) has some implications for the distribution of rents; from the perspective of the CRM country, these effects might be positive in some cases and negative in others (see section 2.1.3). Furthermore, this setting leaves room for opportunistic behaviour of the host country; it could, for instance, impose a new tax on the plant's revenues during the operation period to appropriate a larger share of the rents.[39] If such behaviour cannot be ruled out in advance, the CRM country could be interested in impeding it by requesting an explicit cooperation contract which features corresponding rules. However, firstly, real-world contracts are practically always incomplete and, secondly, enforcing interstate agreements might sometimes turn out to be complicated.[40] If the achievable cooperation gains are high, such solutions might be worthwhile. In cases with only moderate efficiency gains from cooperation, by contrast, the proportionality of transaction costs that go along with such arrangements might be questionable.

MODEL VARIATIONS (C.0) AND (C.1): TWO EOMS

If both countries apply an EOM design, the possible advantages and disadvantages are very similar to the ones in the "Supranational EOM" model. In particular, this also applies to the potential appearance of problems with respect to security of supply, shortfalls concerning national preferences (since decisions are largely left to market actors) and especially cost efficiency; the decentralised EOM model, therefore, seems not considerably more suitable with respect to the underlying objectives than its centralised counterpart. However, the decentralisation of competences at least enables the countries to control the utilisation of cross-border transmission capacities and thus prevent problems

[39] To give another example of opportunistic actions, the host country could (unilaterally) limit the available interconnection capacity between the two countries to an extent that restricts the plants' possible contributions to electricity supply in the funding country**.** Economic theory also refers to such opportunistic actions as "creeping expropriation"; cf. for instance SAWANT (2010) and STEFFEN (2018), who both address this topic when discussing the role of project finance in international infrastructure projects. For concrete examples of retroactive changes to RES-E schemes in EU countries, which might be assessed as opportunistic regulatory actions against foreign investors, cf. FOUQUET / NYSTEN (2015).

[40] Cf. for in-depth analyses on the implications of incomplete contracts WILLIAMSON (1985), ALCHIAN / WOODWARD (1988) and TIROLE (1999) as well as HOFFRICHTER / BECKERS (forthcoming) for a more detailed presentation of the specific context addressed here.

in the neighbouring country from immediately spreading over to the domestic power system. In some cases it might also be reasonable to restrict the available cross-border exchange volume in order to avoid an aggravation of the situation if limited intra-country transport capacities constitute a problem (see section 2.2.2). In other cases, cross-border exchange might alleviate the problems and capacity restrictions would be counterproductive.

3.2.2 Summary

Both the centralised and the decentralised corner solution models show some obvious disadvantages, which can also be regarded as potential advantages of the respective opposite model. A major disadvantage of the centralised solution is the possible neglect of national preferences and circumstances. If decision-making powers are decentralised, the countries can design the institutional framework according to their own targets and local conditions. However, decisions in the neighbouring country do affect the domestic power system, unless countries are willing to completely prevent cross-border exchange and thus also forfeit a large share of the potential benefits of system interconnection. In the decentralised corner solution models, transaction costs of bilateral or multilateral coordination are an important issue, because their existence might prevent the countries from reaping potential gains of cooperation. Tackling the inherent free rider problem and appropriately considering cross-border effects represent further challenges. If there is a conducive transaction atmosphere between the countries, it might be comparatively easy to reach agreements; especially if the benefits of cooperation are large. In other cases, supranational measures might, in principle, be very conducive to increasing welfare across countries.

3.3 Determination of potentially suitable elements of a differentiated governance model

3.3.1 Using the advantages and avoiding or mitigating the disadvantages of the corner solutions

In section 3.2 we investigated corner solutions of governance models in an interconnected power system in order to make effects that arise from centralising or decentralising competences appear as clearly as possible. The obvious disadvantages in both cases strongly indicate that such corner solutions are basically unsuitable for practical application. This assessment very much corresponds to the fundamental rationales for applying federalist governance models in general and suggests that it is necessary to further differentiate when discussing the distribution of decision-making powers in a multi-level governance system. Thus the question to be examined is: Which specific competences should be centralised and which decisions should remain responsibilities of the national states in order to benefit from the respective advantages and to avoid or mitigate the respective disadvantages of centralisation and decentralisation?

Against this background, as a next step of our analysis, we derive a differentiated governance model with a targeted distribution of responsibilities between the supranational level and the national level. When conceptualising the model, we placed a special focus on consistency regarding the division of responsibilities across the relevant decision areas; the underlying considerations in this context are often not explicitly explained during the following discussion.[41] Nevertheless, the outlined governance model certainly does not represent the only solution, which, in comparison to a given benchmark, might promise improvements regarding the achievement of our assumed objectives (cost, security of supply and environmental objectives; see section 1). As a matter of fact, there are numerous conceivable combinations regarding the allocation of responsibilities and each solution might be more or less suitable, depending on the specific circumstances. With this in mind, our proposal for a differentiated governance model should be regarded as a basis for further discussions on the topic.

3.3.2 Transition of the corner solutions towards a governance model with a differentiated allocation of decision-making powers

Based on the examination of the corner solution models, we derive potentially suitable elements of a differentiated governance model. Our aim is to create a model which combines the advantages of the corner solutions, while avoiding or at least mitigating the disadvantages. As an intermediate step we consider certain modifications of the centralised and decentralised corner solution models which might alleviate the detected problems by adding certain decentralised and centralised elements, respectively. As stated during the course of our analysis in section 3.2.1, due to the inherent flaws of the EOM approach we limit the discussion to a CRM framework.

3.3.2.1 Modifications in order to reduce the disadvantages of centralised corner solutions

The examination of the centralised CRM model revealed the following critical aspects (which are partly interdependent or overlapping):

- Centralised solutions might neglect national preferences
- Standardised regulations might not adequately fit to the prevailing circumstances in each country
- Mechanisms established on the supranational level might go along with substantial distributional effects; redistributing rents between the countries – provided that it is desired – might entail high transaction costs
- The lack of direct involvement of the countries in decision-making might cause the need for an active centralisation of any essential dispersed knowledge, which results in additional transaction costs
- The establishment of one specific institutional standard is counterproductive with regard to the development of institutional innovations and determining the most suitable framework design

In order to take account of diverging local preferences and conditions, a differentiation of the rules and requirements could generally be reasonable. This assumes for one thing that the costs of acquiring the necessary information do not exceed the achievable benefits. Furthermore, the differentiation of

[41] The omission of the derivation of certain decisions is partly due to the fact that some selection decisions during the model conceptualisation process were not entirely based on insights from economic theory. Some selection decisions were majorly influenced by the authors' experience as well as input from other experts on the subject.

rules may not undermine the idea of a system-wide optimisation, which limits the extent to which the framework can be tailored to national circumstances. Similarly, an exhaustive compensation of distributional effects is likely to, firstly, go along with heavy transaction costs and, secondly, somewhat contradict the basic concept of the centralised approach. By contrast, compensating only very obvious and large effects to a certain extent seems fairly consistent with the approach and might in some cases be sufficient to significantly increase acceptance among the countries concerned.

More drastically modifying the centralised CRM model, the incorporation of decentralised knowledge could be institutionalised by transferring some competences regarding the provision of generation capacity to the member states. This means, although overarching and binding requirements concerning the CRM design would be made on the supranational level, the countries' regulators would have a certain scope for individual adaptions of the instruments and regulations. In such a governance model, the national regulators can be regarded as executive bodies that support the achievement of centrally established goals, while ensuring the adequate consideration of diverging local conditions. The suitable share and selection of decentralised decisions depends on many factors, not least the severity of problems in a setting with completely centralised competences.

3.3.2.2 Modifications in order to reduce the disadvantages of decentralised corner solutions

In section 3.2.1.2, we identified the following aspects as main problems of the decentralised corner solution models without cooperation:

- Large shares of the potential benefits from system interconnection, which often result from portfolio effects, are not utilised
- Since ensuring security of supply in an interconnected power system exhibits features of a public good, there are certain incentives for individual countries to pursue free riding strategies; preventing such strategies by inhibiting cross-border exchange comes at the expense of system interconnection benefits
- Individual countries tend to not fully take negative or positive cross-border effects into account on their own initiative

In some cases, a decentralised coordination of the countries involved might solve problems. Often, however, reaching interstate agreements does not come without substantial transaction costs; sometimes they might largely outweigh or even overcompensate the achievable gains. Whereas above we examined a setting with only two countries, complexity and transaction costs of decentralised coordination can be expected to considerably increase when a larger number of states are involved.

The (voluntarily) realisation of cooperation initiatives could be promoted by a set of overarching rules established on the supranational level. Such an approach could make it possible to reap a large share of the benefits from system interconnection without imposing obligations on the member states that might conflict with national conditions, goals and preferences. The supranational regulator could, for instance, design a framework for decentralised coordination which offers standard procedures for the determination and sharing of costs and benefits that result from joint initiatives. This would narrow down the scope for manoeuvre countries have in bilateral or multilateral negotiations and thus possibly reduce complexity, which potentially decreases transaction costs and, at best, makes the achievement of agreements more likely.[42] The establishment of binding standards for costs and benefits sharing should, however, be carefully considered, as such specifications might exclude possibly reasonable solutions which lie beyond the limits imposed by the central regulator. Moreover, distributional effects that result from cooperation are often generally difficult to measure and, therefore, designing an appropriate framework might not be a trivial task.[43] Apart from establishing a framework for decentralised coordination − and possibly in addition to this − the supranational regulator (or other supranational institutions) could function as an arbitrator, helping to avoid and resolve disputes between cooperating countries. The existence of such a neutral institution might especially encourage the realisation in cases with significant uncertainties regarding the behaviour of the opposite contracting party.

Externalities could be dealt with very similarly to the described way of handling distributional issues. This means for instance, that standards for the determination and evaluation of effects could be established on a central level. In some cases, it might be worthwhile to address the problems more directly by imposing regulations that decrease the generation of negative externalities or promote the generation of positive ones. However, measuring and attributing externalities to a specific originator is sometimes very challenging in principle; in such cases decentralised coordination might be indispensable.

In order to avoid inefficient redundancies and prevent free riding, increasing the degree of centralisation with respect to decisions on the provision of guaranteed capacity in each country could also be considered. This means that the supranational regulator would set and control individual capacity targets to ensure security of supply as well as adequate contributions of each country; in some cases, transferability of the obligations between the countries might allow for cost reductions. In contrast to a centralised CRM, designing the national institutional frameworks for the provision of power plants, on the basis of which the individual targets are pursued, would remain the countries' responsibility, leaving room for adapting the instruments to the respective local circumstances.

3.3.3 General considerations concerning the creation of regions as an intermediate level

Many of the described problems regarding centralised (supranational) decision-making as well as decentralised coordination between individual sates increase when a higher number of countries are involved. Against this background, establishing an intermediate regional level for decision-making

[42] Cf. HOFFRICHTER / BECKERS (forthcoming).

[43] KONSTANTELOS ET AL. (2017) for instance, suggest applying the so-called "positive net benefit differential" (PNBD) method for the distribution of costs and benefits of collaborative initiatives. For further considerations regarding methods for the identification and sharing of costs and benefits from collaborations on electricity supply (although primarily with respect to grid investment), cf. BUSCH (2017) and FLAMENT ET AL. (2015).

could be helpful for handling some of the issues. This means that the coordination of certain essential matters would be assigned to regional groups of countries with a limited number of members. This might, on the one hand, allow a large share of the potential gains from cooperation to be realised while, on the other hand, significantly decreasing the complexity of coordination compared to a union-wide system optimisation. Successfully reducing problems of coordination, and thus transaction costs, requires a suitable partitioning of regions based on the problems' causes. Since, for instance, diverging national preferences may be a barrier to cooperation, more or less homogeneous goals among the countries (e.g., with respect to the use of certain generation technologies or the aspired security of supply level) within one regional cluster might be conducive to success. Besides, similar national circumstances make it easier to find adequate reglementations which suit the initial situations in all countries sufficiently well. Furthermore, the transaction atmosphere between the countries should be taken into account when defining regional clusters, because it plays an important role with respect to the difficulty of negotiations (see sections 2.1.4 and 3.2.1.2.3).

In cases of substantial problems of coordination between different regions, there might be reasons to limit external electricity exchange capacities in order to avoid complex interdependencies. Whereas a complete separation of electricity networks will hardly ever be a worthwhile option, a targeted manipulation of cross-border flows might sometimes represent a pragmatic solution (see section 2.2.2.2).

The introduction of regional clusters is possible in an originally rather decentralised governance model (i.e. bottom-up) as well as in cases in which decision-making powers are largely centralised (i.e. top-down). Consistently pooling competences on a regional level requires commitments by the countries involved to comply with the common cooperation framework and contribute to the achievement of the underlying common goals on a long-term basis. This implies that national states partly waive their sovereignty regarding future decisions.

Regional cooperations can benefit from support from the supranational level, which could, for instance, aggregate and provide knowledge or promote and coordinate interregional collaboration.

3.3.4 Compilation of potentially reasonable building blocks for a well-differentiated governance model

Based on the considerations heretofore, in this section we present a selection of building blocks for a differentiated governance model (regarding the distribution of competences) in an interconnected power system that might be suitable with respect to the underlying objectives.

Regarding the achievement of environmental and RES-E targets, the institutional framework could feature the following elements:

- If countries in a union of states agree on certain environmental goals, the introduction of binding national targets could be reasonable in order to establish firm commitments and avoid free riding behaviour.

- To increase allocative efficiency through cooperation, it might be worthwhile to allow countries to have their national obligations partly fulfilled by other countries (which consequently would have to overachieve their own targets).
- To take account of diverging national circumstances and preferences, it could be advisable to generally leave the selection of abatement options to the countries. Centralised cross-sectoral mechanisms, such as typical cap and trade schemes, seem compatible with this criterion, since participants usually largely maintain flexibility. However, they are inadequate as a framework for generation investments.
- Extending RES-E capacities can be regarded as a key measure in achieving environmental policy goals in the electricity sector. National regulators are usually well able to assess which contributions RES-E extension measures, among their portfolio of domestic actions, can add to the achievement of national targets (in the majority of developed countries these contributions are assessed to be fairly high). Against this background, it could be reasonable to also specifically agree on binding national RES-E targets (instead of, for instance, only CO_2 abatement targets).
- The national regulators should be free to individually apply targeted instruments which create an adequate environment for RES-E investment.
- If national RES-E instruments are used in parallel to a cap and trade mechanism, it seems important to rule out any negative repercussions enhanced RES-E expansion might have on the CO_2 abatement efforts in other sectors by eliminating any such interdependencies.

Regulations with respect to arrangements for achieving security of supply and certain generation mixes could be based on the following considerations:

- Centralised generation capacity planning or joint planning accompanied by centralised measures, featuring a transnational adequacy assessment, is likely to be beneficial with respect to the underlying objectives. Firstly, a coordinated approach to the provision of plants prevents strategic behaviour and ensures appropriate contributions by each country. Secondly, the costs of attaining the security of supply objective probably decrease due to portfolio effects.
- The idea of coordinated planning could be implemented in a way that countries individually commit to providing a certain amount of generation capacity within their power system, which (on aggregate) meets certain quantitative and qualitative requirements regarding reliability and flexibility. Similar to the case of RES-E plants, a transferability of these obligations could possibly enhance allocative efficiency while achieving a fair cost distribution.
- If regulators know sufficiently well how measures to steer the generation mix contribute to emissions abatement, it could make sense to also address the non-renewable part of plants separately (instead of only including it in a cross-sectoral mechanism, leaving final decisions up to investors).
- There are good reasons to make the design of the institutional frameworks for the provision of plants which guarantee security of supply a national responsibility. However, certain

restrictions on the countries' decision-making scope could be reasonable in order to prevent actions that endanger or contradict common goals. In this way, dispersed knowledge would be directly incorporated into the decision-making process and national states could make sure that their preferences are met; yet another advantage is that applying several differently designed mechanisms in parallel allows a more exhaustive realisation of learning effects.

- In cases in which national preferences – for instance with respect to the desired security of supply level or the use of generation technologies – diverge substantially, it seems necessary to limit cross-border power exchange, because otherwise interdependencies are unavoidable.

When considering measures for the promotion of international cooperation, the following aspects should be taken into account:

- Supranational institutions can play a useful role by offering a general framework for cooperation between countries as well as specific support of voluntary cross-border cooperations in the electricity sector. Possible measures include, among others, the centralisation and provision of knowledge which is relevant for the implementation of cooperative initiatives or the development of standard procedures for determining and sharing the costs and benefits arising from cooperations between the countries involved.
- Especially in case of large international unions, forcing cooperations might be rather more detrimental than conducive to the achievement of the underlying objectives. Since the initial situations in individual countries often diverge, cooperations are not reasonable in all cases.
- Similarly, compulsory requirements to enhance cross-border exchange of electricity (by extending interconnection capacities or increasing their utilisation) seem questionable for several reasons. They undermine, for instance, the countries' sovereignty regarding the use of certain generation technologies and tend to increase the size of possible undesirable distributional effects and externalities.
- If enhancing the trade of electricity between countries is considered highly desirable, it generally makes sense to take measures on a supranational level in order to prevent distortions. When implementing such measures, it is important to always take all further aspects (apart from the functioning of international trade) that are relevant to the underlying objectives adequately into account.
- In order to facilitate the realisation of cooperative initiatives within a large international union, creating regional clusters for the coordination of countries might sometimes be a helpful step; ideally, decisions on an intermediate level combine the advantages of centralised and decentralised decisions.
- Another potentially reasonable measure could be to provide centralised funds, which are used to promote the realisation of cooperative projects which lead to an improvement regarding the underlying objectives.

4 Comparison of the findings to the EU status quo

In this section we discuss selected aspects of the current status quo in the EU regarding the allocation of decision-making competences with respect to electricity supply and existing regulations established on this basis as well as currently considered change proposals. Whereas the conceptual considerations in the previous sections assumed very simplistic governance models, it is important to notice that laws in the EU are certainly not made in strictly top-down organised processes and imposed on the member states. Quite the contrary, many EU bodies are composed of elected representatives from the member states. Having acknowledged that the transfer of decision-making powers to the European level still goes along with a certain loss of authority; partly because a large share of decisions on the supranational level do not require unanimous votes (which, given the size of the union, could arguably be regarded inevitable for a functional legislative process). For simplicity reasons, we do not consistently make any such differentiations in the following, but focus on the fact that decisions on the EU level could possibly conflict with national positions.

The construction of the EU itself can be regarded as a very suitable platform which facilitates reaping the benefits from international cooperation. Also, do parts of the prevailing governance model generally match with the findings from our analysis; some aspects, however, clearly do not conform to our suggestions. This implies room for improvement and indicates that initiating corresponding reforms of the institutional framework might be worthwhile.

Similar to the structure in section 3.3.4, in the following two subsections we first discuss the institutional framework for the achievement of environmental and RES-E targets, followed by considerations regarding instruments for achieving security of supply and a certain generation mix. In contrast to the previous section, the discussion on centralised measures to promote cooperation is directly included into these two blocks.

4.1 Institutional framework for the achievement of environmental and RES-E targets

RES-E EXPANSION PLANNING

The Renewables Energy Directive (2009/28/EC) established the target of covering 20% of final energy demand from renewable sources by the year 2020. This overall target is broken down to (diverging) national targets, which are backed by national renewable energy action plans that demonstrate the steps countries intend to undertake in order to meet their individual goals. Although the common EU target is considered binding, there are no immediate sanctions in case of failures. The EC’s legislative proposal „Clean Energy For All Europeans“(usually referred to as the “Winter Package”) presented in November 2016 and comprising a wide range of actions which, on aggregate, can be regarded as main guidelines for future European energy policy, announced an abandonment of binding individual

RES expansion targets.[44] The proposal for a revised Renewables Energy Directive contains the member states' agreement to reach a 27% renewables share by 2030 on an aggregate EU level. Unlike overarching RES goals, specific goals for the share of RES-E in electricity production have never been implemented on the supranational level in the first place. This can be regarded as generally consistent with the cap and trade mechanism applied in the EU (Emissions Trading System/ ETS), which limits the aggregate emissions including electricity production and several other sectors. As described above, creating a suitable investment environment for RES-E plants requires additional, targeted instruments.

NATIONAL MECHANISMS FOR THE PROVISION OF PLANTS

Member states in the EU are generally free to apply national mechanisms for the provision of RES-E plants. It could be regarded as a design flaw that the RES-E expansion induced by these instruments does not directly affect the emission cap.[45] The EC has to approve national RES-E instruments, which means their designs have to comply with certain standards of state aid law. A major problem in this context can be seen in the concrete specifications of the European regulation, which have a dominant focus on preventing disruptions of the internal market. Broadly speaking, the requirements tend to favour instruments that allocate a larger share of decisions and risks to investors over more selective instruments with moderate investor risks.[46] This practice neglects that − provided national regulators have the required knowledge − well-differentiated institutional frameworks, tailored to the needs of different generation technologies, have a significant potential in reducing the cost of providing power plants.[47] Against this background, the European requirements regarding RES-E instrument design are likely to decrease instead of increase efficiency in many cases. Indications that the EC seems to gradually refrain from the idea of coercing a comprehensive harmonisation of national RES-E schemes, could be regarded as a silver lining in this context.

INTERNATIONAL COOPERATION ON RES-E PROJECTS AND CENTRALISED SUPPORT

Developing the internal market, there are also actions on a supranational level to promote a coordinated provision of RES-E plants. Firstly, member states may involve in voluntary collaborations applying one of the cooperation mechanisms as outlined in the Renewables Energy Directive (2009/28/EC); namely statistical transfers, joint projects and joint support schemes.[48] Secondly, the

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[44] According to the EC proposal, member states shall − instead of committing to binding targets established on the EU level − define their own targets within their national action plans. The determination of national RES targets shall follow the procedure described in Articles 3-5 and 9-11 of the so-called Governance Regulation (see COM(2016) 759 final).

[45] Compare the corresponding suggestion in section 3.3.4.

[46] Technology-neutral instruments are, for instance, preferred over technology-specific instruments; seemingly more market-oriented schemes, such as market premiums, are preferred over schemes that apparently feature more administrative decisions, such as feed-in premiums. While the overall suitability of provision mechanisms ultimately highly depends on a large number of detailed design decisions, banning generally suitable concepts does certainly not help.

[47] Cf. HOFFRICHTER / BECKERS / OTT (forthcoming).

[48] In this paper, we do not examine the three EU cooperation mechanisms, but instead refer to the existing literature which is specifically dedicated to this topic or analyses it in more detail; cf. for instance

EC urges member states to (partly) open their national RES-E mechanisms to plants situated in neighboring countries. According to Article 5 of the "European Commission legislative proposal to revise the Renewable Energy Directive" member states shall grant generators abroad access to at least 10 and 15% of the volume of newly commissioned RES-E plants in the periods between 2021 and 2025, and between 2026 and 2030 respectively. Apart from the internal market motive, these measures are also supposed to achieve potential efficiency gains related to a cross-border approach in the provision of plants.

In the light of the considerations presented in this analysis, obliging member states to open their national provision schemes seems rather detrimental than conducive to the achievement of the underlying objectives. Such general requirements could lead to the implementation of forced cooperative initiatives which, especially when taking transaction costs into account, do not promise net benefits. Moreover, the involvement of neighboring states might sometimes interfere with the achievement of certain national targets and therefore potentially undermine the sovereignty of countries to freely decide upon which generation technologies are used to supply electricity (this right is enshrined in primary EU legislation and was strongly affirmed by the European Court of Justice in its judgment of the famous "Ålands vindkraft" case in 2014).[49] It can be assumed that cooperative projects are realised anyway, if the potential benefits from cooperation are particularly large; this also implies that transaction costs are low, for instance due to similar policy goals or a convenient transaction atmosphere (see sections 2.1.4 and 3.2.1.2.3). There are many examples of successfully established electricity related cooperations in the EU that were established bottom-up (i.e., on a member state level).[50] Unlike mandatory requirements, the supranational promotion of voluntary cooperation between member states might help overcome barriers to the realisation of generally reasonable projects and thus support the overall objectives' achievement.[51]

There are several EU programmes that offer financial support to electricity supply related projects which are considered highly important for the interconnected power system. Whereas grid projects may receive grants which directly contribute to the investments' amortisation (see the following section for a more detailed discussion), such measures do not exist for generation projects. The European Investment Bank (EIB), however, provides loans and other financial instruments as well as advisory services for certain generation projects. Although there are, in principle, good reasons to also support

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Klessmann et al. (2010), Pade / Klinge Jacobsen (2012), Pade / Klinge Jacobsen / Skovsgaard Nielsen (2012), Klinge Jacobsen et al. (2014) and Konstantelos et al. (2017). For an analysis of general challenges in international RES-E cooperations cf. Hoffrichter / Beckers (forthcoming).

[49] The court's ruling in the case C-573/12 „Ålands vindkraft AB v Energimyndigheten" denied generators located in one member state a general right to participate in the provision scheme of another member state (even if the plants exclusively feed into the grid of that country). The rationale of the judgement highlighted, among other things, that the freedom of individual countries to pursue their own environmental goals might be compromised by a guaranteed access of plants based abroad.

[50] The "Pentalateral Energy Forum" and the "North seas energy cooperation" are, for instance, initiatives for the collaboration on electricity supply that were founded by member states. The "North Sea Wind Power Hub" collaboration is driven by the initiative of several national transmission system operators (TSOs).

[51] Cf. Hoffrichter / Beckers (forthcoming).

(positively assessed) cooperative generation projects with grants, the introduction of such measures seems hardly viable as long as European electricity policy decisions are dominated by internal market aspects.

4.2 Instruments for achieving security of supply and a certain generation mix

RESOURCE ADEQUACY PLANNING

Resource adequacy planning is a predominantly national matter in the EU and there are no provisions on the supranational level that lead to an intense coordination of member states;[52] such agreements can only sporadically be found on a state-to-state basis.[53] Enhancing cooperation generally promises cost reductions with respect to achieving security of supply targets. In the longer term, it could even be worthwhile to pursue the establishment of binding commitments by member states to individual resource adequacy contributions; transferrable obligations allow for more flexibility and thus potentially efficiency gains. A precondition for such an approach is that there are clear rules for cross-border grid capacity management in place, which, one the one hand, ensure that generation capacity abroad can be accessed when needed and, on the other hand, respect national preferences. Given the great heterogeneity in the EU, such measures might be rather feasible within limited geographical areas than on a union-wide scale.

NATIONAL MECHANISMS FOR THE PROVISION OF PLANTS

For the purpose of decreasing CO_2 emissions (and other environmental damages), several EU member states take measures to transform their fossil-fuel power plant fleets. The Winter Package proposes that countries should be allowed to voluntarily withdraw emission allowances from the ETS system in such cases in order to avoid negative repercussions. This can be seen as a positive development. Consistent next steps could be to move over to an automated removal of certificates, or even to country-specific CO_2 reduction targets in electricity production.

Similar to the case of RES-E schemes, the European regulation significantly restricts the countries' scope of action regarding the choice and design of mechanisms for the provision of plants that are supposed to ensure security of supply; also, the Winter Package proposes a mandatory opening of national mechanisms in this area. The strong focus on internal market motives on the European level results in a preference of seemingly market-based mechanisms and in a discrimination of many variations of the CRM model that would actually have the potential of effectively solving resource adequacy issues in a cost-efficient manner. Overall, the currently applied practises in this area are highly questionable and should be fundamentally revised.

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[52] The European association of TSOs, ENTSO-E, is annually gathering generation adequacy forecasts from its national member TSOs which are merged into the union-wide Scenario Outlook & Adequacy Forecast (SO&AF). This process could, in principle, be regarded as some form of coordination on a supranational level with respect to generation capacity planning. But in fact, there are no direct interdependencies, since the results do not oblige member states, let alone individual generators, to adapt their generation investment plans accordingly.

[53] Finland and Sweden, for instance, coordinate the provision of reserve capacity.

UTILISATION AND EXTENSION OF INTERCONNECTION CAPACITIES

Since the possibilities to steer the technological generation mix (which is supplying domestic demand) are affected by the situations at national borders, from a country's perspective it can sometimes be desirable to restrict cross-border exchange. As described above, apart from the sovereignty over the generation mix, reasons for this can be found, for instance, in the limitation of distributional effects and the desire to maintain existing price zones in the domestic market. In the EU, the member states' sovereignty is restricted by centralised decisions concerning the provision and usage of interconnection capacities. Regarding the usage of existing interconnection lines, at this point in time countries may generally determine to which part their cross-border capacities are used commercially (this task is often exercised by local transmission system operators). However, it is generally not allowed to limit the available transmission capacity for the purpose of preventing an exacerbation of transport issues within the national grid (see section 2.2.2.2).[54] Moreover, the Winter Package envisages the introduction of so-called Regional Operational Centers (ROCs), to whom the authority over the determination of available interconnection capacities within the corresponding region shall be transferred; besides, these entities would be entitled to determine national reserve capacity requirements. While greater regionalisation seems like a generally reasonable approach to reap the benefits of coordination (see section 3.3.3), further restrictions of the national sovereignty regarding the management of cross-border capacities seem problematic. Apart from the reasons mentioned above, increased complexity of the allocation of decision-making powers between the national and the regional level result in complications regarding the management of grid related problems (especially when they occur suddenly).

The extension of existing interconnection capacity is an explicit EU goal; however, there are no mandatory requirements for member states. The European Council, already in 2002, agreed on a 10% interconnection target (i.e., cross-border capacities should at least equal 10% of the installed generation capacity in each country), but several states failed to reach this target by the originally envisaged deadline in 2005; the deadline was eventually postponed to 2020. After the member states renewed their commitment to the 10% 2020 target in 2014, the EC suggested a complimentary 15%

[54] To give an example, the German TSO TenneT (which is a subsidiary of the national Dutch TSO of the same name) has been limiting the commercially available cross-border transmission capacity between Germany and Denmark in order prevent the necessary amount of redispatch from further increasing (grid congestions frequently occur during times of strong winds in northern Germany where wind power plants are majorly located; for one thing, transmission capacity from north to south is limited; for another thing, conventional base-load plant operators do not always have incentives to reduce the level of production in each of those situations; thus, a large-scale import of power from Danish wind power plants would increase the problem). In view of these processes, the EC recently opened a formal investigation into TenneT, to determine whether EU antitrust rules were broken (i.e., whether non-German generators were discriminated against by the cross-border capacity limitation). Given the actual presence of grid bottlenecks within Germany, removing the artificial limitation of imports would lead to an increased need to redispatch plants (which means producing electricity with a higher consumption of resources) or potentially increased reductions of wind power production (with marginal costs close to zero). The problem could, theoretically, also be solved by splitting the German market into two or more price zones; the German government, however, strongly opposes this step for several reasons. Another way of significantly alleviating problems would be to actively reduce the amount of conventional "must-run" capacity in Germany.

target for 2030, which was endorsed by the member states.[55] In 2017 the EC proposed a further differentiation of the 15% target by adding more specific thresholds, which should indicate the need for increased efforts.[56] The implementation of cross-border capacity extensions is promoted by financial support from centralised funds. Interconnection projects are particularly likely to be approved as Projects of Common Interest (PCIs), which may apply for funding provided under the Connecting Europe Facility (CEF) programme; apart from this, support for cross-border projects may be received from further programmes.[57] In the light of the consideration presented in this working paper, it seems reasonable that there are no top-down instructions for member states to reach mandatory interconnection targets. Given the general consensus among member states on this topic, encouraging the extension of exchange capacities seems conducive to the underlying objectives; especially since it might improve the degree to which portfolio effects are realised. Furthermore, the co-funding of grid projects with a large value to the system (from an overall perspective), is also consistent with our findings.[58]

5 Summary and conclusion

The aim of the institutional economic analysis presented in this working paper was to, firstly, determine and investigate aspects that are relevant to distributing competences within a union of states regarding the provision of power generation capacity. Based on this, secondly, we drew conclusions on the need for reforms in the EU. With this goal in mind, we started by qualitatively comparing simplified extreme versions of governance models in order to determine general advantages and disadvantages of centralising and decentralising decision-making powers. Subsequently, we derived potentially reasonable components of governance models with a more differentiated approach to allocating competences and assessed to which degree the current situation in Europe is compatible with these considerations.

In the EU, member states have transferred certain decision-making powers for the provision of generation capacity to the supranational level. Such a step might, in general, be very reasonable, since supranational institutions can play an important role in harnessing the potential of international cooperation, possibly leading to lower costs of achieving security of supply and environmental

[55] Cf. the EC's "Communication on the European Energy Security Strategy" (COM(2014) 330), which was supported by both the Council and the European Parliament.

[56] Cf. the "Communication on strengthening Europe's energy networks" (COM(2017) 718).

[57] EC (2018) describes the CEF as follows: "[*The CEF*] is a key EU funding instrument to promote growth, jobs and competitiveness through targeted infrastructure investment at European level. It supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services. CEF investments fill the missing links in Europe's energy, transport and digital backbone (…)." Instruments within the frameworks of the European Fund for Strategic Investment (EFSI) and the European Structural and Investment Funds (ESIF) are − rather partly and not exclusively − based on similar motives.

[58] However, it is noteworthy that the actual process for selecting PCIs is seriously contested. Critics have pointed out that the determination of a project's importance (which is based on the performance of cost-benefit analyses) exhibits methodological and procedural issues and that the selection has rather been based on political motives than on efficiency aspects in the past.

objectives; however, an ill-conceived use of centralised decision-making powers might have the opposite effect. The EU electricity sector policy has been characterised by a strong focus on developing the internal market. Although there are certainly convincing arguments in favour of the internal market idea itself, “completing” the internal electricity market conflicts with the established principle of national sovereignty over the generation mix. The overarching ETS mechanism alone clearly does not provide an adequate framework for generation investment. There is a need for targeted instruments for the provision of both RES-E plants and highly reliable generation units that conform with the environmental ambitions in Europe. National mechanisms could generally make sure that the individual goals and preferences of member states are met; however, the EC, as a result of the preference for seemingly “market-based” mechanisms, intervenes against more targeted and differentiated – and thus, if applied in the right situation and manner, potentially more cost-efficient – national instruments. Similarly, the forced opening of national mechanisms to generators abroad as well as centralised instructions for the management of interconnection capacities is not likely to be conducive to the underlying objectives. One reasonable supranational policy measure to support the achievement of common goals could be to promote an agreement of member states on binding individual RES-E targets. The expansion of RES-E plants should directly reduce the amount of ETS certificates in order to prevent negative repercussions. The same applies to measures that aim at phasing out conventional power plants; the possibility to voluntarily withdraw emission allowances in such cases, as proposed in the Winter Package, can be regarded as a step in the right direction.

Summing up, the strong focus of the EU’s electricity sector policy on internal market aspects has led to some questionable developments. Our findings suggest that supranational action should be based on a more differentiated set of goals and have a focus on supporting voluntary cooperations in cases with large expected net benefits. Against this background, the growing debate on fundamental reforms within the EU, which to a large extent is driven by a widespread dissatisfaction with the allocation of decision-making powers between the EU and its member states, should also include electricity supply related topics. The reforms recommended in this working paper, which involve a different approach to the exercise of centralised power, could lead to significant advances in both the adequate consideration of national preferences and the efficiency of electricity supply.

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