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STUDY

Dispatch Hub Compensation Schemes

Study on profit impacts and strategic incentives of alternative compensation schemes for Dispatch Hubs in the Flex-in-Market concept

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Authors
Ingmar Schlecht, Lion Hirth

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This study is a result of a project by Neon Neue Energieökonomik GmbH for Elia Group SA.

Contact:

Neon Neue Energieökonomik GmbH
Karl-Marx-Platz 12
12043 Berlin

Prof. Dr. Lion Hirth
hirth@neon.energy
+49 157-55 199 715

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Table of Contents

1 Introduction

In this study, we outline and analyze compensation schemes for participation in Dispatch Hubs.

Dispatch Hubs. Dispatch Hubs are a corner stone of the Flex-in-Market concept presented by Elia Group (2019). They are groups of strategically located flexible resources (e.g. conventional or renewable generation units, loads or redispatch potential), which the market can optimize independently of the bidding zone in which they are (otherwise) located.

Variants. The concept of Dispatch Hubs foresees two different implementation variants, the Market Bids variant, and the Redispatch Potential variant. In the Market Bids variant, units are removed from the zonal market and placed in a Dispatch Hub, which in this variant is like a separate virtual bidding zone. Such a placement of units into a zone has important practical implications and would therefore have to be valid for a relatively long time (we assume one year in the remainder of this study). In the Redispatch Potential variant, units stay in the zonal market, but TSOs bid the units' redispatch potential (potential to deviate from the schedules resulting from the zonal market) into Dispatch Hubs, which again are part of the Market Coupling. The first part (Section 2 and 3) of this study focuses on the Market Bids variant. The Redispatch Potential variant is discussed in Section 4.

Compensation. While the technical implementation of Dispatch Hubs was and continues to be analyzed in separate studies, the question of how units in a Dispatch Hub should be compensated and what strategic incentives result from such compensation was not yet addressed in depth. Compensation is relevant, because units in Dispatch Hubs are facing a different treatment to units that are dispatched as part of the zonal market. This study aims to fill this gap by outlining different compensation schemes and analyzing the resulting economic effects from the compensation schemes.

Focus. In analyzing the compensation schemes, we focus on participation incentives, distributional effects, market power, strategic bidding, and (dis-)investment incentives.

2 Model and groundwork

Before we discuss individual compensation schemes in Section 3 and 4, this section outlines our stylized model and discusses aspects that apply more generally to all compensation schemes. This model is focused on the Market Bids variant of Dispatch Hubs. The discussion of compensation in the Redispatch Potential variant of Dispatch Hubs is confined to section 4.

Table 1. Definitions.

Term	Definition / Explanation
Compensation	The term is used two-sided, so that it includes both positive payments by a TSO to a unit (e.g. if prices in the Market Bids Dispatch Hub are lower than in the zonal market) as well as payments from the unit to a TSO (e.g. if prices in the Dispatch Hub are higher than the zone). The compensation can therefore be positive or negative depending on the price difference between a Dispatch Hub and the zonal market.
North/South	We use the term North to describe oversupplied (abundant) and South to describe undersupplied (scarcity) regions regarding their position relative to the grid constraint. The wording comes from the German discussion on redispatch, where frequent North-South congestion occurs. In our discussion, the terms North and South are to be understood as placeholders for any over- or undersupplied region relative to the grid constraint. In the nodal pricing literature, the region we call North is often labeled export constrained and the region we call South as import constrained. In other words, we use North as the term to describe the region in which additional supply worsens the congestion pattern and South to describe the region in which additional supply improves the congestion pattern.
Unit	The term covers generation, load or storage units. We use the term where all these unit types would be possible. However, we use the term in the "direction" of generators, and we leave it to the reader to apply the opposite sign when thinking about load units. That means, a sentence like "a unit in the South benefits" means (a) a generation unit in the South "benefits" (b) different unit types are possible and (c) it is implied that the opposite applies to load units, i.e. a load unit "loses" (even if that is not explicitly expressed). The default unit type when reading the text is therefore a generator. Also, unless otherwise stated, for the sake of brevity we do not distinguish between a unit and its owner. Therefore, a sentence like "a unit bids its marginal cost" is to be understood as "the owner of a unit bids the marginal cost of its unit".
Status quo market design	The current market design with ex-post cost-based redispatch where Dispatch Hubs are not yet introduced. We define cost-based redispatch as status quo to remain in line with our earlier work on redispatch markets (Hirth & Schlecht, 2020) and because under perfect cost-based redispatch profits are only influenced by zonal revenues and not by congestion management.
Zonal market	The "large zone" that co-exists with Dispatch Hubs and that contains all units not placed in Dispatch Hubs. This is our benchmark for compensation, as it defines what units would earn if they would not be placed in a Dispatch Hub. Note that this is distinct from the "status quo" market design (defined above) where Dispatch Hubs have not yet been introduced.

2.1 Model setup

Model. To analyze the effects of compensation schemes on the incentives for units, we use the model introduced in our earlier work on redispatch markets (Hirth & Schlecht, 2020, and Neon & Consentec, 2019) and extend it to cover Dispatch Hubs. It is a stylized merit-order model with two nodes, North and South, within one bidding zone modeled in detail, depicting the need for congestion management (Figure 1). There are different types of generators in the model with a variable cost structure as depicted. All load is located in the South of the bidding zone. The role of Dispatch Hubs in influencing cross-border trade possibilities with other bidding zones is not modeled in detail. The focus lies on compensation of units in a Dispatch Hub relative to staying in the zonal market. One can assume that the impact of Dispatch Hubs on cross-zonal trade (and hence prices) is implicitly reflected in the price curves.

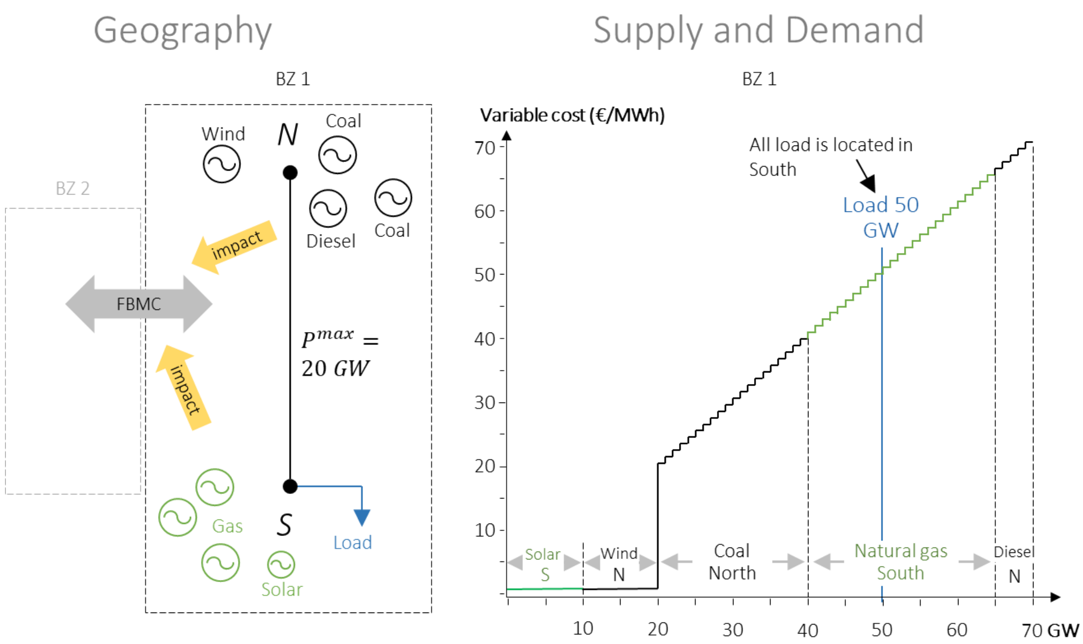

Figure 1: The model: Geography, supply, and demand in an exemplary hour (before introduction of Dispatch Hubs).

2.1.1 Status quo market design

Cost-based redispatch. In the status quo market design, i.e. a zonal setup with cost-based redispatch, the outlined model would result in a market clearing as depicted in Figure 2, with a clearing-price of 50 €/MWh. The market result implies congestion on the critical branch, so that 10 GW need to be redispatched down in the North and up in the South. Under cost-based redispatch, these units must ramp down or up on the TSO's request. They get compensated based on variable costs (plants ramped down must surrender their saved variable costs and plants ramped up get compensated for their additional variable costs). We abstract from the fact that this could be subject to estimation errors, which leads to a lower efficiency of the cost-based approach in actual operation than we depict in our model.

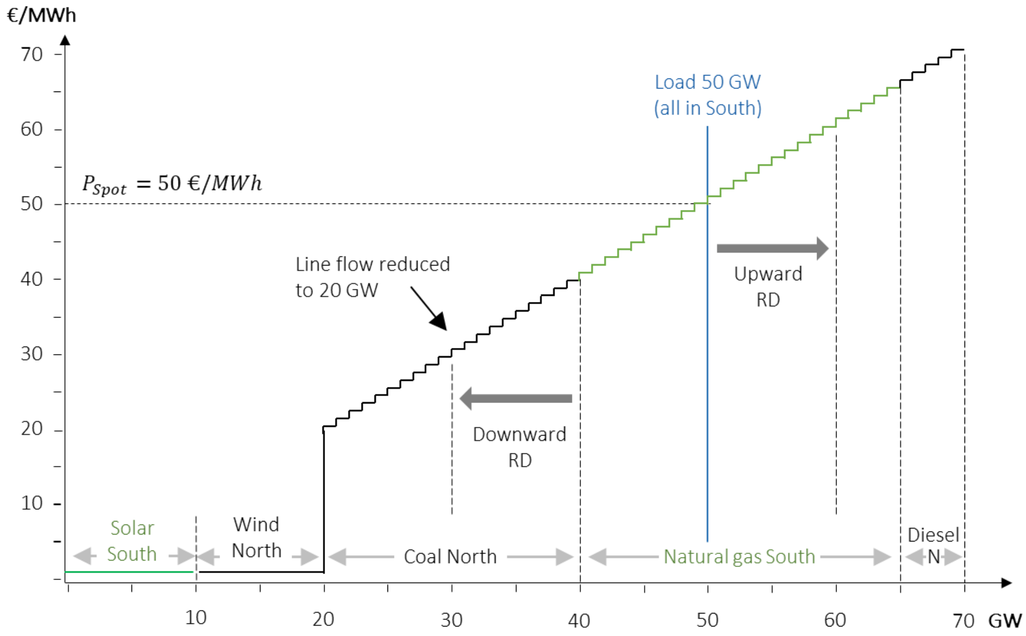

Figure 2: Zonal spot market with redispatch in the absence of Dispatch Hubs.

2.1.2 Dispatch Hubs

Introduction of Dispatch Hubs. We now introduce Dispatch Hubs to the model, which enable a separate optimization of a group of power plants within the market coupling respecting critical branches. Different configurations of Dispatch Hubs are possible regarding which plants are selected to become part of a Dispatch Hub and which ones stay in the zonal market. In the example in Figure 3 we show a Dispatch Hub where only those units take part which were necessary for redispatch in the cost-based regime (Figure 2) – as they are sufficient to solve congestion. Note that since Dispatch Hubs are stable over many hours (e.g. one year) that configuration would not necessarily solve congestion in all hours, so in other hours (not shown in the model) further redispatch might be needed.

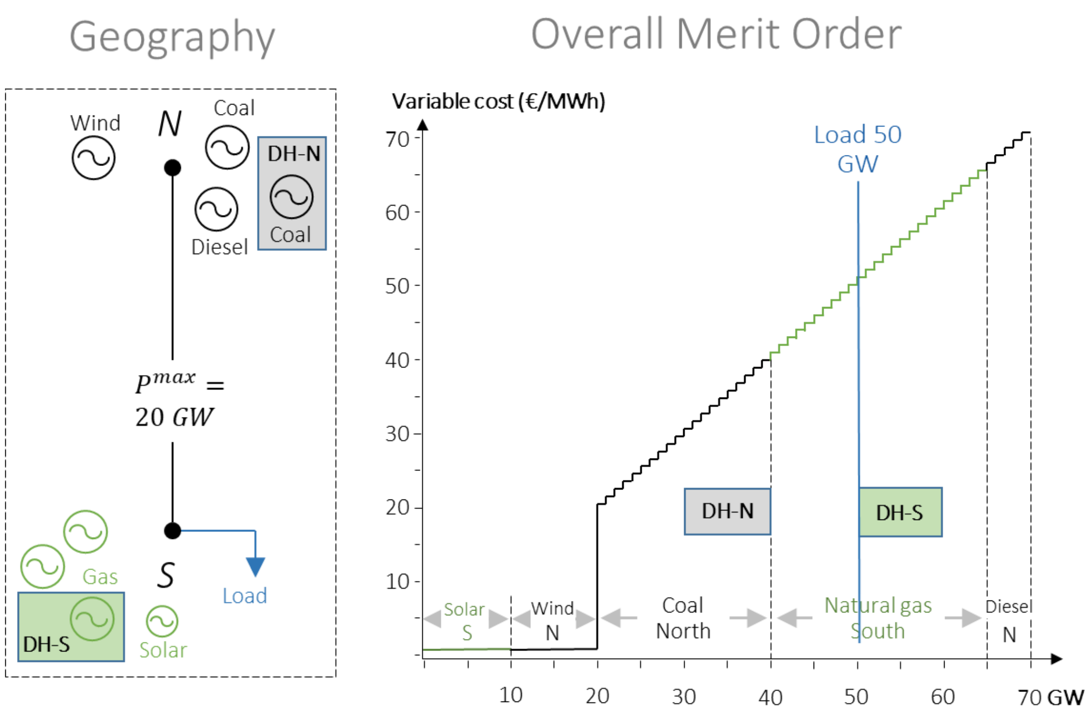

Figure 3: Exemplary hub configuration: Relevant units for redispatch are moved into Dispatch Hubs.

Activation of Dispatch Hubs. An advantage of Dispatch Hubs is that they integrate congestion management already into the market clearing so that no or fewer congestion remains to be solved in curative measures by the TSOs. Figure 4 shows the result of the market clearing in the modeled hour with Dispatch Hubs. Given the constraints on the critical branch (20 GW line capacity from North to South, see Figure 3 above), the Northern Dispatch Hub cannot export at all in the hour, while the Southern Dispatch Hub fully exports to serve the zonal load respecting line constraints at least cost. The clearing price in the Northern Dispatch Hub will be 30 €/MWh and in the Southern it will be 60 €/MWh.

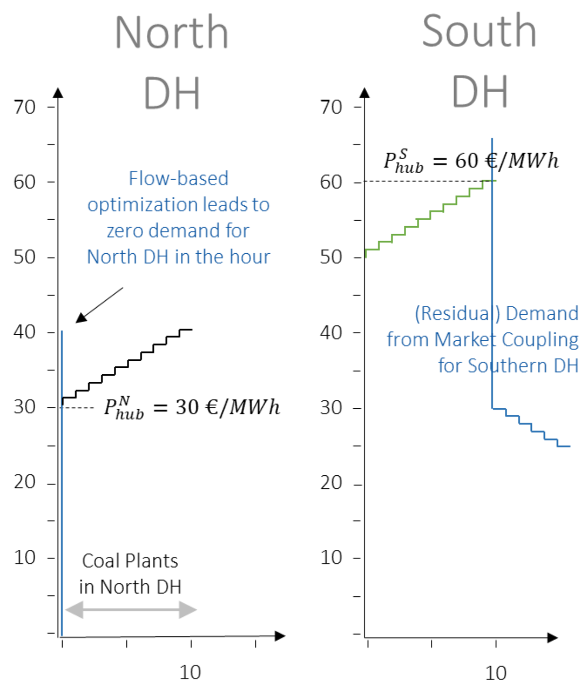

Figure 4: Market clearing in Dispatch Hubs.

Multiple clearing prices. An important take-away is that with Market Bids Dispatch Hubs, there will be (in case of binding constraints on the critical branch) multiple prices at the same time: One price for each of the Dispatch Hubs and one zonal price. We do not discuss the determination of the zonal price in this study in detail. Separate analysis shows that the zonal price will (depending on the configuration of Dispatch Hubs) be either one of the Dispatch Hub prices or any price between the Dispatch Hub prices. For the examples in the remainder of the paper, we assume a zonal price of 50 €/MWh.

Unintuitive flows. It is important to note that flows are often unintuitive from Dispatch Hubs to a zone (i.e. flows from a high price to a low price area). This means, in Dispatch Hub operation, flows from a high price Southern Dispatch Hub to a medium price zone are to be expected. Also, the lack of (or limited amount of) flows from low price Northern Dispatch Hubs to the zone is a common feature of Dispatch Hubs. This is a feature of the flow-based optimization finding welfare optimal dispatch respecting critical branches. It is the equivalent to the down-redispatching of low cost (Northern) units and up-redispatching of expensive (Southern) units in the status quo cost-based redispatch.

2.2 Configuration of Dispatch Hubs

When configuring Dispatch Hubs, TSOs would choose the units most effective at solving congestion. In this section, we first discuss what makes a unit well-suited for congestion management, focusing on the position of plants along the merit-order. Second, we discuss potential welfare implications of selective Dispatch Hubs, especially when entry is voluntary.

2.2.1 Suitability of units for Dispatch Hubs

Best units for congestion management. In the shown example in Figure 3, we select only the plants best suited (in the exemplary hour) for congestion management into a Dispatch Hub. These units are best suited, because in the North they are the plants with the highest variable costs of those that would be running in a zonal market, and in the South, the selected plants are the cheapest available units that are not running in the zonal market. Therefore, the selected Northern plants would be the best to ramp down and the selected Southern plants would be the best to ramp up. As the example shows only one selected hour, it is exemplary only. For determining which plants are best suited for inclusion in a Dispatch Hub over an entire year, it would be necessary to determine which plants are just above (South) or just below the zonal clearing price (North) in many hours of the year (during which congestion occurs).

Unsuitable units for congestion management. Units which, by their cost structure, already choose the system optimal dispatch state in the zonal market, have no additional value for congestion relief by entering a Dispatch Hub. These are units with very high variable costs in the North which do not run independently of their placement in a Dispatch Hub, but also very cheap plants in the South, which run anyway, independently of their placement in a Dispatch Hub. Since these are already in their dispatch state most favorable for the system, placing them in Dispatch Hubs provides no additional congestion relief.

Expensive units for congestion management. A third group of units would be useable for solving congestion, but expensive at doing so. These are the cheapest Northern plants (as it would be a waste ramping these cheap plants down while keeping more expensive Northern plants running) and the very expensive Southern plants (as it would be a waste starting these expensive units up instead of the cheaper ones).

Relation between availability and suitability. As the most economic units for congestion management are always the ones with a marginal cost closest to the zonal price, they are also the ones which often switch between being scheduled and not being scheduled on the zonal market. A key problem is that there is an inverse relationship between a unit's (zonal price-induced) availability for redispatch and its attractiveness for (and likeliness of) redispatch when available. That means, a unit whose supply decision on the basis of the zonal price is such that it is always available for redispatch (i.e. a very cheap Northern plant that always runs or a very expensive Southern plant that never runs) is likely one that is not attractive for redispatch. More attractive plants for redispatch are those with variable costs closer to the zonal price level. These, however, are not available for redispatch as often, because depending on the varying hourly zonal price they might chose to run or not run in some hours – and are thus available only in those hours where their zonal supply decision results in the right dispatch state for being available for redispatch. This is depicted in Figure 5.

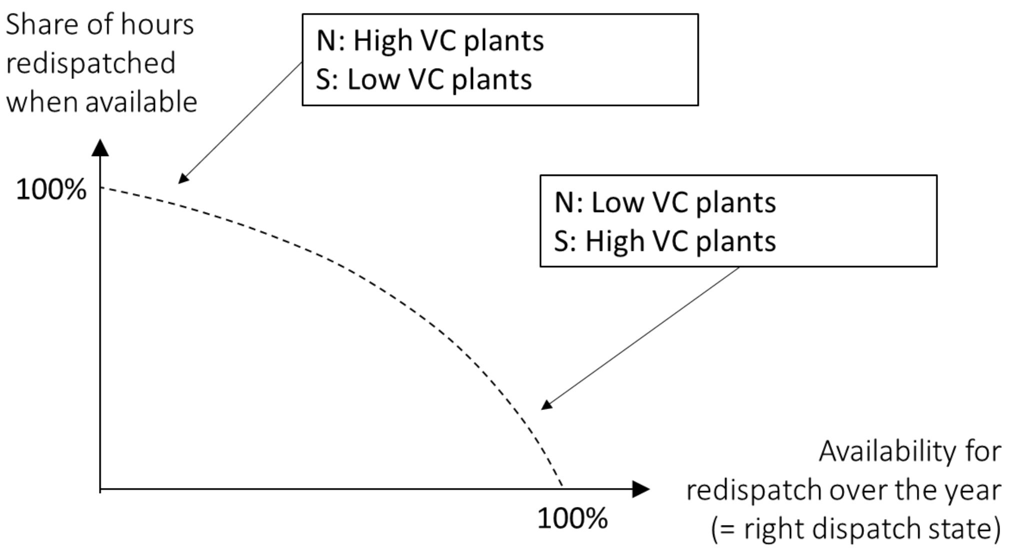

Figure 5: Inverse relation between (merit-order induced) availability and likeliness of redispatch.

Availability criteria. Due to this inverse relationship, availability criteria (such as "units must be available for redispatch at least 80% of the hours in a year") would exclude the best units and are therefore not an option for attracting the right units into Dispatch Hubs. Even entry criteria that only require availability in hours where congestion occurs are unsuitable to attract the right units if congestion is uncorrelated to price, as is the case in Germany.

Load-flow sensitivities. In reality (but not in our two-node example) units also differ by load-flow sensitivity, i.e. their sensitivity on the congestion in a meshed grid. This adds a further dimension to the selection problem that we abstract from in our example. Effectively, it would change the plain merit-order to become a sensitivity weighted merit-order where variable cost differences and differences in sensitivity on the critical branch jointly determine the cheapest way to solve congestion. We believe for the analysis of the incentives stemming from compensation schemes, the chosen model without differences in sensitivity is sufficient.

2.2.2 Welfare impact of voluntary entry

The compensation schemes in Section 3 differ with respect to whether units enter voluntarily or are obliged to enter the scheme. With voluntary entry, Dispatch Hubs could become scattered with some relevant units remaining in the zone and some joining the Dispatch Hub. This has implications on welfare optimality.

Comprehensive Dispatch Hubs. While the idea of Market Bids Dispatch Hubs is to only move units most relevant for congestion management into them, theoretically it would also be possible to move all units into Dispatch Hubs. Figure 6 shows such a setting, where all units are either placed in the Northern or the Southern Dispatch Hub. This could be compared to a bidding zone split, where only load is placed in the remaining large zone. An advantage of such a setting would be that the selection of units would not matter anymore and congestion between the hubs could always be solved (at least in the two-node example) in a welfare optimal way.

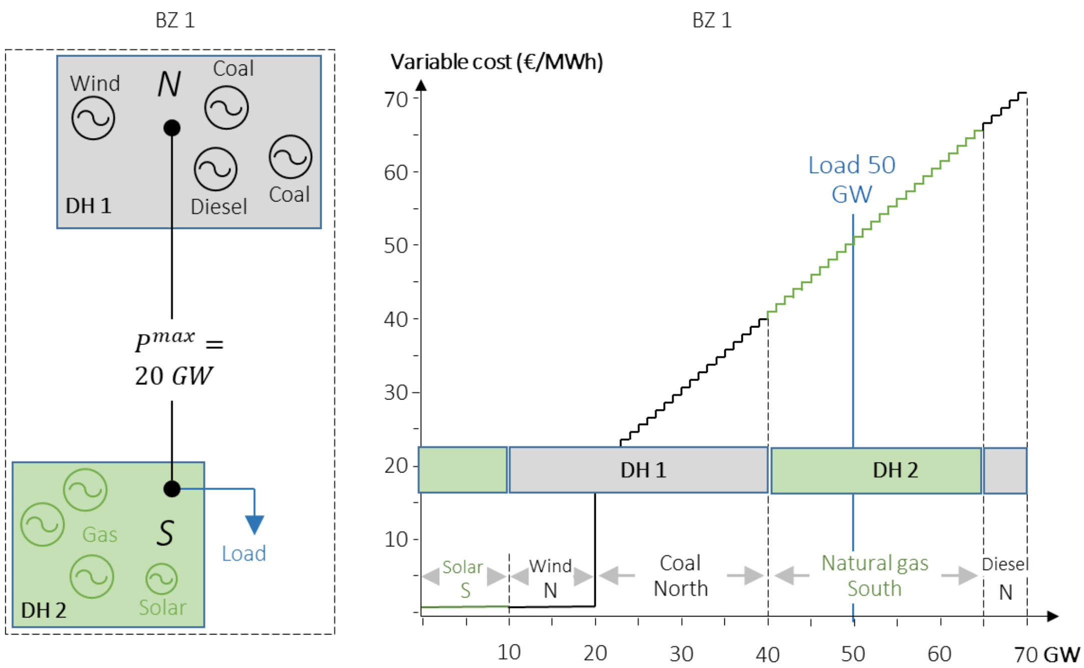

Figure 6: Exemplary hub configuration: All units are moved into Dispatch Hubs

Optimal selective Dispatch Hubs. Dispatch Hubs can remain to be welfare optimal even if they are selective. Such a selective Dispatch Hub was presented in Section 2.1.2 and Figure 3, where only the units most relevant for congestion management were selected into the Dispatch Hub.

Welfare-loss from selective schemes. Some selective Dispatch Hub configurations, however, result in dispatch decisions that fall short of welfare optimality. These configurations are particularly likely in voluntary compensation schemes where units decide to join or not to join. Suboptimal dispatch results can occur in these settings because the units in Dispatch Hubs might not be the best to solve congestion. During operation, Dispatch Hubs that contain only a suboptimal subset of units physically available in the location might already be able to solve all congestion even if they are not the cheapest to do so. By solving congestion, they eliminate the need for cost-based curative redispatch. But some of the best units to solve congestion, which are not part of the Dispatch Hub but part of the cost-based redispatch, are never activated. This is illustrated in Figure 7. To keep the dispatch efficient, it would therefore be necessary to include all the "best" units in Dispatch Hubs. This shows an advantage of schemes where units do not voluntarily decide to join but are instead obliged and selected by the TSO.

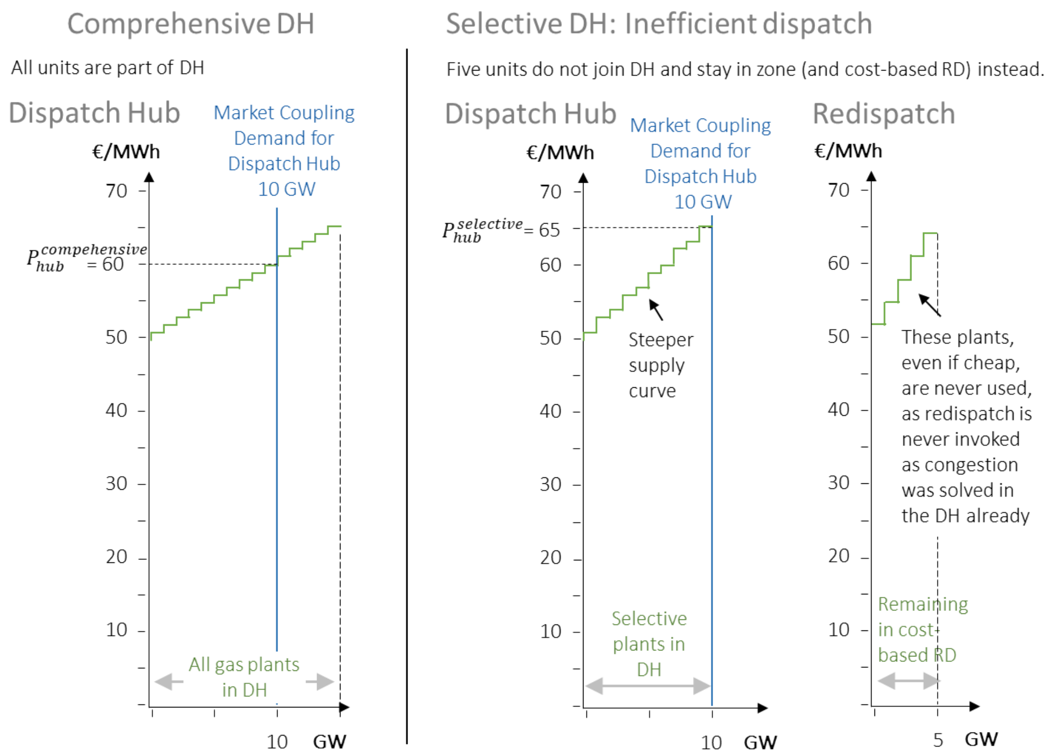

Figure 7: Welfare loss from selective Dispatch Hubs as some cheap units remain unused (only the South is shown in the graph)

Selection criteria create incentives. If TSOs decide on units' participation in Dispatch Hubs, they will likely do so based on selection criteria. Such selection criteria, e.g. in the North, could be "being a unit that is in the market dispatch more than 80% of the time when congestion occurs". Such selection criteria could create incentives to behave differently to avoid being placed in a Dispatch Hub if there was no compensation for units in Dispatch Hubs. Outsiders (units not yet in the Dispatch Hub) in the North, could behave in the zone so that they are not selected into the Dispatch Hub. Units already part of a non-compensated Northern Dispatch Hub on the other hand could behave so that they no longer qualify for future Dispatch Hub participation and are released into the zone again. A possible strategy would be for a Northern generator to bid itself out of the zonal market for some congested hours to fall underneath the threshold of hours one needs to be available for redispatch if that is the selection criterion. From a congestion perspective, the effect would be desirable. The opposite is the case for the South, where it is attractive to become part of a non-compensated Dispatch Hub. There, pricing oneself out of the market would be a beneficial strategy to trigger inclusion, which is aggravating congestion.

Clear separation between Dispatch Hub and zone necessary. In all Market Bids Dispatch Hub approaches, a clear separation between units that are part of the Dispatch Hub and those that are part of the zone must be put in place. This is especially challenging for cases where it is hard to draw a clear line between units, such as in the case of industrial own production, where generation and load could be behind a single meter. Individual balancing responsibilities are necessary for those assets that are part of a Dispatch Hub and those that are not.

2.3 Compensation fundamentals

2.3.1 Adequate compensation level

To set the basis for the discussion of compensation schemes, it is useful to determine the level of adequate compensation and to define what benchmark there is for determining it.

Possible benchmarks. There are different possible benchmarks for the intended level of rents units should earn in a Dispatch Hub, the rents in the status quo market design, the rents under zonal pricing or the rents under perfect nodal pricing. While the first two follow grandfathering and protection of confidence motivations and foster political acceptance of Dispatch Hubs, the last one is motivated by economic efficiency considerations. In a nodal pricing system, rents for units in oversupplied regions are generally lower and in undersupplied regions higher than under zonal pricing, which correctly incentivizes (dis-) investment of units in the different locations. In the absence of compensation, the Market Bids Dispatch Hub design would bring rents for units closer to the nodal pricing efficient benchmark.

Compensation to zonal. The compensation schemes discussed in this report all aim (with varying suitability) to make units financially equal to the zonal market that exists concurrently to Dispatch Hubs. This is a useful target especially given that it enables TSOs to regularly re-assess the selection of units into Dispatch Hubs and re-configure them. For units, such compensation would have the advantage that the zonal price remains the proxy for expected profits regardless of whether they are selected into Dispatch Hubs or not. If (existing) units were compensated below zonal profits, they would legally object their inclusion in Dispatch Hubs, and if they were compensated above zonal profits the costs to TSOs and thereby to ratepayers would be unnecessarily high. A bidding zone split would have similar profit impacts for units, but political acceptance might be better because the reconfiguration is less frequent and geographical regions likely larger than in the case of Dispatch Hubs.

No compensation to status quo. It is important to note that the zonal benchmark we select is the zone that exists concurrently to Dispatch Hubs and not the status quo zonal market with ex-post redispatch. Thereby, we assume that the changes to the general zonal price on introduction of Dispatch Hubs (see Elia Group, 2019) will be acceptable for units – similar to the price changes that are to be expected from any bidding zone reconfiguration. Instead, the important aspect to compensate is selection of individual units into Dispatch Hubs as compared to staying in the zonal market.

Aim. Therefore, the aim of compensation is to prevent both windfall profits as well as windfall losses from units that are selected into Dispatch Hubs relative to their position in the zonal market. As far as possible, compensation schemes are designed not to interfere with the operation of Dispatch Hubs (i.e. the welfare creation) but only focus on distribution of welfare across actors.

Trade-off. In essence, discussions on compensation for Market Bids Dispatch Hubs are a trade-off between economically efficient long-term price signals and revenue protection for units. Therefore, it is closely related to policy decisions.

Profit changes. When units join a Market Bids Dispatch Hub without compensation, their profits change. Figure 8 shows the profit changes for different plants. It shows that for the hour displayed, units in the North with variable costs below the zonal clearing price of 50 €/MWh would incur a loss of up to 20 €/MWh while those Northern units with variable costs above 50 €/MWh would see unchanged profits (zero in either case, as they would neither generate under the zonal nor under the Dispatch Hub price). In the South, the profits of units increase by up to 10 €/MWh for all those units with variable costs below the Southern Dispatch Hub price of 60 €/MWh. The maximum loss or gain is always reached for plants to the left of the merit-order, while plants with variable costs between the zonal and the locational hub price experience smaller profit changes. In a meshed grid, the merit-order would be a load-flow sensitivity weighted merit-order, which we abstract from here.

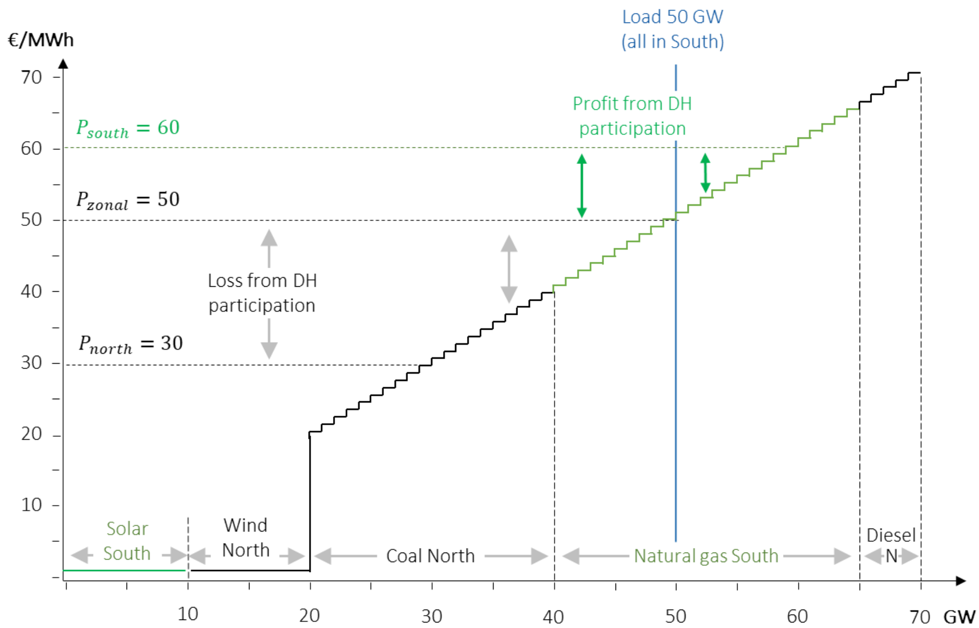

Figure 8: Profit changes due to Dispatch Hub participation in the absence of compensation. The price P_{zonal} denotes the zonal price, P_{south} the southern Dispatch Hub price, P_{north} the northern Dispatch Hub price.

Adequate compensation. To set units financially equal to the profits they would have made in the zonal market (which we define to be the adequate compensation), a compensation is necessary that exactly equalizes these extra profits or losses. For each hour, and for a single plant, the adequate compensation formula is:

$$Compensation_{North} = \begin{Bmatrix} (P_z - P_h)capacity_p & \textbf{if } vc < P_h < P_z \\ (P_z - vc)capacity_p & \textbf{if } P_h < vc < P_z \\ 0 & \textbf{if } P_h < P_z < vc \end{Bmatrix} \geq 0$$

$$Compensation_{South} = \begin{Bmatrix} (P_z - P_h)capacity_p & \textbf{if } vc < P_z < P_h \\ (vc - P_h)capacity_p & \textbf{if } P_z < vc < P_h \\ 0 & \textbf{if } P_z < P_h < vc \end{Bmatrix} \leq 0$$

Where vc is the unit's variable cost, P_z is the zonal price, P_h is the price on the Dispatch Hub and $capacity_p$ is the electrical capacity of the plant. The adequate compensation level is the ideal theoretical compensation. In Sections 3 and 4 we outline practical implications of different implementations of compensation schemes.

Compensation can also be negative. In all cases "compensation" can mean a payment from system operators to market parties, or from market parties to system operators. In other words, compensation payments can have either sign, positive or negative. The sign convention in this report is that a compensation is positive when the payment is from system operator to market parties.

2.3.2 Applicability of compensation

For all compensation schemes, there are three general design options to be made in terms of the applicability of compensation.

Excluding new assets from compensation. First, compensation schemes could be limited to existing assets, so assets with a commissioning date after the introduction of Dispatch Hubs could be excluded from compensation if they are selected into a Dispatch Hub. This would provide improved locational investment incentives for new assets (lower rents in the North, higher rents in the South) – although frequent re-configuration of Dispatch Hubs and the uncertainty of whether a unit is selected into a Dispatch Hub could undermine these incentives. To provide more stable (positive or negative) locational investment incentives from Dispatch Hubs for new units, new units would need to be guaranteed to be placed in a Dispatch Hub and these must be long-term stable. Also, even if new assets would be placed mandatorily in non-compensated Dispatch Hubs this does not mean that overall (dis-) investment signals would be correct, since existing assets still face wrong incentives to dis-invest with too strong dis-investment South and too little dis-investment North.

Phasing-out compensation. Second, compensation schemes could be restricted to be temporary only and be designed to be phased-out after several years. In that case, compensation would be solely an instrument to ease the transition for units to finally face the locational Dispatch Hub prices.

Excluding asset types for policy reasons. Another possibility would be to exclude certain asset types from compensation so that they face their underlying locational price. For that asset type, this would provide dis-investment incentives in the oversupplied region and investment incentives in the undersupplied region. However, such discrimination along technology types could likely be challenged in courts and is therefore unlikely to be a solid policy.

Trade-off with ability to frequently reconfigure. In any case where units are not compensated, it becomes more problematic to re-configure Dispatch Hubs, as this has profound profit impacts for units in the Dispatch Hub. Therefore, there is a fundamental tradeoff between providing correct investment signals (which a non-compensated Dispatch Hub scheme does) and the ability for TSOs to frequently re-configure Dispatch Hubs according to grid and congestion patterns.

2.4 Economic incentives

For each of the compensation schemes discussed in Section 3 and 4, we focus on five different economic incentives and phenomena.

Strategic bidding. A core question is whether there are detrimental strategic bidding incentives arising from the compensation schemes. In the context of this report, we define strategic bidding as incentives for units to bid such that they increase rents above the intended level of the compensation scheme without making use of market power. That means strategies must be possible for small, atomistic actors. The intended level is “zonal rents” for schemes that aim to compensate towards the zonal level and “locational rents” for schemes that aim to make units face the locational Dispatch Hub price. The discussion of strategic bidding incentives in compensation schemes is related to the discussion on inc-dec gaming in redispatch markets (Hirth & Schlecht, 2020, and Neon & Consentec, 2019).

Market power. Being relatively small (compared to zonal markets), Dispatch Hub participants will often have more market power than they have in large bidding zones. Compensation schemes can be a key factor aggravating or mitigating the incentives to exercise such market power.

(Dis-)Investment. Even though Dispatch Hubs are not necessarily stable and can be re-configured, participation in Dispatch Hubs can create changes to economic rents that change the incentives to invest or dis-invest. We analyze to what degree this is the case for the different compensation schemes.

Distribution. Compensation can create economic winners and losers in terms of redistributing economic surplus between different groups of market parties (participants in different Dispatch Hubs, participants of the zonal market) and rate payers who bear the net cost of the system through grid fees.

Asset types. The compensation schemes vary in how well they are suited to attract different asset types. The suitability varies especially regarding flexibility types new to congestion management, such as loads or small-scale storages.

3 Compensation in Market Bids variant

In this section, we discuss compensation schemes for the Market Bids variant of Dispatch Hubs. In the Market Bids variant, units bid directly into Dispatch Hubs without a TSO as intermediary. Six different compensation schemes for the Market Bids variant were evaluated in this study. They distinguish themselves by the following criteria:

- **Who bids?** In schemes 1-6, market participants are placed in the Dispatch Hub. Hence they have to separate their portfolio between the zonal market and the Dispatch Hub. They receive the Dispatch Hub wholesale prices plus, possibly, a compensation. In schemes 7-8, which are discussed in Section 4, TSOs place redispatch cost curves in dispatch hubs. Market parties receive the zonal price plus, upon redispatch execution by the TSO, possibly a compensation for participation in redispatch. They are not, however, exposed to the Dispatch Hub price.
- **Voluntary or mandatory**. In three compensation schemes (5, 6, 8), participation is voluntary. Here, payments must be financially attractive enough to incentivize participation. The other five schemes are mandatory for market participants, so participation incentives are not a precondition for a functionable design.
- **Compensation timescale**. The schemes differ in the timescale in which compensation works. While schemes 3, 4, 7 and 8 compensate on hourly level, schemes 2 and 5 compensate on yearly or longer-term level and scheme 6 has hourly and yearly compensation components.
- **Determination of compensation levels**. Schemes also differ in the way compensation levels are determined. In schemes 3, 5, and 8 compensation is based on market parties' bids. In schemes 4, 6, and 7 compensation is based on the costs of market parties, as estimated by system operators or regulatory authorities. In scheme 1, there is no compensation. In scheme 2, compensation is based on historic produced energy, a proxy for profit impacts of Dispatch Hub participation.

	Scheme	Who bids?	Partici-pation	Timescale of compensation	Determination of compensation
1	No compensation	Market parties	Mandatory	-	-
2	Financial Transmission Rights	Market parties	Mandatory	Yearly	Historic production-based
3	Bid-based hourly	Market parties	Mandatory	Hourly	Bid-based

4	Cost-based hourly	Market parties	Mandatory	Hourly	Cost-based
5	Ex-ante auction	Market parties	Voluntary	Yearly	Bid-based
6	Cost-based offer	Market parties	Voluntary	Hourly compensation plus yearly participation premium	Cost-based
7	Redispatch potential, cost-based	TSO	Mandatory	Hourly	Cost-based
8	Redispatch potential, market-based	TSO	Voluntary	Hourly	Bid-based

Selective vs. comprehensive. For the performance of Dispatch Hubs it is also important whether they are comprehensive (i.e. comprise all units in a particular area) or selective (i.e. comprise only a subset of units selected by the TSO)

3.1 (1) Mandatory without compensation

3.1.1 Characterization and intention

In this approach, selected units are mandatorily placed in a Dispatch Hub. Market parties placed in the dispatch hub are cleared at the respective Dispatch Hub price, without any further compensation. Thus, Northern generators in the Dispatch Hub see their revenues reduced as compared to the zonal market, because the Northern Dispatch Hub price tends to be lower, and hence both margins and volumes will tend to decline. Vice versa, Southern generators' profits increase. Hence there will be a significant distributional impact for units assigned to a Dispatch Hub.

Intention. This approach intends to be as simple as possible and to avoid strategic incentives as well as bureaucratic and regulatory overhead.

Like small bidding zones. This compensation scheme is comparable to introducing just another bidding zone in the market coupling for the specific units placed in the Dispatch Hub. Conceptually, it is identical to market splitting. It is a simple and clean approach and uses the existing market-coupling framework. It may face the same political difficulties as the re-design of bidding zones, or even further opposition as the decision which units to place in the Dispatch Hub might seem arbitrary to market parties. The major difference nevertheless is that in a typical bidding zone split, also demand is cleared at a different price, whereas in this with Dispatch Hubs, effects are limited to those units (generators or consumers) in the hubs.

Comparison to Italy's PUN. This design bears some similarities to the Italian market design in which generation is cleared at sub-country zonal prices while load is cleared at one national uniform price (the *prezzo unico nazionale*, or PUN). There are, however, also marked differences to this design. First, while the Italian design clears all generation at the sub-country zonal prices, the Dispatch Hub design only selects individual units that are particularly relevant to congestion management, while remaining units stay in the zonal market. Second, the Dispatch Hub design is implemented under a flow-based congestion management approach, which by design is more suitable to act effectively and precisely on congestions than a rougher ATC approach. Third, while the Italian market design causes problematic issues to the Euphemia market clearing algorithm due to paradoxically rejected load bids under the ex-post calculated PUN price, which must be fixed in additional iterations, this problem does not occur for the Dispatch Hub market design. In the Dispatch Hub market design, both the Dispatch Hubs as well as the zonal market that contains the remaining load entities and remaining generators are treated like normal zones in Euphemia, and do not necessitate ex-post calculations. However, as an important similarity, both the Italian and the Dispatch Hub market design lead to two parallel distinct prices at the same geographic locations. Therefore, in both the Italian PUN market design and the Dispatch Hub market design, there is a need to cleanly separate units facing the Dispatch Hub price from load or units facing the zonal price to avoid undue arbitrage between the two prices.

3.1.2 Assessment

Strategic bidding. Units in this scheme cannot increase their rents above the intended level by ways that would be possible for atomistic (small) units. Therefore, there are no strategic incentives in this scheme. All (small, atomistic) units face only their locational price and can neither benefit from arbitrage between different markets nor influence their compensation. There could however be an incentive to influence participation in the Dispatch Hub itself, if the TSOs select units to enter Dispatch Hubs based on their availability for redispatch in a zonal market. In the North, outsiders (units not yet in Dispatch Hub), would behave in the zone so that they do not enter the Dispatch Hub (this would be beneficial for the system, because generators would ramp down – which is desirable – to be unavailable for redispatch). In the South, outsiders (units not yet in Dispatch Hub) would try to enter the Dispatch Hub. This would mean they want to show that they are units available for redispatch, so they have an incentive to choose the operation status that is undesirable, i.e. choose not to run in the market in hours where upward redispatch is needed, so they are available to provide such redispatch. Therefore, the incentive effect of influencing participation would be desirable in the North but undesirable in the South. These incentive effects from selection can be avoided if either the Dispatch Hub is comprehensive (so that there is no longer a selection, which essentially is not the idea of Dispatch Hubs) or if selection is based on criteria that cannot (or no longer) be influenced by market actors, such as historical operation patterns in pre-Dispatch Hub periods. Also, the strength of these incentives depends on the predictability of the selection decision, because following the outlined strategies is costly for units and only profitable if the result they anticipate is correct.

Market power. There is significant potential for the abuse of locational market power. The locational price factors directly into units' profits, so all generators in scarcity regions have an incentive to inflate the price through overbidding and/or physical withholding of generation capacity. Market power in the scarcity region is only limited by the welfare optimization as part of the flow-based market coupling, but if constraints on critical branches are binding, significant locational market power can be exercised in the South. This means that units in the scarcity region will be able to capture a higher share of the welfare gains than in a competitive setting and increase overall price levels. Therefore, we believe this scheme only works with some way of market power control – e.g. by regulating to cost-plus bidding if individual units become pivotal.

(Dis-)investment. As this scheme grants units only the locational price, it provides optimal (dis-)investment incentives, at least in the absence of market power on the Dispatch Hub. While there are also other schemes that provide the optimal locational rent to Southern plants, it is the only one which also provides the right dis-investment incentives to existing Northern units.

Distribution. Distributional impacts are heavy: Northern generators lose, Southern win. This is likely to implicate political and legal challenges, especially since only a subset of units is assigned to Dispatch Hubs. A selective Dispatch Hub without compensation negatively discriminates against the subset of plants selected for the Dispatch Hub in oversupplied regions and positively discriminates plants in undersupplied regions.

Asset types. This compensation scheme is the best suited to accommodate all kind of asset types, including loads and storages. As the scheme is not compensated, there are also no informational needs coming with compensation in this scheme.

3.2 (2) Mandatory financial-transmission rights

3.2.1 Characterization and intention

In this scheme, units are mandatorily assigned to Dispatch Hubs, but compensated using Financial Transmission Rights (FTRs). Generators placed into a Dispatch Hub would be eligible to receive a share of the congestion rent that arises because of the price differences between hub and zone. This can also be a negative amount (e.g. for Southern Dispatch Hubs). This idea is inspired by the idea to compensate generators with FTRs in the transition from zonal to nodal pricing in various power markets of the United States. Compensation is imprecise because price spreads are not evenly distributed over time and could be larger or smaller at the specific hours when the plants are available.

Intention. The intention is to offer some compensation to units but spare the bureaucratic overhead (and possibly misguided incentives) that comes with exact compensation.

Compensation rule. FTRs can be specified and allocated in many ways. Here we assume a baseload FTR, corresponding to the sum of hourly price spreads (determined ex-post) between zonal and Dispatch Hub price for one year. The financial value of the FTR would be positive in the North, so generators receive a payment from TSOs. In the South, the value would be negative, implying a payment from generators to TSOs. FTRs could be allocated in various ways, e.g. according to current or historical capacity or production. Allocating FTRs according to nameplate capacity would be a complete compensation only for baseload plants; all other generators would be over-compensated. For this reason, we assume FTRs would instead be allocated based on energy using the historical production (grandfathering).[1] A wind plant will therefore get less FTRs per nameplate capacity than a nuclear station that was running baseload in the past. While the capacity (amount) of FTRs is fixed ex-ante, the financial payment associated with it only becomes clear ex-post, when prices on the Dispatch Hub and the zone materialize.

Profit function. The simplified profit function looks as follows. It is composed of the revenue on the Dispatch Hub (P_h), variable costs of production (vc) and the FTR-based compensation. Q denotes production quantity.

$$\pi = Q(P_h - vc) + cap_{FTR}(P_z - P_h)$$

Imprecise compensation. In any case, compensation will be imprecise, i.e. overall profits will differ from the uniform zone counterfactual. This is because the FTRs a unit gets do not necessarily compensate correctly for the hours in which the specific plant's production occurs. A wind plant in the North that produces predominantly during hours in which Northern Dispatch Hub prices are especially low compared to the zonal market would, for example, not be compensated enough by the FTR compensation, because the price spread during production-hours is higher than the baseload price spread it gets compensated for.

3.2.2 Assessment

Strategic bidding. There are no incentives for price takers to deviate from bidding their marginal costs to the Dispatch Hub, as compensation only depends on prices (the Dispatch Hub price and the zonal price) and is independent of the unit's quantity produced in the current year. Therefore, we conclude there are no strategic incentives according to our definition. To avoid strategic effects, it is important that the FTRs are allocated based on grandfathered historic energy produced before the introduction of Dispatch Hubs. Otherwise, there could be incentives to over-produce in oversupplied regions to increase the amount of FTRs assigned.

Market power. Units with market power have an incentive to influence the Dispatch Hub price, both because they receive the price (when producing) and because the price determines the value of their FTR (regardless of if they are producing or not). The incentive to exercise market

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[1] This is also in-line with Kunz et al. (2016) who propose energy-based FTR allocation as a better match for compensation than capacity-based allocation on introduction of a nodal pricing system in Europe.

power can go both ways: In hours where the unit produces more than it is compensated for (i.e. more than the FTR volume), it has an incentive to increase the Dispatch Hub price. In hours, where it produces below its amount of FTRs, it has an incentive to depress the Dispatch Hub price to increase compensation (North) or decrease payments (South).

(Dis-)Investment. For existing assets, disinvestment incentives are distorted, leading to too little dis-investment North and too much dis-investment South. A possibility would be to phase-out the FTRs over the years, so that at the end of the phase-out period the correct locational disinvestment incentives take hold. For new assets, investment incentives could be provided by forcing and guaranteeing placement in the Dispatch Hub without compensation.

Distribution. With FTRs, generators are exposed to some profit changes compared to the zonal market, because compensation (as elaborated before) is imprecise for any non-baseload power plant. As in scheme 1, this could lead to legal and political challenges, especially when selection into a Dispatch Hub is at the discretion of the TSO.

Grandfathering. An issue of this compensation scheme is that the assignment of FTRs are grandfathered based on historical production before the existence of Dispatch Hubs. That benchmark becomes outdated the longer Dispatch Hubs exist. Also, for new units there is no such benchmark.

Asset types. This compensation scheme is relatively well-suited to accommodate all asset types, including loads and storages. There are some informational needs for the initial assignment of FTRs, but there is no need to assess variable costs or other detailed information about the units. It is thus also possible to integrate loads or storages with this compensation scheme.

3.3 (3) Mandatory bid-based hourly compensation

3.3.1 Characterization and intention

In this scheme, units are compensated ex-post hour-by-hour based on bids, prices and dispatch to make them earn as much as they would have earned in the zonal market given the bids they submit to the Dispatch Hub. The underlying assumption is that bids are a proxy for marginal costs – which turns out to be a wrong assumption given the incentives from this compensation scheme.

Intention. The intention of this scheme is to set units financially indifferent to the zonal market and thereby avoid the distributional consequences of scheme 1 and 2.

Compensation rule. Units that earn their revenues on the Dispatch Hub get an additional hour-by-hour compensation based on bids, prices and dispatch with the intention to make them reach the same profit level (neither more, nor less) they would have earned in the zonal markets assuming their bids represent their true marginal cost. For each hour, and for a single plant, the compensation formula is:

$$(\max(bid, P_z) - \max(bid, P_h))\ capacity_p$$

where bid is the unit's bid (assuming the full capacity is bid at the same price) in the Dispatch Hub, P_z is the price in the zone P_h is the price on the hub and $capacity_p$ is the plant's capacity.

Profit function. The simplified profit function then becomes the following. It is composed of the revenue on the Dispatch Hub, production costs and the FTR-based compensation. Q denotes production quantity.

$$\pi = Q(P_h - vc) + (\max(bid, P_z) - \max(bid, P_h))\ capacity_p$$

The mechanics of this compensation is shown in the examples in Box 1.

Box 1: Examples of bid-based compensation in scheme 3

Three examples, based on the model from section 2, clarify the compensation.

- a 1 MW plant in the North bids its variable cost of 10 EUR/MWh
  - On the Northern Dispatch Hub, this would mean it would be dispatched at 30 €/MWh.
  - At the same time, the zonal price is 50 €/MWh.
  - A compensation of 20 € brings the unit equal to zonal profits.
  - Compensation formula: max(10, 50) - max(10, 30) = 50 - 30 = 20
- a 1 MW plant in the North bids its variable cost of 40 EUR/MWh
  - On the Northern Dispatch Hub, this would mean it would be not be dispatched.
  - At the same time, the zonal price is 50 €/MWh.
  - A compensation of 10 € brings the unit equal to zonal profits.
  - Compensation formula: max(40, 50) - max(40, 30) = 50-40 = 10
- a 1 MW plant in the South bids its variable cost of 55 EUR/MWh
  - On the Southern Dispatch Hub, this would mean it would be dispatched at 60 €/MWh.
  - At the same time, the zonal price is 50 €/MWh.
  - The 5 € additional profits must be seized to reach zonal profit level (0 €).
  - Compensation formula: max(55, 50) - max(55, 60) = 55-60 = -5 (i.e. negative!)

Bids are not marginal costs. If all units would bid their marginal costs, the compensation would reach the zonal level. However, units could bid differently to their marginal costs and thereby increase their profit level. They could thereby unduly increase their compensation.

3.3.2 Assessment

Strategic bidding. The scheme provides obvious incentives to increase compensation by changing bids if units can anticipate the marginal unit. The rents that can be captured here are exactly equivalent to the rents captured by inc-dec gaming in redispatch markets (Hirth & Schlecht, 2020). How strategic bidding in this scheme works is highlighted in the examples in

Box 2. No obvious remedies (other than using costs, not bids, as basis for compensation – see next variant (4) for this) exist to our knowledge.

Box 2: Examples for strategic bidding in scheme 3

Two examples based on the model from Section 2 clarify the strategies.

- A 1 MW plant in the North with marginal costs of 70 €/MWh
    - The unit could bid 31 €/MWh to increase its compensation relative to true cost bidding.
    - Given the Northern Dispatch Hub price of 30 €/MWh, it would not be dispatched – its high variable costs are therefore irrelevant.
    - Given the zonal price of 50 €/MWh, it would be compensated 19 €.
    - The risk for the plant is that the price on the hub turns out to be higher than expected (e.g. 32 €/MWh). Then the plant must run and incurs a loss.
- A 1 MW plant in the South with marginal cost of 10 €/MWh
    - The unit could bid 59 €/MWh to decrease the negative compensation relative to true cost bidding.
    - Given the Southern Dispatch Hub price of 60 €/MWh, it would be dispatched.
    - Despite the additional profits compared to the zonal market that clears at 50 €/MWh, it would only have to withdraw 1 € and not its true additional revenue of 10 €.
    - The risk for the plant is that the price on the hub turns out to be lower than expected (e.g. 58 €/MWh). Then the plant is not scheduled and makes no profits, compared to the high profits it would make under true cost bidding.

Market power. There is significant potential for the abuse of market power. Compared with scheme 1, where incentives for the abuse of market power are the highest, in this scheme they are to some degree softened. This is because, in the South, the higher the price, the higher the negative compensation becomes, taking away the price increases. However, as shown above, units can bid strategically to reduce negative compensation. Therefore, together with strategic bidding, units can exercise market power profitably. The necessity of strategic bidding comes at an additional risk, so it is likely to reduce the expected profitability of the exercise of market power relative to scheme 1, but market power remains a significant problem in this scheme.

(Dis-)Investment. For new assets, correct investment incentives could be provided by placing them in Dispatch Hubs but not compensating them. For existing assets, in the rational perfect-foresight equilibrium, this scheme leads to higher rents compared to the zonal market on both sides of the constraint, North and South. In the North, it therefore increases the (already too high in the zonal market) incentives to keep assets running that would not be profitable at locational prices and thereby delay decommissioning. In the South, the extra rents from strategic bidding have a positive effect on preventing disinvestments. If units bid strategically (and are able to anticipate the marginal unit correctly), they can increase their level of rents to the level that induces optimal (dis-)investment incentives. This is because strategic bidding for Southern plants effectively makes them capture the full locational rent – and avoid the negative compensation to zonal level. Market power would increase that level of rents even further above the optimal level.

Distribution. Units that do not behave strategically and always bid their marginal costs have unchanged profits compared to the zonal market. However, rationally bidding units increase their profits – both North and South of the constraint. These are windfall profits to the units that must be borne by ratepayers.

Asset types. If strategic bidding is accepted, this compensation scheme is suited to accommodate all asset types, including loads and storages, as compensation is only based on bids and not on costs, which would be harder to assess.

3.4 (4) Mandatory cost-based hourly compensation

3.4.1 Characterization and intention

Like scheme 3, units are compensated (or charged) ex-post hour-by-hour to make them earn as much as they would in the zone. However, compensation is based on (estimated) costs, rather than bids.

Intention. The intention of this scheme is to compensate units to reach zonal profit levels yet remove incentives for strategic bidding by disentangling the unit's compensation from its actions within the Dispatch Hub. The idea is to mimic an economic lump-sum compensation, i.e. a compensation that appears as a fixed block that cannot be influenced by the unit.

Compensation rule. Units earn their revenues on the Dispatch Hub plus (or minus) an hour-by-hour compensation based on prices, dispatch and estimated costs to make them reach the same profit level (neither more, nor less) they would have earned in the zonal markets. For each hour, and for a single plant, the compensation formula is:

$$(\max(vc_{estimate}, P_z) - \max(vc_{estimate}, P_h))\ capacity_p$$

where $vc_{estimate}$ is the TSO's estimate of variable cost of the power plant, P_z is the price in the zone, P_h is the price on the hub and $capacity_p$ is the plant's capacity.

Profit function. The profit function is composed of the revenue on the Dispatch Hub, production costs and compensation.

$$\pi = Q(P_h - vc) + (\max(vc_{estimate}, P_z) - \max(vc_{estimate}, P_h))\ capacity_p$$

Compensation independent from production. Note that compensation does not depend on the actual production decision Q, because compensation is based on estimated variable costs and on what production decision would be expected given the estimated variable costs (the latter is part of the logic of the *max* formula). This has the (convenient) feature that compensation becomes independent from the unit's actions within the Dispatch Hub.

Cases. Spelled out for individual cases, and with *optimal* production (Q) decisions assuming $\mathrm{vc} = \mathrm{vc}_{\mathrm{estimate}}$, the profit function becomes:

$$\pi_{optimal}^{North} = \begin{cases} Q(P_h - vc) + (P_z - P_h)\ capacity_p & \textbf{if } vc_{estimate} < P_h < P_z \\ (P_z - vc_{estimate})\ capacity_p & \textbf{if } P_h < vc_{estimate} < P_z \\ 0 & \textbf{if } P_h < P_z < vc_{estimate} \end{cases}$$

$$\pi_{optimal}^{South} = \begin{cases} Q(P_h - vc) + (P_z - P_h)\ capacity_p & \textbf{if } vc_{estimate} < P_z < P_h \\ Q(P_h - vc) + (vc_{estimate} - P_h)\ capacity_p & \textbf{if } P_z < vc_{estimate} < P_h \\ 0 & \textbf{if } P_z < P_h < vc_{estimate} \end{cases}$$

Desirable feature 1: Removal of market power. The resulting profit function has two highly desirable features. First, it removes local market power (if cost estimates are right, i.e. $\mathrm{vc} = \mathrm{vc}_{\mathrm{estimate}}$), as the hub price cancels out of the profit function. If cost estimates are wrong, incentives to exercise market power are still reduced and only apply to the degree that cost-estimates are wrong.

Desirable feature 2: Efficient dispatch even if cost-estimates are wrong. Second, the dispatch in this scheme remains efficient even if the TSO's cost estimates are wrong. If the TSO's cost estimate is not correct (e.g. because there is information asymmetry between the unit owner and the TSO), this only affects the compensation, not the plant's production decision. The incentives are such that the plant's production decision is still subject to the local price signal, even if the TSO's cost estimates deviate from the true costs. This enables efficient self-dispatch – despite the cost-based nature of compensation. Box 3 provides examples for compensation in this scheme.

Box 3: Examples of cost-based compensation in scheme 4

Three examples, based on the model from section 2, clarify these desirable features.

- Example 1: No market power, despite dominant firm in the Southern Dispatch Hub.
  - Assume all units in Southern dispatch hub with variable costs from 50 to 60 €/MWh belong to the same company.
  - These units are each 1 MW in size and have variable costs increasing in steps from 50 to 60 €/MWh and the TSO has a correct estimate of these.
  - Additionally, there is one competing 1 MW power plant in the Southern dispatch hub by a different company at variable costs of 70 € MWh.
  - Assume the *competitive* Southern clearing price to be 60 €/MWh.
  - At the same time, the zonal price is 50 €/MWh and does not change.
  - ➔ Bidding higher than variable cost – e.g. all units at 69 €/MWh – would not be profitable for the firm, as with increasing hub prices and thereby increasing revenues, compensation payments from the unit to the TSO ("negative compensation") also increase – exactly offsetting the revenue gain, so the units would be left with the zonal profits (0 €) even if they exercise market power.
  - ➔ If the firm tries to raise prices even further, e.g. by just pricing its 60 €/MWh variable cost unit with a bid of 80 €/MWh, it would even lose, as this would mean the competitors' 70 €/MWh plant would enter the market instead and be price-setting at 70 €/MWh with the firm's unit not being dispatched. Since the TSO's cost estimate of the plant is 60 €/MWh, the TSO would still ask for "negative" compensation payments of -10 €/MWh (regardless of whether the plant was running), as the TSO would have expected it to run at the clearing price of 70 €/MWh.
- Example 2: Efficient dispatch, despite wrong TSO cost estimates.
  - Assume the TSO estimates a Southern plant to have variable costs of 59 €/MWh, but the true variable cost is 70.
  - Given the Southern clearing price of 60 €/MWh, the TSO would expect the unit to run and make a profit of 1 €/MWh (i.e. 1 € more than the zero profit it would have made on the zonal market), which it would ask the unit to withdraw regardless of its actions on the Dispatch Hub (i.e. regardless of whether the unit actually choses to run or not)
  - Given its knowledge about the true variable cost of 70, the unit decides not to run in the Dispatch Hub. This is its optimal decision, yet it must still withdraw the 1 € that the TSO had expected the unit to earn. This means, the TSO's estimation error had distributional consequences (imperfect compensation) but the dispatch remained efficient with the (unexpectedly expensive) unit having decided not to run. This is an important efficiency advantage over, say, cost-based redispatch, where information asymmetries in cost estimation lead to flawed redispatch merit-orders that cause suboptimal units to be dispatched.

Difficulty of cost estimation. While cost-estimation might be feasible (even if not perfect) for most conventional units as their cost-structure is relatively simple and mainly depending on plant characteristics, fuel costs and CO2 prices, for other plant types it is more difficult if not impossible to estimate variable costs. Among these units are in particular storage assets (batteries, pumped-storage) and loads. For storage, costs depend on the opportunity cost of storage content, which largely depends on the operation pattern chosen by the storage operator. For load variable costs of load curtailment depend on the opportunity costs of forgone production, which is almost impossible to estimate objectively by the TSO or regulator. This means, the scheme will not be possible for load entities and difficult for storage assets. In this aspect, it shares a key disadvantage with cost-based redispatch.

3.4.2 Assessment

Strategic bidding. There are no incentives for strategic bidding in this scheme. As compensation does not depend on actual bids of the unit (except through prices on the hub), a (small, atomistic) unit without market power cannot increase compensation by strategic behavior.

Market power. Units in this scheme normally do not have an incentive to abuse market power. This is because the hub price P_h cancels out of the profit function if cost estimates are right. Only if cost estimates are wrong, there could be an incentive to increase prices, but only to the extent to which cost estimates are wrong. This means, that locational market power stays in the very limited boundaries of the TSO's cost estimation error.

(Dis-)Investment. For new entrants, correct investment incentives could be provided by not compensating new units. For existing assets, dis-investment incentives equal the incentives in the zonal market. Therefore, there is a lack of decommissioning North and too high pressure to decommission in the South. Arrangements for phasing out compensation could provide incentives over time.

Distribution. If cost estimates are correct, then units placed in the Dispatch Hub are neither better nor worse off from being placed in the Dispatch Hub, so there are no significant distributional effects for these units.

Asset types. This compensation scheme is well-suited to integrate units with a relatively straightforward to assess cost-structure, but not feasible for units such as loads or small-scale storages, where the willingness to pay or variable costs are not possible to assess objectively. This is because compensation depends on cost estimates – and where these are not possible, units cannot be compensated based on this scheme. One advantage in terms of the informational needs of this scheme compared to e.g. cost-based redispatch in the status quo market design is that even if cost-estimates are not precise, the dispatch will still remain efficient and only compensation might be imprecise. In that regard, some more asset types might be possible to integrate even under this approach than in today's cost-based redispatch.

3.5 (5) Voluntary ex-ante auction

3.5.1 Characterization and intention

In this variant the TSO holds procurement auctions for procuring units to enter the Dispatch Hub for a fixed period (e.g. a year). Once in the Dispatch Hub, units do not get any further compensation but face the locational Dispatch Hub price for their generation. The TSO selects the cheapest units in a uniform clearing auction.

Intention. The idea of this scheme is that units are not forced into the Dispatch Hub but can freely chose to enter or stay away from it. This is to also enable flexibilities such as load or storages to participate, for which the cost structure is not well-known, and to avoid negative distributional impacts for units placed in the Dispatch Hub (and thereby avoid the political and legal challenges the selection of units into Dispatch Hub would otherwise cause). A hope is that by running an auction and fostering competition, there would not be over-compensation and units would join once they are marginally better off in the Dispatch Hub than in the zone (which we show to not be the case and instead significant infra-marginal rents to occur).

Compensation rule. Units voluntarily bid into an auction in which the TSO procures generation capacity to enter the Dispatch Hub. There could be one auction per year with annual validity (decision to enter the Dispatch Hub for one year). Once units enter a Dispatch Hub, they no longer operate in the zonal market but operate in the Dispatch Hub instead and their operational production decisions face the Dispatch Hub price. Compensation does not change based on what happens within the year, so units must have good anticipation of what profit impacts entering a Dispatch Hub will have for them.

3.5.2 Assessment

Strategic bidding. In the hourly energy market within the Dispatch Hub, there are no strategic bidding incentives in this scheme. However, this scheme enables units to bid strategically in the entry auction to reap significant windfall profits. This is because units in the North anticipate that the last unit in the North to be procured for entering the Dispatch Hub will ask for a minimum compensation of the full price differences (summed up over all hours of the year) between the Northern hub price and the zonal price. In the South, units anticipate that the last unit to be procured to enter the Dispatch Hub will not be willing to pay anything for being placed in the Dispatch Hub – so in anticipation of that, all other units also do not provide a positive bid even though Dispatch Hub participation gives them significant extra profits. As these are possible even for atomistic (small) units, we conclude that strategic bidding incentives are present and significant under this scheme.

Strategic bidding: Bidders anticipate marginal unit. In a non-discriminatory auction in which the other units anticipate who the marginal price-setting unit in an auction for entry into Dispatch Hubs will be, they will not have an incentive to undercut that price, even if they would be able to bid cheaper given their own cost structure. This means, all units would reap the full compensation of, in our model, 20 €/MWh in the North and no unit would pay negative compensation in the South. This means all units in the South eventually receive the Southern Dispatch Hub price without having to pay their additional profit back. In the North, it means all units could receive the full price difference between zonal and Dispatch Hub price as compensation, even if they do not incur profit changes of that amount. This is especially striking for plants that would never run in either zonal or Dispatch Hub market, such as the Northern Diesel power plants. They would be compensated without ever running, which could even provide incentives to invest in such "ghost power plants" to capture rents.

Market power. There is market power both in the entry auction stage as well as in the Dispatch Hub operation. In the auction, a unit knowing that it is among the few ones to be available for placement in the Dispatch Hub could ask higher than competitive prices as compensation for Dispatch Hub entry. During operation, the price on the Dispatch Hub factors directly into the unit's profits, which again provide incentives to increase the price above the competitive level.

(Dis-)Investment. For new entrants, correct investment incentives could be provided by not compensating new units. For existing assets, in the rational perfect-foresight equilibrium, this scheme leads to higher rents on both sides of the constraint. In the North, compared with the zonal dis-investment incentives, which are already inefficiently low, dis-investments are even less incentivized because units make additional profits. In the south, rents reach the optimal level in the absence of market power, because through strategic bidding units reap exactly the locational rent – although in reality this level will never be reached exactly because strategic bidding might be risky if units cannot anticipate the marginal unit correctly.

Distribution. There are significant additional profits for units from this scheme and higher costs to TSOs and ratepayers. The distributional effects could also heavily rely on units' ability to predict prices on Dispatch Hubs, which will be especially challenging in the beginning of Dispatch Hub operations as well as following any reconfiguration.

Asset types. This compensation scheme is suited for all asset types including loads and small-scale storages, if the large windfall profits for units bidding strategically are accepted. The scheme does not have any advanced informational needs for TSOs and instead relies on bids of market participants, so it is possible even under information asymmetry. The difficulty of predicting market prices on Dispatch Hubs however makes bidding difficult for all asset types.

3.6 (6) Voluntary cost-based offer

3.6.1 Characterization and intention

In this variant the TSO offers units to enter the Dispatch Hub for a fixed period (e.g. a year) under a cost-based compensation scheme ("compensation rulebook") plus a fixed participation premium. The scheme can best be described comparing it with two other schemes, 5 and 4. Like 5, this is a voluntary scheme that units can either accept or reject and their decision is valid for a predefined time period (e.g. a full year). However, unlike 5 (where units can choose their desired price in a e.g. yearly participation auction) units get an offer, in which the TSO proposes a compensation rulebook that is identical to the cost-based compensation of scheme 4 plus an additional fixed premium to make it attractive to accept the offer. If units reject the offer, they remain in the zonal market and face cost-based redispatch.

Intention. The intention of this scheme is to combine the advantages of schemes 4 and 5 by being a voluntary scheme (like 5) but eliminating most windfall profits by being cost-based (like 4). It also shares with 4 the positive side-effect that the compensation rules remove locational market power but still make units efficiently self-dispatch according to local price signals. The self-dispatch alone is a significant advantage over cost-based redispatch as it means dispatch will be efficient even if the TSO's cost-estimates are incorrect.

Compensation rule. The compensation in this scheme largely equals the compensation from scheme 4, with the only difference of an additional fixed participation premium. We denote the hourly equivalent of the annual participation premium with fix. For each hour, and for a single plant, the compensation formula is:

$$(\max(vc_{estimate}, P_z) - \max(vc_{estimate}, P_h))\ capacity_p + fix$$

Participation premium. The participation premium fix would need to be set in a way that it is as small as possible (to avoid large windfall profits at the expense of rate payers) but large enough so that it would incentivize participation. Since even in the absence of the participation premium the compensation should already be acceptable for the units, the premium can likely be small. It is needed to make the unit slightly better off than not accepting the offer. To achieve this, at least the transaction costs and any other forgone profits (i.e. from balancing) would need to be covered by the participation premium, plus a small extra premium. Therefore, in realistic settings the extra premium will likely be much smaller than the first part of the compensation formula which covers the energy price differential.

Profit function. The profit function is composed of the revenue on the Dispatch Hub, production costs and compensation.

$$\pi = Q(P_h - vc) + (\max(vc_{estimate}, P_z) - \max(vc_{estimate}, P_h))\ capacity_p + fix$$

Compensation independent from production. As in 4, compensation again does not depend on the actual production decision Q, because compensation is based on the fixed premium, estimated variable costs and on what production decision would be expected given the estimated variable costs.

Cases. Spelled out for individual cases, and with *optimal* production (Q) decisions and assuming $\mathrm{vc} = \mathrm{vc}_{\mathrm{estimate}}$, this becomes:

$$\pi_{opt}^{North} = \begin{cases} Q(P_h - vc) + (P_z - P_h)\ capacity_p + fix & \textbf{if } vc_{estimate} < P_h < P_z \\ (P_z - vc_{estimate})\ capacity_p + fix & \textbf{if } P_h < vc_{estimate} < P_z \\ 0 + fix & \textbf{if } P_h < P_z < vc_{estimate} \end{cases}$$

$$\pi_{opt}^{South} = \begin{cases} Q(P_h - vc) + (P_z - P_h)capacity_p + fix & \textbf{if } vc_{est} < P_z < P_h \\ Q(P_h - vc) + (vc_{est} - P_h)capacity_p + fix & \textbf{if } P_z < vc_{est} < P_h \\ 0 + fix & \textbf{if } P_z < P_h < vc_{est} \end{cases}$$

Price discrimination. Effectively, this scheme is an attempt at preventing the high rents that occur in scheme 5 through effective price-discrimination. Instead of paying the same compensation to all units (as in scheme 5), here the total yearly sum of compensations for a unit depends on the estimated variable cost of the unit (as well as market outcomes). The highest compensation is paid to those units that lose most from Dispatch Hub participation while units that are indifferent to Dispatch Hub participation are also not compensated (apart from the fixed participation premium).

3.6.2 Assessment

Strategic bidding. As in scheme 4, there are no incentives for strategic bidding. As compensation does not depend on actual bids of the unit (except through prices on the hub), a unit without market power cannot increase compensation by strategic behavior.

Market power. As in scheme 4, units normally do not have an incentive to abuse market power. This is because the hub price P_h cancels out of the profit function if cost estimates are right. Only if cost estimates are wrong, there could be an incentive to increase prices, but only to the extent to which cost estimates are wrong. This means, that locational market power stays in very limited boundaries.

(Dis-)Investment. For new entrants, correct investment incentives could be provided by not compensating new units. As in scheme 4, for existing assets, dis-investment incentives equal the incentives in the zonal market – assuming the fixed participation premium fix is small enough to be irrelevant as a (dis-)investment signal. Therefore, there is a lack of decommissioning North and too high pressure to decommission South of the constraint.

Distribution. As in scheme 4, if cost estimates are correct, then units placed in the Dispatch Hub are – given the participation premium fix – just slightly better off from being placed in the Dispatch Hub, so there are small but not significant distributional effects for these units.

Asset types. Like scheme 4, this compensation scheme is well-suited to integrate units with a relatively straightforward to assess cost-structure. Comparing with scheme 4, it is slightly better at integrating flexibilities such as storages and loads, because of its voluntary nature. That means, even if costs are hard (but to some degree possible) to estimate, it could be a feasible scheme. In that case TSOs would make cost-based offers based on rough cost estimates and loads or storages could decide if they want to take this offer. This could come at the expense of some windfall profits for these unit types where costs are hard to estimate, but would have the advantage of integrating these units into congestion management, which could provide welfare gains.

4 Compensation in Redispatch Potential variant

In this section we analyze compensation in the Redispatch Potential Dispatch Hub variants. We look at two different Redispatch Potential variants of Dispatch Hubs, a cost-based and a market-based alternative. The core difference in the Redispatch Potential variant compared to Market Bids Dispatch Hubs is that here units do not bid directly into the Dispatch Hub but instead remain in the zonal market. The TSO then bids the redispatch potential of these units into Dispatch Hubs to enter the Market Coupling. We keep the analysis short, because the setting is identical to the one in our earlier study on redispatch markets (Hirth & Schlecht, 2020, and Neon & Consentec, 2019). We refer to that material for an in-depth analysis.

4.1 (7) Mandatory redispatch potential, cost-based

4.1.1 Characterization and intention

Intention. The intention of this scheme is to introduce Dispatch Hubs with as little change to the current market setting as possible, which could be feasible in a shorter-term than the alternatives. Cost-based compensation aims to prevent strategic bidding.

Compensation rule. Units earn their revenues on the zonal market and get cost-compensated if they are redispatched. In the South, if they chose not to run in the zonal market but were redispatched up, they get their variable cost compensated. In the North, if they chose to run in the zonal market, but are redispatched down, they must withdraw their saved variable costs to the TSO but keep the zonal profit.

4.1.2 Assessment

Strategic bidding. There are no incentives for strategic bidding in this scheme if cost and volume estimates are accurate. This is because units are in that case financially indifferent to redispatch, so they have no incentive to behave to make redispatch more or less likely. In case of inaccurate cost or volume estimates, units might however have such an incentive, which could go in either direction depending on the direction of the estimation error. If TSO cost estimates are above the true costs, then it might be beneficial for a Southern unit to provoke upward redispatch and vice versa for Northern power plants. However, this incentive is limited to the extent that cost and volume estimates are wrong and is likely to be significantly smaller than in market-based approaches where bids are free.

Difficulty of cost estimation. The same caveats regarding the difficulty of cost-estimation from scheme 4 also apply here. This means, that the scheme is difficult or not feasible for some flexibilities such as storage assets (batteries, pumped-storage) and loads.

Cost-estimates determine dispatch. A key disadvantage in this scheme compared to the cost-based Market Bids variant (scheme 4 and 6) is that here the final redispatch is determined by the TSOs and actual physical dispatch is based on the redispatch merit-order of the TSO. That means, inaccuracies in cost estimation result in a welfare loss. This is not the case in the Market Bids variants where units self-dispatch.

Market power. Units in this scheme remain in the zonal market and do not enter a smaller locational market. Therefore, they cannot influence a locational price. Market power is therefore constrained to the same market power any other actor in the zonal market obtains, but there is no specific locational market power.

(Dis-)Investment. In terms of (dis-)investment incentives, this scheme reaches the same incentives as the existing zonal market. It therefore leads to over-investment (or lack of decommissioning) North and under-investment (or premature decommissioning) South.

Distribution. If cost estimates are correct, then units redispatched as part of the Dispatch Hub are neither better nor worse off, so there are no significant distributional effects for these units.

Asset types. This compensation scheme is well-suited to integrate units with a relatively straightforward to assess cost-structure, but not feasible for units such as loads or small-scale storages, where the willingness to pay or variable costs are not possible to assess objectively. It is therefore equally restricted in its applicability to asset types as scheme 4. However, the importance of correct cost estimates is even higher in this scheme, as in this scheme even the final dispatch depends on the cost estimates and not only compensation.

4.2 (8) Voluntary redispatch potential, market-based

4.2.1 Characterization and intention

Intention. The intention of this scheme is to enable all types of assets (generators, but also flexibilities such as storages or load) to participate in Dispatch Hubs without leaving the zonal market.

Compensation rule. Units earn their revenues on the zonal market and additionally participate in redispatch markets. In the redispatch markets, they provide bids to be ramped up or down. Participation in redispatch markets is voluntary and the price can be freely chosen by market participants.

4.2.2 Assessment

Strategic bidding. In principle, this scheme offers the same strategic bidding incentives to market based redispatch outside of the Dispatch Hub context. Therefore, inc-dec strategies are possible and congestion in the zonal market is aggravated – even if solved simultaneously in the Market Clearing by means of the Dispatch Hubs. However, the introduction of Dispatch Hubs might change redispatch market prices in either direction, so the outcome is not strictly identical, even if the same underlying incentives remain.

Market power. In addition to strategic bidding, there is locational market power, if units in the South would anticipate their scarcity. This effect comes on top of the strategic bidding incentives.

(Dis-)Investment. (Dis-)investment incentives in this scheme are distorted. In the North, the additional profits from inc-dec strategies increase rents further from the zonal level, and thereby aggravate the over-investment (or lack of decommissioning) in the North. In the South, rents reach the optimal locational Southern rent if all units engage in inc-dec gaming, without exercising market power. If units in the South exercise market power in addition to inc-dec gaming, rents are above the optimal locational level.

Distribution. All units would win (at the expense of the TSO and thereby ratepayers) in this scheme. This is because inc-dec gaming increases rents across the board and the locational market power in scarcity regions aggravates the problem.

Asset types. This compensation scheme is suited for all asset types including loads and small-scale storages, if the large windfall profits for units bidding strategically are accepted. The scheme does not have any advanced informational needs and instead relies on bids of market participants, so it is possible even under information asymmetry.

5 Discussion and recommendations

There is no silver bullet compensation scheme. Every scheme comes with disadvantages and problems, which we summarize, discuss, and compare in the following. We start with four lessons learnt from the analysis of individual compensation schemes, before comparing all schemes and pointing out our recommendations.

Cost-estimates decouple compensation from dispatch decision. A favorable feature of the cost-based schemes 4 and 6 is that compensation in these schemes is independent from the actual bids and dispatch decision of units (without market power) within a Dispatch Hub. This is desirable, not only because it removes the incentive for strategic bidding, but also because it leads to efficient dispatch decisions even if cost-estimates are wrong. The latter would be a strong advantage also compared with cost-based redispatch in the status-quo market design.

Cost-based compensation curbs market power. We also find that cost-based compensation schemes for Market Bids Dispatch Hubs not only curb strategic incentives to increase compensation, but also curb locational market power while retaining the advantage of self-dispatch according to the locational prices on the Dispatch Hub. Thereby, Market Bids Dispatch Hubs with cost-based compensation schemes offer a tool to enable locational self-dispatch without locational market power and strategic incentives. The downside of cost-based schemes is that cost estimates are not available for all flexibility types.

Voluntary auctions attract the wrong units first. A conclusion of our analysis of scheme 5 is that a voluntary, non-discriminatory auction would attract the least favorable units for inclusion in Dispatch Hubs first. These are expensive plants in the North (which do not run in the zonal market in most hours anyway) and cheap baseload plants in the South. Both have nothing to lose (or much to win) from being included in a Market Bids Dispatch Hub, but do not improve the congestion situation. This is because they would already be in their most desirable system state for congestion relief in a zonal market. There seems to be no easy way out. Adding minimum availability ("upward margin"/"downward margin") requirements for eligibility in the Dispatch Hub entry auction would again have undesirable effects: It would lead to overly expensive units for congestion management as the best units would be excluded. This is because the best units for congestion management are those available units with variable costs close to the zonal clearing price – which often do not meet high availability thresholds.

Voluntary (selective) schemes risk suboptimal welfare results. Selective Market Bids Dispatch Hubs that include some units but not other units with similar variable costs risk resulting in situations where the final dispatch is not efficient. This is because congestion might then be solved fully by the units in the Dispatch Hub, even if they might not always be the cheapest to do so. Therefore, care must be taken in selecting units into Dispatch Hubs – and entry schemes must find ways to avoid this effect. Mandatory entry could be a solution. Another could be to complement Market Bids Dispatch Hubs with redispatch potential TSO bids.

5.1 Comparison of compensation schemes

Every scheme comes with disadvantages and problems, which we summarize, discuss, and compare in the following. Table 2 provides an overview of the assessment results.

Table 2: Overview of assessment results

	Scheme	Market power	Strategic bids	Distribution	Flexible assets	Promising
1	Mandatory without compensation	Yes	No	Strong Winners/losers	Yes	Yes
2	Mandatory Financial Transmission Rights	Reduced	No	Moderate winners/losers	Yes	Yes
3	Mandatory bid-based hourly	Yes	Yes	All units win	Yes	No
4	Mandatory cost-based hourly	No	No	Close to zonal	No	Yes
5	Voluntary ex-ante auction	Yes	Yes	All units win	Yes	No
6	Voluntary cost-based offer	No	No	Slight wins	Partly	Yes
7	Redispatch potential, cost-based	No	No	Close to zonal	No	Yes
8	Redispatch potential, market-based	Yes	Yes	All units win	Yes	No

Market power. All Market Bids variants provide incentives to exercise market power in the operation stage of the Dispatch Hub, for the simple fact that Dispatch Hubs are small. However, in some of the schemes, compensation almost eliminates those incentives (Figure 9). Full incentives for the abuse of locational market power remain in schemes 1, 3, 5 and 8, where they would need to be addressed through mitigation measures such as price caps or increased regulatory scrutiny. In scheme 2 incentives are reduced by the extent units are (to some degree) shielded from the locational price by the FTR contract. Schemes 4, 6 and 7 shield units from the locational price almost completely, and thereby almost eliminate the incentives to abuse market power: essentially, if generators inflate the Dispatch Hub price, they do increase their revenues from selling electricity but at the same time reduce the compensation accordingly. The incentives in these schemes only remain to the extent that cost estimates are inaccurate. Therefore, cost estimations in these schemes are a tool to curb locational market power.

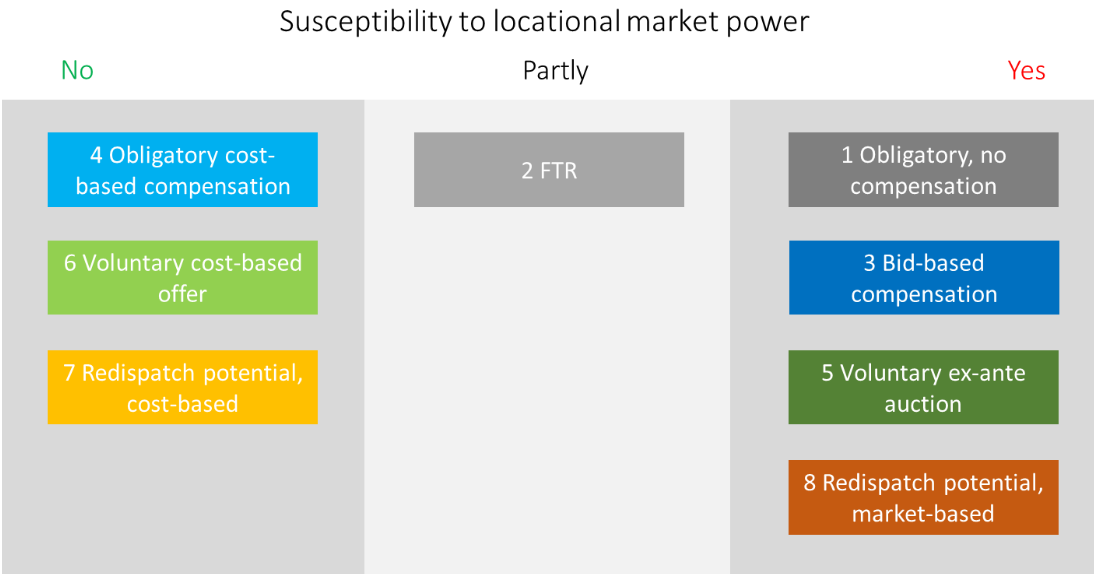

Figure 9. Susceptibility to locational market power

Strategic bidding. Some compensation schemes allow market parties to extract rents in an unintended way, even if they do not possess any market power. We have called such behavior "strategic bidding" in this report. Strategic bidding is possible in schemes 3, 5 and 8. In these schemes, if units can make predictions about the marginal unit, they are able to reap significant additional rents compared to the intended zonal ones. The schemes therefore lead to an over-compensation of units in Dispatch Hubs if parties behave rationally.

Compensation independent from bids. Such strategic bidding incentives are absent from those schemes in which compensation is independent from bids, i.e. market parties lack the possibility to impact compensation through their own bidding and production decisions (other than through its influence on the price, which is discussed separately under market power). Schemes 4, 6 and 7 use cost estimates to calculate the compensation (both price- and volume-wise) and hence do not provide room for strategic bidding. Decoupling compensation from bids has the advantage that it prevents gaming and, for the market-bids variant, leads to efficient dispatch decisions based on the Dispatch Hub prices. It does, however, require estimating the underlying production costs, which is difficult particularly for energy storage and loads.

Distribution. Some schemes imply significant distributional consequences, i.e. produce economic winners and losers relative to the zonal market (Figure 10). These distributional consequences can either be by design or result from the strategic bidding discussed above.

- Distributional consequences by design are present in scheme 1, which does not compensate units moved to a Dispatch Hub. This makes some units better, some worse off from being moved to Dispatch Hubs.
- Distributional consequences from strategic bidding are present in schemes 3, 5 and 8. In these schemes, the distributional changes are always beneficial to all participating units and come at the expense of ratepayers.
- The least distributional consequences compared to being in the large zone can be expected from all schemes that rely on cost estimates to compensate to zonal level. These are schemes 4, 6 and 7. As voluntary schemes need at least some participation incentive, scheme 6 allows units slightly higher rents than the other cost-based schemes by means of its fixed participation premium.
- The FTR compensation (2) creates winners and losers, but partly compensates towards zonal rents.

In addition to these effects, any change to the zonal prices (outside the Dispatch Hub) compared to the status quo will also have distributional implications compared to the status quo for all schemes that compensate units. These are not depicted in Figure 10 because the reference is the zonal market that exists concurrently to Dispatch Hubs.

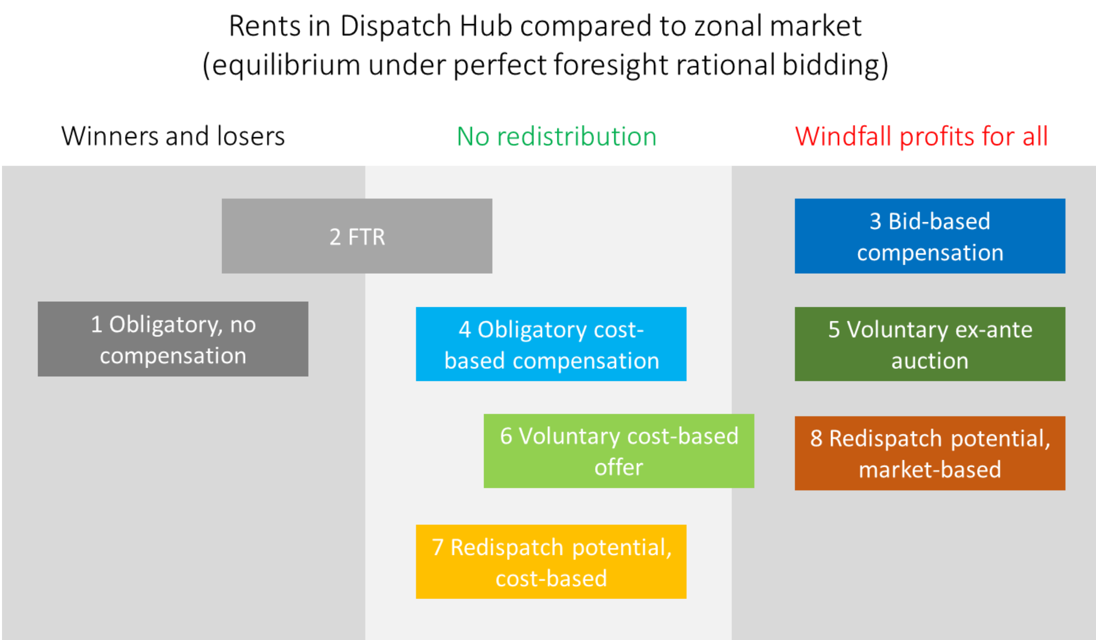

Figure 10: Distributional effects of compensation schemes

Asset types. The schemes vary regarding which asset types they are suitable for. Some schemes require regulatory estimates of costs (4, 6 and 7). Such estimates are relatively straightforward for large thermal units such as fossil condensing plants, but more difficult for flexible units including storage, consumers, and peaking plants, but also combined heat and power plants. Therefore, these schemes are not well suited for these types of units. An exception could be scheme 6, the voluntary cost-based offer, which relies on cost estimates, but at the same time is voluntary, so that units could still chose whether to accept the cost estimates or not. This means the scheme could work even if cost estimates would be rough.

For all compensation schemes that do not require cost-estimates, integration of all asset types is straightforward (schemes 1, 2, 3, 5 and 8). The feasibility of the different compensation schemes for units with hard-to-estimate cost structure is depicted in Figure 11.

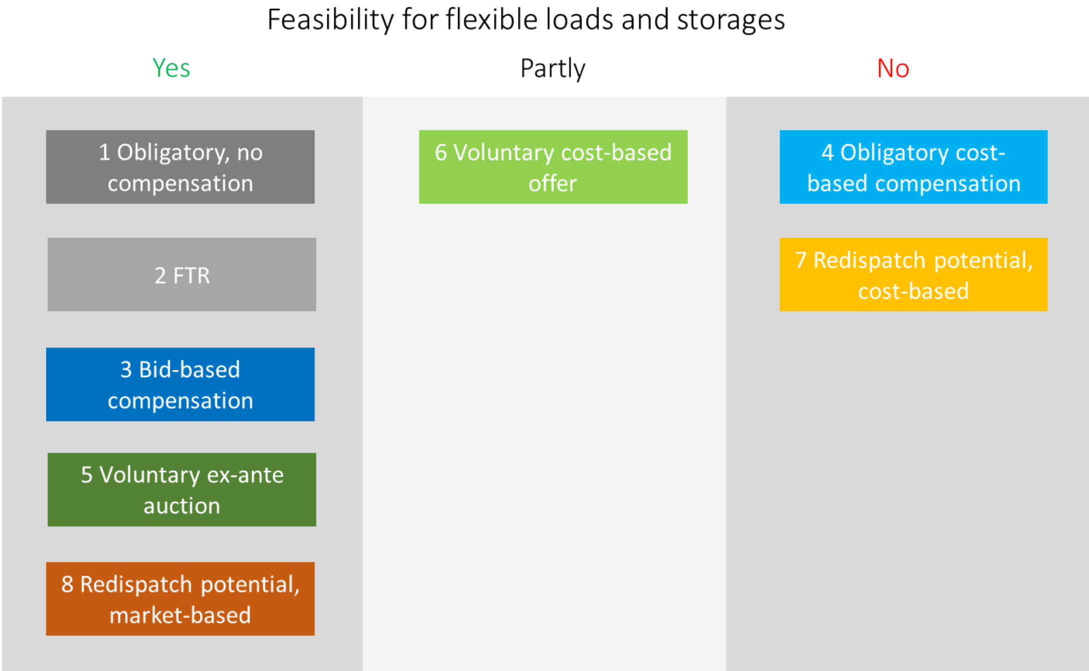

Figure 11: Feasibility to integrate new unit types into congestion management.

(Dis)investment incentives. The rents units earn under the different schemes (shown in Figure 10) also determine incentives for new investments and plant closures. The schemes creating winners and losers (scheme 1, but also to some extent 2) provide the best (dis-)investment incentives, as they lead to lower rents in surplus and higher rents in scarcity regions. Schemes with rents like zonal lead to unchanged (dis-)investment incentives compared to the zonal market. Schemes providing higher rents to all units create the optimal (dis-)investment incentives in the South but lead to increased overinvestment (or increased lack of decommissioning) in the North, as even Northern units earn more under those schemes that yield strategic bidding incentives. It should be noted that not only the existence of such price signals per se, but also the credibility and long-term stability of such signals determine their effectiveness in stimulating (dis-)investment.

Efficiency. There are differences in the economic efficiency that can be achieved with Dispatch Hubs across the compensation schemes. The differences in economic efficiency stem from three factors present in some schemes: Market power, lack of self-dispatch and selectiveness.

- Market power (if exercised and not prevented by regulatory measures) can reduce economic efficiency if a Dispatch Hub's residual demand is elastic. Financial or physical withholding of generation capacity in Dispatch Hubs could lead to either economically efficient demand to retract or inefficient plants inside or outside of Dispatch Hubs to produce at higher variable cost to substitute withheld generation capacity. Such inefficiencies could occur in schemes 1, 3, 5, 8 (and to some degree 2) if market power is not prevented by regulatory measures.

- Self-dispatch, which is desirable from an efficiency perspective, is present in all but one of the compensation schemes we analyze, even in those where cost-estimates are used to calculate compensation. Only in scheme 7, regulatory TSO cost-estimates are used to schedule power plants. This can result in an inefficient dispatch in case of information asymmetries between the plant owner and the TSO about variable costs.
- Market Bids Dispatch Hubs are meant to be selective, i.e. to only include plants most relevant to congestion management. If the right plants are selected, this is unlikely to impede efficiency. This fixed selection of plants assumes that those relevant to congestion management are relatively stable over time. However, schemes in which plants voluntarily decide to join a Dispatch Hub risk missing some plants that would be most efficient to solve congestion. Then congestion will be solved by suboptimal plants, leaving some more efficient ones unused. This is reducing the efficiency of voluntary schemes 5 and 6.

5.2 Recommendations

There is no compensation scheme that solves all problems. Choosing the right compensation for Dispatch Hub participants involves trade-offs and weighting different objectives against each other. In this sense, it is ultimately a political decision.

We recommend discarding those schemes that create strategic bidding incentives. This is the case for 3, 5, and 8.

The remaining compensation schemes offer a stark choice:

- Scheme 1 has many attractive features, in particular because it does not provide strategic incentives, because it works well with all technologies, and because of the investment signals it provides. It will, however, lead to strong redistributive effects and provides incentives to abuse market power, and investment signals hinge on credibility. Scheme 2 mitigates some of the effects, but still creates winners and losers.
- Schemes 4, 6 and 7 do not create strategic incentives either, because compensation is based on cost estimates. This has the attractive side effect that market power is mitigated. However, it will be difficult to include flexibility resources, in particular loads, in these schemes, because of the challenge of accurate cost estimates. The choice between 4 and 6 will ultimately be determined by the willingness (and feasibility) to make dispatch hub participation an obligation. Among the mandatory schemes 4 and 7, scheme 4 has the advantage of self-dispatch, which results in efficient dispatch decisions even if cost-estimates are inaccurate, but it is selective (which scheme 7 is not), so the efficiency depends on the TSO's selection of units to enter Dispatch Hubs. Scheme 7 could be a short-term no-regret option given that its implementation would be transparent to market parties.

If it is mostly generators that ought to be placed in Dispatch Hubs, we would cautiously recommend scheme 4.

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