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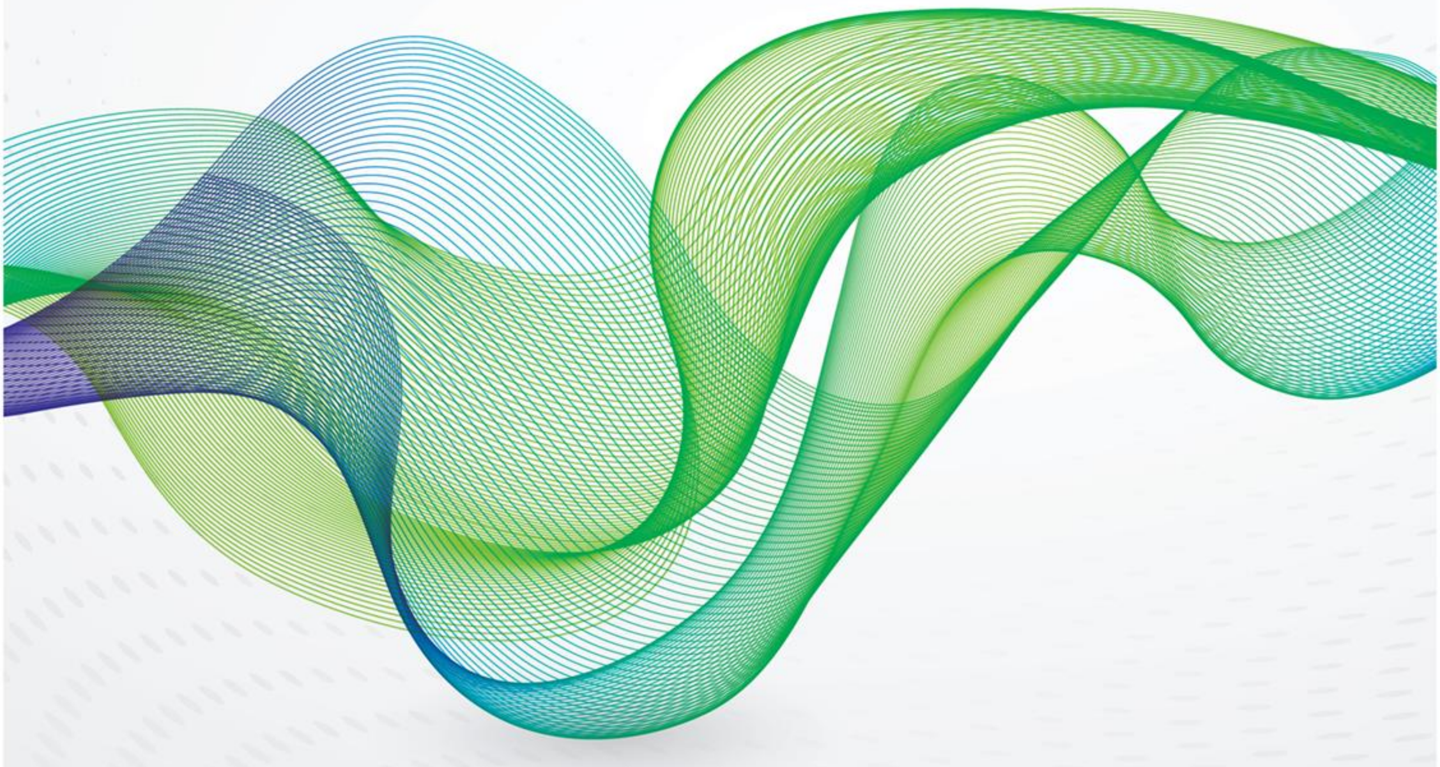
Market-based allocation and differentiation of access rights to network capacity in distribution grids



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Abstract

Traditionally, distribution networks were dimensioned to handle demand peaks which were driven by demand for heating in the winter and cooling in the summer. However, with the current decarbonisation strategy based on electrification, the distribution network infrastructure will have to evolve with increasing electricity demand from other sectors and with stronger emphasis on volatility and flexibility in both generation and demand. The ‘fit and forget approach’ to network access is unlikely to be suitable during the energy transition era. In this regard, a key challenge facing electricity distribution grids is how to efficiently integrate new and flexible grid users. In this paper we analyse the concepts of universal versus restricted network access as well as listed pricing versus market-based allocation of network access rights. Differentiating access can increase efficiency and under ideal circumstances, market-based allocations and listed prices can be equivalent. We discuss different dimensions of access and the design of products and market rules for market-based allocation of access to electricity distribution grids. Adequate design serves to balance the benefits of differentiation and market-based allocation with the related complexity, resulting transaction and the negative effects of market power. With restricted connection agreements on the rise and network operators buying back access as flexibility, the insights from this analysis accompany a current trend in electricity distribution grids and inform policy making and regulation.

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1. Introduction

Flexible demand-side technologies and intermittent distributed generation are transforming electricity distribution systems. In combination with new technologies for grid control and grid enhancement, efficient coordination becomes key for system operation. The question that emerges is: how to capitalize on the new potential to optimize utilization and sizing of the grid.

As suggested by the name, distribution grids historically served to distribute centrally generated electricity to dispersed consumers. Central generation was largely flexible and operated to meet established demands for electricity. Increasingly, this has shifted to distributed systems where intermittent, and therefore less flexible, generation injects electricity in a decentralized manner while consumers, in turn, operate flexibly according to the availability of cheap energy in the system.

In this changed environment, the traditional concepts of access to network capacity and how it was allocated are challenged. Intermittent, distributed generators (such as wind farms) at times utilize only a fraction of the capacity they are assigned access to. Yet, significant grid enhancements may be necessary to accommodate the access requirements of new, additional generators. Ideally, distributed energy systems allow for the option of sharing and coordinating access requirements in addition to, or as an alternative to, network expansion. To do justice to continuously evolving energy systems, mechanisms are needed that not only assign access to constrained systems efficiently, but which enable any given allocation to adapt and evolve along with the system.

Therefore, in this paper we analyse the concepts of universal versus restricted network access, as well as listed pricing versus market-based allocation of access rights. Listed pricing for universal access is the standard framework for network access. Network operators traditionally list (ideally cost-reflective) prices *ex ante* and network users are free to universally utilize their purchased capacity – although households connected with a certain fuse capacity may reach their threshold only occasionally, if several appliances happen to get activated simultaneously. Equally, they would be entitled to charge their electric vehicles at full withdrawal capacity every evening, which would have a significant effect on the overall system. Thus, generic prices may not incentivize active users sufficiently to coordinate with the grid, and universal access does not provide the incentives to optimize utilization of constrained capacity. As an alternative or complement, we explore auctions and secondary trading of differentiated access dimensions. The analysis in this paper focuses on efficient utilization and sizing of electricity networks – in other words, on efficiency (both short- and long-term) as a main criterion. We demonstrate that in principle, and in the absence of strategic bidding and excessive transaction cost, market-based allocations and listed prices can be equivalent. From this baseline, we analyse market rules and product dimensions that are particularly promising for access to network capacity and discuss under what circumstances market-based allocation of restricted access might add value in practice.

In an increasingly complex energy system, offering restricted access dimensions enhances efficiency up to the point where transaction costs outweigh the benefits. Liquid markets and the absence of market power are critical for market-based allocation to enhance efficiency. These conditions are not merely given circumstances existing in an energy system. Competition in distribution grids is obviously linked to potentially small numbers of generators behind a constraint, or consumers within a specific network strand. Yet, the possibility of abusing potential market power strongly depends on market design. In the same vein, the effect of transaction cost is stronger in grids with small, uninvolved users than with institutional ones, and market design influences, to some extent, the transaction cost faced by less resilient user groups. Therefore, benign circumstances for efficient market-based allocation can be established via adequate design of products and market rules. Conversely, market-based allocation depends on the adequate design of access products and market rules to limit transaction cost, enhance competition, and prevent abuse of market power.

The paper is organized as follows: the next section sets out the background and general literature on differentiated network access, pricing, and auctions as mechanisms for capacity allocation. Section 3 then illustrates the equivalence between both approaches (listed pricing and market-based allocation) in principle: absent transaction cost, with full information and competition, or at least without market power. Subsequently, section 4 discusses design options for access products, market rules, and secondary trading to limit the potential shortcomings of market-based allocations. Section 5 transfers these findings to an exemplary distribution setting, relates them to current developments in Europe, and discusses potential limitations due to market power and transaction cost. Finally, section 6 provides the concluding remarks to inform the further evolution of market-based allocation in practice.

2. Background and literature

This paper analyses the efficient allocation of access to existing and future grid capacity, with a focus on electricity distribution and the European context. In the following, we first discuss different dimensions of access, concerning their value and implication for system efficiency, and then assess the literature on efficient provision of network access.

2.1 Access rights and network use

Network users need access to grid capacity to withdraw or inject electricity at a specific location and time. Access rights are assigned by the network or system operator, who oversees the availability of existing capacity as well as the demand for future capacity by network users. The system operator can be the network operator, as well as an independent or collective institution. System users acquiring access rights could be consumers, generators, retailers, and aggregators, as well as combinations thereof. If access is universal, capacity assigned to one user may be blocked for others, at least to a certain extent, even when it is not used. To facilitate coordination and efficient system development, access rights may vary regarding firmness and depth. Access or use which triggers a lower incremental cost can be cheaper, and thus provide incentives to adjust demand for capacity. This optimizes network cost with the potential utility derived, and thereby maximizes efficiency. In the following, we briefly discuss[1] the dimensions of

- quantity,
- direction,
- location,
- depth,
- time, and
- firmness.

Network access occurs as withdrawal and injection. Generators and consumers require only one, while batteries and prosumers need access in alternating directions. Within a network, reverse directions can balance out, to a certain extent, reducing the required capacity as compared to the sum of all individual access requests. Therefore, in demand-dominated networks, access for injection can be provided at lower cost than for withdrawal, and vice versa. The quantity of access can be defined as power or energy volume. From a system operation perspective, the maximum load determines how much capacity is required and energy volume is largely irrelevant. Yet users often prefer the concept of being entitled to a certain quantity of energy for withdrawal or injection over time (for comparison: Xu, 2019). In European distribution systems, access prices are shifting towards power as the charging parameter. Most member states of the EU charge, at least partially, per connected capacity for establishing access initially, but the number of those that base recurring access prices on load is on the rise (ACER, 2020).

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[1] For a more detailed illustration of this concept see Brandstätt & Poudineh (2020).

Network access is physically bound to a specific access point at a certain network level. Most network users are settled. Yet, some use cases, such as electric vehicles, might benefit from mobile access rights. Today, the default rights often give access to the entire grid. However, with increasing decentralization, local access (to the level of a neighbourhood or local grid) could be granted more cheaply than global access.[2] Austria and Portugal have recently introduced reduced charges for energy communities that share electricity at a local level (Bridge 2019). Additionally, the cost of access rights may vary between regions. This is currently the case, for example, in Austria (ACER, 2021).

Access rights usually refer to a specific time slot. Overall, a user requires access over the assets' entire use time, meaning years or decades. Yet, this necessity varies, with a minimum time span of only hours or minutes of homogenous access requirement. The value of access varies over time with the availability of capacity; it is generally higher during peak than off-peak times, and lower in summer than in winter in cold countries and vice versa in hot countries. In Europe, most countries time-differentiate the value of network access, at least for withdrawals. Many of them differentiate between day- and night-time, slightly fewer also consider peak and off-peak periods, and some also consider seasonal differences in access value (ACER, 2021). Historically, access was granted infinitely at full fuse capacity. Today, reduced access during peak periods is increasingly common. In Germany, for example, network operators can curtail renewable generation during peak times up to a certain threshold of overall yearly curtailment without compensation (CEER, 2018). Colloquially, the term 'access' suggests optionality. Yet, different degrees of firmness affect the efficient provision of network capacity. Optional and therefore arbitrary[3] access is provided at higher cost than binding or firm withdrawal or injection. In view of the existence of some proportion of arbitrary access, controllable or curtailable access can reduce cost even further. A fixed profile corresponds to a bundle of varying amounts of binding access over several time slots. Efficient allocation is likely to increase utilization, as various mixes of different types of access rights can be supplied based on the same capacity.[4]

2.2 Capacity allocation and capacity development

Any demand for grid capacity is assigned in the above dimensions. For example, arbitrary withdrawal requires a corresponding quantity of dedicated network capacity. Alternatively, it is partially offset by controllable withdrawal or by on-site injection. Timelines are critical. Traditional network investments typically last longer than facilities which use the network. Access requirements vary over an asset's lifetime, whereas network capacity remains largely fixed. Despite efficient timing of investment plans in general, inefficiency arises from delays in delivering capacity. In practice, queues occur for users' grid connections; these may be resolved on a first-come-first-served basis, or result in pro rata curtailment. While the delay itself cannot always be prevented, it is intuitive that an efficient mechanism should help prioritize and share connections according to users' valuations. Market mechanisms or listed prices enable a system operator to alleviate existing constraints. Ideally, they also help in efficiently restraining grid expansion, in circumstances where coordination mechanisms can permanently manage grid congestion. Efficient provision of capacity necessarily implies scarcity where the cost of capacity

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[2] In fact, any actor who trades on the global market requires global access. If (part of the) energy is settled within a neighbourhood, then network cost is reduced.

[3] We avoid the term 'flexible' in this context due to the ambiguity of the word from the perspective of users and network operators. 'Flexibility' from the user's perspective is covered by optional access, while it exhibits arbitrary injection or withdrawal from the system operator's perspective. And 'flexibility' from the perspective of system operators means 'controllable' access, while this means restricted access from the perspective of users.

[4] For example: with a free transport capacity of 1.5 MW, the system operator can either connect one generator of 1 MW unlimitedly and put the next 1 MW of generation to be connected on hold until capacity has been expanded. Alternatively, she can connect both at only 750 kW, or connect both at 1 MW with the option to control in case of scarcity.

provision exceeds its aggregated utility.[5] In the following we compare approaches for capacity allocation and development in theory and in practice.

Currently most electricity distribution systems employ *listed prices* to finance existing capacity and some sort of *regulatory planning* based on expert projections to provide future grid capacity.

Efficient allocation is only one, often minor, concern when devising the price structure.[6] Literature advocates the efficiency of marginal prices. A user's decision to utilize network capacity is informed best when assigned the cost of providing precisely the additional unit of capacity demanded. In the short term, past investments are sunk and additional – in other words marginal – cost is the only variable network cost. Thus, utilization of existing capacity is efficient, with short-term marginal pricing based only on the negligible variable cost of the network. For efficient investment and expansion, however, the fixed cost of adding new capacity must be considered. Thus, long-term marginal cost includes variable costs as well as a fraction of fixed cost. Faced with long-term marginal prices, a user's decision to utilize the grid takes into account any potential network expansion required for this utilization. Pricing approaches established by Boiteux (1960) and Steiner (1957) differentiate between long-term marginal prices mainly for peak uses and short-term marginal prices for off-peak uses. This can be viewed as allocating the fixed cost of capacity to the fraction of use which causes them – namely peak load, predominantly. Such a pricing structure essentially represents time as well as locational differentiation.[7] Accordingly, users are ideally charged for the fraction of capacity they utilize.

The main strength of regulated pricing is that it protects consumers from paying monopoly prices to the network. Yet, one obvious limitation is the requirement of information (which may be hard to obtain) on the level and elasticity of demand as well as on network cost specific to the respective type of use. Assigning lumpy and fixed network cost to distributed network users can be a complex task in itself. In practice, simpler two- or three-part tariffs consisting of fixed, capacity, and volumetric prices are in place.[8] Volumetric prices are sometimes differentiated for peak and off-peak periods or netted for on-site generation. Capacity prices may be charged for available or for used capacity – sometimes reflecting coincident network load. Generators in distribution grids may be subsidized and fully or partially exempt from network use-of-system charges. In the European Union, generators are fully exempt in all but 10 EU member states (ACER, 2021). In Germany, a system of negative distribution tariffs to reward distributed generation is currently being phased out. Additionally, renewable generators often have priority access to the grid and are spared from curtailment until the last resort (CEER, 2018, Annexes 18–20). Direct cost of connection is largely billed directly to users. In Europe, charges to generators often specifically reflect the cost of connecting them, while consumers are more likely to face lump sum charges (ACER, 2021). Potentially efficient changes have been analysed recently by Pollitt (2016), Simshauser (2016), Picciariello et al. (2015), Schittekatte & Meeus (2020), and Brandstätt (2021), among others.

Market mechanisms and particularly auctions are now widely used in the electricity sector – namely to procure renewable and reserve capacity. Also, pool-based electricity trading is standard today, and the first implementations of markets for flexibility or congestion management have taken place (for comparison see: Anaya & Pollitt, 2020; Keay & Robinson, 2019). Yet, markets for network capacity are

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[5] This is in contrast with the traditional paradigm of system operators' function, which assumes the need to connect and cater for any requested network use. In fact, for power generation, this paradigm no longer holds for systems in which the network is not adequate to accommodate generation peak, and thus curtailment is accepted up to a certain percentage, or on the basis of some sort of compensation (see, for example, Furusawa et al. 2019).

[6] Other important dimensions may include rate stability, transparency, and overall fairness.

[7] Time differentiation is obvious, as prices vary during peak and off-peak time. From the fundamental literature, it becomes clear that fixed cost needs to be specific to a particular demand. In other words, in a more complex network, peak prices would differ between different network levels or network strands. Thus, locational differentiation is implicit in this pricing approach.

[8] For an overview of European practice see, for example, ACER (2021).

less common; the closest reference points are auctions for access to gas storage and terminals, while the construction and operation of transmission links (including offshore) has also been procured (for example, Greve & Pollitt, 2012), and access to some interconnectors is allocated via auctions. Market mechanisms can be used first to assign access rights and subsequently also to trade those rights. In theory, there are seemingly infinite options to design auctions for the efficient allocation of goods in almost any circumstances.[9] Thus, it is tempting to assume network access could be auctioned efficiently as well. Auction-based allocation of energy network capacity, possibly in combination with a secondary market, was discussed when Ofgem suggested market-based allocation to the UK's electricity transmission grid (for example by Stern & Turvey, Newbery, Helm, McDaniel and Yarrow – all 2003). They were rather critical of auctions, particularly regarding the expansion of grid capacity. Stern & Turvey (2003) warn of underinvestment, as system operators benefit from congestion and system users may understate their demand. Concerns include limited liquidity, monopsony power, and collusion (Newbery, 2003; Helm, 2003; Mc Daniel, 2003), as well as complexity and transaction cost (Stern & Turvey, 2003; Yarrow, 2003). All authors, however, acknowledge the potential of auctions in principle – and more specifically for capacity allocation – under stringent conditions. In view of energy networks, one main prospect is the revelation of information on the actual demand for network capacity. For operation and planning, network operators assume future demands for capacity based on past manifestations of demand. However, electric vehicles and heat pumps introduce new demands into distributed systems, while on-site generation changes withdrawal patterns. This complicates expert assessments on capacity demanded, based on past utilization and future projections. With auctions, network users ideally reveal their demand via submitted bids. If households, or their aggregators, submit to the network operator the specifics of how much access they require and what they are willing to pay, demand projections are facilitated greatly. This seems ever more important with new technologies for demand-side flexibility, on-site generation, and storage in distribution grids. Good information on demand can help the network operator or regulator to trade the provision of capacity at a certain cost against the possibility of forgoing the supply of a certain demand, when the utility obtained would be lower than the cost. Therefore, we reassess the question of markets for distribution capacity in view of less meshed topologies with fewer competitors, end-consumer access, and increasing flexibility of network users.

Auctions in general are prone to strategic behaviour. In the case of network capacity this is likely exacerbated by a natural monopoly on the seller side. Bidders, on the other hand, may benefit from limited liquidity or potential for collusion. Additionally, access rights are a precondition to compete in several other network-related markets, raising incentives for predatory behaviour. As we will discuss later on in section 4, adequate market design is critical to overcome such potential weaknesses of market-based allocation.

Strategy on the seller side, in the context of access to network capacity, encompasses three main aspects:

- First, as a natural monopolist, the network operator can exercise market power to increase scarcity, raise prices, and maximize her own revenue rather than overall efficiency. This is well understood in literature and acceptably handled in practice. In this analysis we therefore assume monopoly regulation aligns the network operator's incentives efficiently. Thus, the decision whether to expand capacity would still rely on some projection of future demand for restricted, as well as for unrestricted, access. The information and transparency accompanying the auction can assist this process. Good incentives for system operators to

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[9] For a practical overview see, for example, Klemperer 2004 and 1999.

develop the grid efficiently are needed, either institutionally (namely with independent or collective operators) or through adequate regulation of such factors as outputs or margins.[10]

- Secondly, and linked to natural monopoly, the network operator is faced with particularly long investment cycles and must handle the associated risk. It seems unlikely that a futures market for capacity can secure all investment ahead of time (see, for example, Helm, 2003). The lifetime of network assets usually surpasses that of facilities of network use. A new distribution line lasts for several decades, yet consumers are unlikely to commit to paying for access 20 or 30 years ahead of time. Hence, network operators risk recovering only part of their investment if demand for capacity changes in the future or does not develop as expected.
- Lastly, the network operator is traditionally responsible for system reliability and must therefore retain some excess capacity or flexibility. Unless alternative reliability mechanisms are established (for example, as proposed in Billimoria & Poudineh, 2019), this may strengthen bidders' position in an auction. The network operator or her regulator would be held responsible for system failure even if provoked by users' reckless bidding strategies (see, for example, Newbery, 2003).

Strategic interests on the buyer side can be grouped into two main categories. The first is to *obtain access at lower cost* and the second to *prevent access for up- or downstream competitors*.

- The motivation to shade bids or understate demand is twofold (for example, as discussed for multi-unit setup in Ausubel et al., 2014). If bidders reveal their actual willingness to pay when valuations are private and discrete, they risk paying more than necessary. If there is a gap between their own bid and running-up bids, optimally they would bid only slightly higher than their closest competitor. Suppose, bidders do not know whether there is a gap, or its size. If they guess running-up valuations, they risk losing the auction. Yet, if they bid their own valuation, they will normally win, but pay more than if they had guessed correctly.[11] On the other hand, if objects have common but uncertain value, necessarily those bidders who estimate that value most optimistically will win the auction. Upon winning, it is revealed that their bid was in fact too optimistic, cursing the win.[12] Access rights to network capacity, like almost all goods, encompass some proportion of private as well as common value. Additionally, values may be somewhat interdependent. It is well understood, for example, that demand for electricity, and consequently for network capacity, scales with outside temperature or correlates with days of the week. Consequently, network users bidding for access are likely to understate their demand. Intuitively, bid shading is particularly risk free in the absence of competition, or if an agreement can be struck implicitly with competitors.[13] Additionally, over time, bidders may have the opportunity to learn their position in the market and even exchange signals with competitors.

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[10] Naturally, network operators may seek to increase profits by inducing scarcity beyond the efficient level. Several options have been designed and applied to prevent this. When prices or profit margins are fixed by regulation, the incentive to abuse market power is removed. Similarly, in an institutional setting where expansion is decided independently of asset ownership and the related returns, this incentive is removed as well. The same accounts for collective operation, where the network owner is involved in the decision but needs to achieve consensus with all other concerned stakeholders.

[11] Suppose a network user is willing to pay 10 for access to a certain part of the grid. This valuation is private, in other words, it is unknown to the network operators or other bidders. Additionally, assume willingness-to-pay of the user with the next-lower valuation is only 5. If the initial user wins access to the network at a price of 10, he wasted 4, since he would have won at 6 just as well.

[12] Note that, while shading the initially optimistic bids is a strategy to avoid winners curse, the result from this type of bid shading is not necessarily inefficient.

[13] We assume that explicit collusion is handled by antitrust regulations.

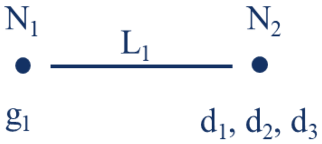
- The second major strategy for bidders is predatory behaviour. Strong bidders, such as incumbent network users, may want to secure access to capacity to prevent others from competing with them in the energy markets. Think of a generator buying access to an import-constrained part of the grid. By securing all network capacity for himself, he may be able to obtain higher revenues by selling his electricity in the constrained market than if a competitor had access and was able to drive down prices. If the incumbent controls all existing transport capacity, competing generators cannot offer their electricity via the network. As a consequence, the withholding generator can increase its profits in a therefore less-competitive energy market. The initial loss from bidding higher, or of winning more capacity than needed, can be compensated for by monopoly rents in subsequent, network-based markets.

3. Theoretical equivalence in revenue and allocation

Next, we illustrate that, in theory and under ideal circumstances, listed pricing and market-based allocation result in equal allocation of access rights and equivalent revenues for the network operator. Importantly (and contrary to limitations faced by real-life applications), we assume that network cost can be determined specifically per unit of capacity. Further, we assume the network operator knows users' willingness to pay in the case of listed pricing and that users do not have incentives to bid strategically in the case of market-based allocation. Under ideal circumstances, the network operator is regulated effectively to mitigate the incentive to extract monopoly rents.

To illustrate the equivalence between both approaches, we consider a simple two node network, where a generator on one node (N_1) exchanges electricity with three users with demands on another node (N_2), as depicted in figure 1. These network users require access rights to the capacity of the connecting line (L_1).

Figure 1: example two node network



The quantities demanded and utilities obtained by all three demands are depicted in table 1. Both utility and quantity vary between an off-peak period with lower demand and a peak period with higher demand. Furthermore, we assume capacity cost for L_1 of 3 monetary units per unit of capacity.

Table 1: users' quantities demanded and utilities

		user$_1$	user$_2$	user$_3$
quantity of capacity demanded	off-peak	1	1	1
	peak	2	2	2
utility per unit of capacity	off-peak	1	2	3
	peak	2	3	4

Universal access

Initially, we consider the allocation of capacity units of universal access – in other words, access to peak and off-peak period combined. From peak and off-peak utilities, in combination with the respective quantities, we therefore derive utilities for a first and second unit[14] of universal access as depicted in table 2.

Table 2: users' combined utilities

		user$_1$	user$_2$	user$_3$
combined utility per unit of universal access	1st unit	3	5	7
	2nd unit	2	3	4

Listed prices in this framework are set at the cost of capacity, namely at 3. Hence, all units with a utility from 3 onwards are purchased. Likewise, in an ideal market-based allocation, where demands bid truthfully, their stated willingness to pay is exactly the utility displayed in table 2. A regulated network operator would accept all bids meeting her capacity cost (in other words, bids ≥ 3).[15]

In both settings, all demands obtain a first unit of access and demands 2 and 3 additionally obtain a second unit, as highlighted in table 2. This is intuitive, as with both approaches the threshold for allocation of access rights is a utility larger than capacity cost. Thus, the network operator expands L$_1$ to 5 units of capacity, recovering her cost of 15 monetary units. With listed prices, as well as with market-based allocation, users obtain a surplus of 7 monetary units.[16]

Differentiated access

Next, we consider the extension of allocating access which is restricted to the peak or off-peak period – in other words non-universal, differentiated access. Optimal listed prices for this framework are peak-load prices according to the firm peak case as discussed by Boiteux (1960) and Steiner (1957). Accordingly, the price for access in the peak period is set at full capacity cost, namely at 3. Access in the off-peak period is priced at variable cost (here at zero). At these rates, all users buy their one unit of off-peak access demanded as shown in table 1. Additionally, users 2 and 3 buy two units of peak access, from which according to table 1 they derive utilities of 3 and 4 (in other words ≥ the listed peak price of 3). In a market-based setting with truthful bids, network users submit their actual period-specific utilities according to table 1. The network operator then sorts these bids in descending order. To reflect the complementarity regarding supply of capacity in peak and off-peak periods, she then pairs peak and off-peak bids as depicted in table 3. Finally, the network operator again accepts all bid pairs larger than her capacity cost (namely > 3) as highlighted in table 3.[17]

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[14] Initially users require one unit of off-peak and two units of peak access. A universal access right allows for access in both the peak and off-peak period. Therefore, one unit of universal access combines the utility of both periods. For instance, user 1 derives a utility of 1 (off-peak) plus 2 (peak), in other words 3 in total, from the first unit of universal access. The second unit, in principle, also provides for access in both periods. However, as users only require a second unit of peak but not off-peak access, the utility they derive from the second unit of universal access is lower.

[15] For simplicity, we assume, that the network operator can provide any required amount of capacity in time. Thus, we do not distinguish between existing and yet-to-be built capacity. Further, also for simplicity, we ignore variable cost in this illustration. While, in reality, variable costs for a network would be low, but not zero, they do not structurally influence the allocation and would ideally be charged *ex post* to actual use rather than in connection with the access right.

[16] We derive surplus as the difference between utility and prices paid. User 1 buys (or respectively is allocated) one first unit of capacity, which she values at 3 and pays 3 monetary units for. Thus, her surplus is 3 – 3 = 0. Analogously, surplus$_2$= (5 – 3) + (3 – 3) = 2 and surplus$_3$= (7 – 3) + (4 – 3) = 5.

[17] In this simplified example, clearing prices and listed (peak) prices are equal for universal access and for differentiated access. This is because variable cost is zero and because the example is set in a firm peak framework. With variable cost of, for example, 1 (per unit of capacity and per period), the price of universal access is 5, and 4 for peak access. Given that variable cost only accrues to capacity utilization and not necessarily to capacity reserved for universal access, the price could actually be less than 5 and would have to be higher than 4. In a shifting peak setting, on the other hand, the listed prices for peak and off-peak access would share fixed cost by a proportion corresponding to the elasticities of their respective demands.

Table 3: network operator's sorted bids

pairs							
pairs	off-peak	u_3: 3	u_2: 2	u_1: 1			
	peak	u_3: 4	u_3: 4	u_2: 3	u_2: 3	u_1: 2	u_1: 2
pair bid		7	6	4	3	2	

Again, both settings produce equal allocation and revenue. Users 2 and 3 obtain all units of access that they bid for, while user 1 only obtains one unit of off-peak access. The network operator expands L1 only to a capacity of 4 units, recovering her full cost of 12 monetary units. Demands obtain a surplus of 8 monetary units (surplus_1= 1, surplus_2=2, surplus_3=5).

Comparison

Thus, with less capacity supplied and built, surplus of the restricted access example exceeds surplus with universal access. To explain this, table 4 compares utility, cost, and surplus for the allocation of universal and differentiated access. In the case of allocating differentiated access, the first user's peak demand is not supplied. This reduces overall cost by 3 but forgoes utility of only 2. Hence, surplus increases by 1 when allocating differentiated rather than universal access.

Table 4: comparing the allocation of universal and differentiated access

	universal access			differentiated access		
	user_1	user_2	user_3	user_1	user_2	user_3
off-peak units	1	1	1	1	1	1
peak units	1	2	2	0	2	2
utility	3	8	11	1	8	11
cost	3	6	6	0	6	6
surplus	0	2	5	1	2	5

Importantly, this gain materializes due to the change in access rights and both listed pricing and market-based allocation are in theory able to deliver it. This observation holds under ideal circumstances, which in reality are rare. Both approaches suffer in practice from the difficulties in assessing long-term marginal network cost. Listed pricing additionally presumes that network operators or regulators know network users' utilities. Markets exhibit a mechanism to reveal bidders' willingness to pay, but in turn are prone to strategy. In the following, we will therefore discuss design options to limit these fallacies for market-based allocation.

4. Markets for network access

In the following, we examine market-based approaches for the allocation of access rights in view of their efficiency in allocating and developing the grid. We first discuss products designed to give access to network capacity, particularly with regard to any resulting complexity. Next, we review market rules for auctions and their implications for market power and competition in network-related markets. Finally, we discuss the option of resale – in other words secondary trading – to correct this initial allocation over time.

Auctions for network access are, in principle, largely subject to design challenges that are similar to those facing any other auction. Yet, demand for access to network capacity is typically for multiple units. Hence, we mostly refer to the theory for multi-unit auctions as surveyed by Kwasnica & Sherstyuk

(2013) and Cumpston & Khezr (2020). At the same time, the amount of access rights available is not necessarily known in advance and is not fixed in the long term. This is because the amount of access rights that can be supplied in one dimension, such as injection, may depend on the demand for access in another dimension, such as withdrawal. Available capacity on one part of a meshed network also depends on the utilization of other parts of the grid. Additionally, in the long term, the network operator may expand or divest the grid in order to match demand. This points to analyses of endogenous supply (see, for example: LiCalzia & Pavan, 2005; Khezr & Menezes, 2019). With differentiated access rights this expands to a problem of multiple objects, as summarized for example by Armstrong (2000). Interrelated preferences, complementarities, and substitutability between different dimensions, as described above, add further complexity (see, for example, Cramton et al., 2005).

4.1 Auction products

For *validation of access rights*, system operators need to define rights in a way that can guarantee exclusiveness, and also enable them to detect, prevent, or punish violation of rights, even after they have been transferred among users. With knowledge of the technical characteristics of the system, operators are able to ensure that a certain combination of access rights sold to consumers is physically feasible.[18] This may be a complex task, but there is practical experience in the context of transmission rights (see, for example, Rosellón & Kristiansen, 2013). The complexity associated with loop flows reduces in less meshed distribution systems, and with more detailed information on actual use of capacity (via smart devices). Communication infrastructure and technical prequalification can ensure compliance in the dimensions of time and firmness. Violations with regards to depth are likely only detectable *ex post*. An extension of balancing responsibilities could enhance compliance and administer penalties.

The value of access to network capacity differs with *advance of access rights*. Facing or expecting scarcity, network operators can decide to allocate more capacity in the future than is currently available. In the long run, the question is whether capacity should be expanded, or if scarcity can be managed at lower cost. If a generator sells baseload generation on a futures market, he can commit to firm access ahead of time with the same advance as the futures market. Yet, it is unrealistic to expect that a network operator can initially sell access rights to all her assets over their entire lifetime.[19] Thus, network operators risk not fully recovering their investments. With market-based allocation, this risk is at worst equal to that of regulatory planning. As soon as at least some access rights can be sold long term, part of the risk has been shifted from the regulated network operator (and eventually society) to market parties.

For network access, we distinguish between *universal* and *restricted access rights*. Restrictions can concern the dimensions of direction, location, depth, time, and firmness – as discussed in 0. Given a certain price difference, network users might, for example, be willing to accept restricted rather than universal access. For a market to efficiently align access supplied, it is crucial that types of access rights capture cost drivers and consumer preferences. Whenever different dimensions of access do not impact network cost or users' utility, access products need not be differentiated.[20] There is a general trade-off between complexity and efficiency. Products that are too simple, or that are too small in number to

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[18] We assume that there is some mechanism to coordinate between transmission and distribution system operator (or interconnected system operators at the same level), so that each system operator can efficiently manage their own market without interfering in the others'.

[19] Users' planning horizons are shorter than operators'. Also, it is desirable that some capacity is available at shorter notice to facilitate market entry and cater for less predictable network use. Independent of the advance of access auctioned, this may be handled via secondary trading.

[20] For example, if there is no congestion in one part of the grid, cost does not differ by location in this part of the grid. Also, if there were congestion, but users always require access to the entire grid area, there would be no benefit from locational differentiation of access rights.

provide choice, will not reflect preferences adequately, and will fail to capture efficiency. Yet, the more differentiated the product, the more complex and potentially less liquid the market. Different types of access are generally imperfect substitutes; certain dimensions can also be complements.[21] As Kwasnica & Sherstyuk (2013) point out, market power scales with bidders per unit – in other words, with many different dimensions of access, the potential for market power could increase. Hence, too fine a differentiation likely entails inefficiency due to market power. On the other hand, a market mechanism that captures a variety of dimensions as substitutes may be less vulnerable to market power (Klemperer, 2004) as competition essentially occurs not only between users but also between product types.[22] Essentially, users can avoid complexity so long as simple products, like unrestricted access, are available as an option. In fact, small bidders may participate in auctions as price takers, simply announcing their required quantities. For the system operator, any additional effort associated with complexity needs to make an estimate using profit or additional benefit to society. The field of auctions is evolving both in theory and in practice, and designs have been developed which can handle a variety of products while remaining relatively simple. A recent auction design proposed for multiple units and different product types is the product-mix auction (Klemperer, 2018). Lastly, a degree of complexity can develop within a market, and network users can be given the opportunity to suggest new bundles and product dimensions to better capture their preferences.

4.2 Auction design

Auctions are often evaluated regarding their ability to allocate goods efficiently[23] and to raise revenue for the seller. In the following we focus on strategic interests for bidders and sellers as introduced above, and discuss design options to remedy potential inefficiencies from strategy.

Bid transparency is a central feature affecting strategic behaviour in auctions. The process of network users submitting sealed bids for access rights, to some extent, impedes learning about competitors' valuations. Sealed bids also prevent signalling via unusual bidding behaviour, thus hindering implicit collusion. They further encourage participation by weaker (namely small or less resourceful) bidders in view of limited supply or predatory behaviour.[24] On the other hand, sealed bids reinforce uncertainty about the common value of access rights and thus potentially worsen a winner's curse. Anonymous but open bids can be a compromise between the two options.[25] For access rights to network capacity, abuse of individual or collective market power in the auction (as stated, for example, by Stern & Turvey (2003) and Newbery (2003)) and in related markets (as pointed out for example by Yarrow (2003)) are likely more relevant than uncertainty about the common value.

Repetitions similarly enable learning, signalling, and retaliation (Nedelec et al., 2020). The length of access periods determines how often auctions for network capacity repeat. Short access periods imply more frequent opportunities to assess and react to competing network users' bids. Short-term access also harbours higher investment risks for network operators as well as for users. Regularly repeating

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[21] If a user accepts curtailment in one time slot, he might require firm access in the subsequent one to make up for it. Different dimensions of access can be bundled to reflect complementarity, and users would submit their alternative preferences for different types of access (or bundles thereof) depending on price.

[22] Due to the interdependence of network access in different dimensions, demand in one dimension may affect supply in another dimension. Thus, in the same way that a competing bidder for the same access right undermines a network user's ability to obtain a particularly low price for her required access, demand for a substitutable dimension may moderate her market power indirectly via the amount of access rights available in that dimension.

[23] Note, that in this paper we assess 'efficiency' as welfare maximization, whereas in classic auction theory the term often refers to efficient allocation of items to those bidders who value them most.

[24] This is, in fact, due to a potential inefficiency with discrete, private valuations – bidders find it harder in general to reduce their bids close to uprunning bids. Weak bidders are more likely to 'occasionally' outbid a strong bidder who reduced their bid too far.

[25] If bids are nevertheless submitted in several open rounds, an ascending auction generally facilitates more learning and signalling than a descending one. This is because ascending rounds additionally enable bidders to retaliate when their peers deviate from collusive agreements, whereas in a descending auction a deviating bidder wins and thus immediately ends the auction.

auctions may mean higher procurement effort and increased complexity – in sum, leading to higher transaction cost for network users. In turn, network users with limited demand predictability can adjust their bids for short access periods more precisely. It also makes them less likely to get locked into unnecessarily large and expensive contracts if alternatives become available (Keay & Robinson, 2019). More frequent repetitions facilitate for entry in generation or retail markets, as new network users get a fresh chance at winning access to their required capacity with every round. Lastly, with shorter access rights, the risk that bidders might default on their bids due to bankruptcy during the access period will decline.

Pricing rules are critical for discovery of demand elasticity. A reserve price for network access may limit bid shading below an unfeasible level, preventing windfall profits in the case that network users manage to outsmart network operators and regulators. Obviously, determining reserve prices is as challenging and prone to inefficiency as pricing of network access in general. In theory, however, the sheer existence of a positive reserve price often eliminates equilibria with low revenue and low efficiency that involve a zero-bid strategy. Uniform, rather than discriminatory, pricing encourages network users to reveal their actual utility from access. If the final price depends only on marginal bids, some surplus is guaranteed on all higher valuations. Additionally, by simplifying bidding strategies, uniform pricing reduces transaction cost and thereby facilitates entry. Yet, with multiple unit demand, and particularly if bids around the margin originate from the same bidder, uniform pricing may lead to inefficiency. A marginal bidder essentially only competes against himself and will attempt to outbid his highest competing bid which is less than his true valuation. On the contrary, with discriminatory pricing, bidders must necessarily shade their willingness to pay to make some profit.[26] Ideally, they bid their expectation of marginal price for all required units.[27] Given the difficulty of determining adequate network expansion and increasing demand elasticity, reliable information on network users' utility from network access is invaluable. As this, in fact, poses one of the strongest arguments in favour of market-based allocation, it seems intuitive that pricing of network access would be uniform.[28] Furthermore, Vickery auctions, or the so-called Ausubel auction, employ a second price rule for the marginal bid (or with multi-unit demand, for the marginal bidder) (Cumpston & Khezr, 2020). This reinforces truthful bidding and thus cures bid shading with private information and uncertainty about common values, as described above in the context of sealed bids. Demand for network capacity is often thought of as rather continuous, yet in less liquid markets bidders' private values might increase rather stepwise.

Several measures outside core market design can additionally shield markets against abuse of market power. Priority of new connections and order of curtailment may scale with bids submitted for access rights. Network users who submitted lower bids would thus be connected last and curtailed more often. Such an accompanying rule could at least partially undermine the incentives for underbidding. Furthermore, listed pricing may serve as a fallback option or a regulatory threat wherever market-based allocation fails. Assuming positive effects from market-based allocation – not only for network operators but also for users – could discipline the exertion of market power to some extent.

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[26] In turn, compared to a discriminatory approach that users could not evade, uniform pricing limits revenue – and, assuming that additional revenue would be reinvested in the provision of additional capacity for lower valuations, also efficiency.

[27] In this case, uncertainty about network capacity encourages truthful bidding – at least to some extent. As network users find it harder to guess a price, they must bid truthfully, at least for those bids they expect near the margin. Network users are likely to face some uncertainty if additional investment is determined based on overall bids or in view of new technologies which can enhance the grid's flexibility in the short term.

[28] 'Uniform pricing', in this case, refers explicitly only to uniformity between different bids for the same access products. Prices for network access resulting from a market with a uniform pricing rule may indeed vary between different categories of access and between access allocated at different times.

4.3 Secondary trading

Notwithstanding an initially efficient allocation of access rights, secondary trading plays a vital role in harvesting the potential of market-based allocation of network capacity. Resale may occur bilaterally or on a dedicated platform, among network users or between users and the system operator. Market parties may downgrade or split up products for resale – in other words, resell arbitrary access as controllable, trade global for local access, or potentially exchange their curtailment risk in operational timescales. System operators would engage in a secondary market, for example to offer additional access when the initial allocation does not utilize the grid to its limits, or to sell additional access when price levels justify it. Network operators can also buy back access if that is cheaper than expanding to accommodate the demand, or if available capacity has changed with expansion – for example due to loop flows. In 2003, Yarrow concluded that buy-back would likely not be competitive, and would give users offering to return their access rights market power over the network operator. If network operators cannot build additional capacity quickly, they will essentially need to depend on buy-back to resolve congestion. Users offering to return access rights may anticipate this and overstate their compensation bids. However, this prospect might be changing, in view of increasing operational flexibility due to grid-enhancing technologies and storage.

Allowing resale of access rights can both correct an initially inefficient allocation – for example via grandfathering or uninformed listed prices – and also complement initial auctions for network access. Problematically, however, relying on secondary markets to correct an initially inefficient allocation shifts surplus from the regulated network operator to private market parties. In theory, this can be partially ameliorated by a tax on resale, but at the expense of some allocative efficiency. Additionally, resale essentially legitimizes monetary transfers between colluding competitors. On the other hand, the benefits of resale are manifold. Both network operators and users benefit from long-term allocation of capacity. Yet, the valuation of access rights sold or obtained, running several years into the future, may change over time. To reflect this, access rights can be traded in a secondary market until the actual time of access. Thus, resale can benefit congestion management in the short-term perspective, while helping the fine tuning of capacity planning over time in view of longer-term products.

Encouraging resale is often deemed beneficial in view of predatory behaviour. Use-it-or-lose-it arrangements are common for both electricity transmission and for capacity in the gas sector. Such rules may seem less expropriative if excess rights can be sold before they expire (see, for example, Newbery, 2003). A penalty for capacity withholding, on the other hand, enforces resale even further. With access rights differentiated in firmness, forcing resale may not even be necessary, as essentially only the relatively expensive arbitrary access allows users to withhold capacity.

Institutional resellers such as aggregators or intermediaries can reduce complexity, especially for smaller users who otherwise would not get involved efficiently in markets for grid access. Intermediaries may collect information on future demands and thereby efficiently take over risks which are currently borne by the network operator, and eventually by society. Under specific circumstances, intermediaries could even moderate local monopsony power. In a setting with repeated allocations, as Yarrow (2003) observes: ‘any party thinking that larger players in the market might underbid could potentially bid for more capacity […] with a view to reselling later, at a higher price, in secondary markets.’ This is particularly true when valuations change over time, for example due to urgency or entry in up- or downstream markets. Ahead of time, a network user may still expect to obtain access at a low price in one of the subsequent allocation rounds. Thus, as time progresses closer to actual delivery, her willingness-to-pay would increase. Similarly, if competition in one part of the energy market increases, a generator, for example, might derive more value from gaining access to another part of the network with higher prices. However, in order to resell to a network user they initially outbid, intermediaries would likely need significant bargaining power and deep pockets.

5. Applications in practice

Two common examples illustrate the potential of, and challenges facing, market-based allocation of network access:

- new intermittent generators,
- additional flexible consumption.

In the following, we sketch challenges facing the allocation of network access for these two cases and apply the theory from section 4, combined with references to applications in practice across Europe. Thereby we discuss to what extent real world circumstances, such as market power and transaction cost, would limit the applicability and benefits of market-based allocation of network access.

5.1 Increasing distributed, renewable generation

For the first case, assume a new wind generator that seeks to connect in a constrained part of the grid. Incumbent generators occupy the existing capacity but do not always utilize it fully. Efficient allocation would incentivize incumbents to share existing capacity with the new generator until additional capacity is available. Depending on value added from new generation and cost of additional network capacity, efficient allocation may even render expansion obsolete altogether. For this example, we find the benefits of differentiating access rights and discuss the potential effects of market power among users, such as deterring new entrants, and also the possibility of monopsony power facing the network operator and thus understating demand. While it seems crucial to take market power into account, when designing the allocation mechanisms, it seems that it would not be prohibitive for market-based allocation in this framework.

It is easy to see the benefits of restricted access rights in this context. In order to efficiently share existing capacity, it is vital to differentiate access during peak and non-peak times. When the link to the larger network is congested, generators can still get access to the local grid, where they might share storage. The network operator can also offer curtailable, rather than guaranteed, access and thereby force the generators to share existing export capacity.

Additionally, assume for this example that a new generator seeks to establish his access interest facing two incumbents and would benefit if capacity needs to (or at least can) be (re-) assigned with relatively short notice. In theory, incumbents might attempt to *deter entry* and thus prevent competition in the energy market by abusing their established position within the network. Capacity withholding seems very relevant for interconnectors between neighbouring markets. Yet, within a liquid and congestion-blind energy market, incentives to deter a single wind farm are likely to be small. In distribution grids and in Europe in general, it is still quite common that electricity markets ignore congestion ‘at first’ and resolve constraints subsequently via countertrading or redispatch. In such a setting, the benefit of deterring a local competitor in the global market is likely negligible. If access rights to existing capacity are assigned to incumbents over the long term, the new generator can make an offer for currently unused off-peak capacity. In the absence of incentives for predatory behaviour, the incumbents benefit from accepting the additional revenue. If, however, incumbents do gain from deterring new entrants, their market power is limited if the network operator can provide additional capacity relatively flexibly and cheaply. As network capacity is increasingly delivered not only by building new lines and transformers, but also via grid-enhancing technologies, storage, or by exploiting existing curtailment ranges, the potential of incumbent market power is limited. In the United Kingdom, for example, system operators tender prespecified flexibility from network users such as these incumbent wind generators. Essentially, they are buying back differentiated dimensions of initially uniform access rights assigned via listed prices. If flexibility can be procured reliably at reasonable prices, the new generator can be connected without additional grid reinforcement. If incumbents refuse to sell their access, or ask for too much compensation, capacity may be provided by the network operator instead. Then, incumbents would lose their competitive advantage while also foregoing the compensation offered. In France, on the other hand, new connections in constrained grid areas are always curtailable (Clastres, 2019), while in Germany, network operators can curtail renewable generation during peak times up to a certain yearly energy threshold (EEG, 2020). With the risk of curtailment, especially if uncompensated, the incentive to abuse market power reduces further. By sharing capacity, the incumbent is at least able to receive some revenue from reduced access.

Initially, the two incumbent generators possess *market power* when obtaining access rights from the system operator in a market-based framework. Section 4.2 discussed several circumstances resulting in incumbents' bids severely understating their willingness to pay for their desired access rights. A new generator introduces some competition.[29] With short access periods, the new entrant gets an immediate, recurrent chance to outbid the incumbents, essentially forcing them to raise their bids closer to their actual utility. In theory, repetitions offer an opportunity to learn about other users' demand and to signal towards a collusive agreement. However, with interdependent demands from several largely identical generators in the same location, such collusion may be rather difficult to conceal, and antitrust measures could easily be applied. In the case of long-term access, the mere prospect of the new generator may already raise revenue above monopsony levels. In anticipation of an opportunity to resell access rights at higher prices in a more competitive setting in the future, an intermediary buyer could outbid the incumbents, thereby raising prices and essentially breaking the monopsony. Such behaviour, however, bears significant risk and it remains to be seen whether in practice any party would discover this role for themselves.

5.2 Integrating additional, flexible demands

A second circumstance that is often considered for a more efficient allocation of access is best illustrated via electric vehicles. Assume a conventional network user, such as a household or a business, switches from combustion engines to electric vehicles. This affects the overall capacity and dimensions of access required by this user. Efficient allocation incentivizes vehicle charging when existing grid capacity is idle, unless the utility obtained from charging justifies expansion.

This situation also calls for time-differentiated access. Non-firm access additionally provides the framework for curtailment. Here, the *complexity and transaction cost* of differentiated products and market-based allocation are critical. A household or small business customer is unlikely to engage in regular access auctions to charge the electric vehicle. Hence, longer access terms seem appropriate. Small users also initially find it difficult to assess the utility lost in case of curtailment. In Germany, for example, the debate around a non-firm access regime for electric vehicles revolves around the price difference between arbitrary and non-firm access (Consentec, 2020). If users rely on unrestricted access at all times and locations, they can also place price-taking, essentially very high, bids. In fact, the new framework for network access in Spain offers longer access periods for smaller customers, with larger customers being offered a greater number of shorter periods (Gomez et al., 2020). Alternatively, aggregators can manage their preferences to match cheaper access dimensions by delaying charging during the night. The aggregator could then purchase the corresponding access rights as an intermediary, to shield smaller users from the complexity related to the more efficient, market-based allocation.[30]

In theory, an aggregator representing most network users within this grid area can exercise *market power* towards the system operator. For standard-type network users such as households and small businesses, however, strategic behaviour is easily detected by benchmarking comparable users in different grid areas, exposing the strategic behaviour to antitrust measures. Also, if the aggregator

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[29] While negligible in the global energy market, the effect on access to local capacity would be significant.

[30] This essentially represents a form of listed pricing, yet only for those users who are better off with listed pricing, while allowing all other users to benefit from market-based allocation.

seeks to cover part of his demand with cheaper, non-firm access, the network operator may prioritize these low-valued access rights for curtailment.

6. Conclusion and outlook

In this paper we examine options to improve the utilization and development of distributed energy systems. In particular, we analyse the concepts of universal versus restricted network access, as well as listed pricing versus market-based allocation of network access rights. In an increasingly complex energy system, offering restricted access dimensions enhances efficiency up to the point where transaction costs outweigh the benefits. We demonstrate that absent information asymmetries and strategic bidding, market-based allocations and listed prices can be equivalent in principle. In practice, however, both approaches suffer from the difficulty of determining the specific cost of capacity. Also, both approaches rely on regulation for the network operator, to mitigate the incentive to extract monopoly rents. The efficiency of listed pricing is limited further by the network operators' lack of information on either users' willingness to pay or their flexibility. Markets for access rights, on the other hand, potentially reveal this information. Yet, this depends on adequate design of access products and on market rules to limit transaction cost, enhance competition, and prevent abuse of market power.

The analysis in this paper highlights the importance of achieving a good mix between short- and long-term access products – the latter benefit network operator and users alike by limiting risks, while the former enhance competition and allow for short-term adjustments. The balance between simple and differentiated access options is also critical. Small uninvolved network users require simplicity, while differentiated options are a precondition for incorporating user-sided flexibility into the system. Interestingly, potential substitution and complementarities between differentiated access dimensions may also limit market power. Preventing learning and signalling, for example via sealed or at least anonymous bids, controls market power further. Market-based allocation incorporates information on users' actual utility implicitly. This kind of information, however, likely has a value for regulation and efficient system development beyond the immediate allocation of network capacity. It is best extracted via uniform pricing for access rights (of the same dimension). Electricity distribution systems are currently evolving dynamically due to flexible demand-side technologies, distributed generation, and innovative grid technologies for control and capacity enhancement. In such a framework, the possibility of continuously adjusting allocation of access rights is beneficial both for network users and operators. In fact, the first instances of market-based allocations we are seeing today are network operators buying back certain dimensions of access rights that were initially assigned universally via listed prices. The next step seems to be the allocation of a priori restricted access rights.

In addition to concerns regarding economic efficiency, market-based allocation of network access likely entails further social and political challenges. Efficient price signals may fail to steer network users, who are not entirely rational or are simply unexperienced. Even if it enables savings, users with electric vehicles, for example, may not adapt charging behaviour (fully and initially) for a variety of reasons, such as: the comfort of charging immediately, being ready to drive right away, and an initial unawareness of (or limited availability of) tools and applications to automate charging decisions. Consequently, given the reliability and security of supply at stake, politicians, regulators, and network operators may hesitate to rely on relatively uncertain market-based reactions. Experience gained, especially in these first settings, will inform and inspire any further move towards auction-based allocation of access rights.

References

ACER (2021): ‘Report on Distribution Tariff Methodologies in Europe’, February 2021, accessed on 27 March 2021 at: https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Report%20on%20D-Tariff%20Methodologies.pdf

Anaya, K.L. & Pollitt, M. (2020): ‘Milestone 3 – Regulation and policies for local flexibility markets: Current and future developments in seven leading countries’, Project Report, accessed on 27 March 2021 at https://project-merlin.co.uk/wp-content/uploads/2020/11/SSEN_Cambridge_Milestone3_v5_pages.pdf.

Armstrong, M. (2000): ‘Optimal Multi-Object Auctions’, *The Review of Economic Studies*, 67, pp. 455–81.

Ausubel, L.M., Cramton, P., Pycia, M., & Rostek, M. (2014): ‘Demand Reduction and Inefficiency in Multi-Unit Auctions’, *The Review of Economic Studies*, 81(4), pp.1366–400.

Billimoria, F. & Poudineh, R. (2019): Market design for resource adequacy: A reliability insurance overlay on energy-only electricity markets, *Utilities Policy*, 60, art. 100935.

Boiteux, M. (1960): ‘Peak-load pricing’, *Journal of Business*, 33 (2), pp. 157–79.

Brandstätt, C. & Poudineh, R. (2020): ‘Rethinking the Network Access Regime: The Case for Differentiated and Tradeable Access Rights’, *Oxford Energy Forum*, 124, pp. 24–28.

Brandstätt, C. (forthcoming): ‘Network charging schemes and self-supply: instruments to prevent self-reinforcing dynamics’.

Bridge (2019): ‘Energy Communities in the EU’, Report, December 2019, accessed on 27 March 2021 at https://www.h2020-bridge.eu/wp-content/uploads/2020/01/D3.12.d_BRIDGE_Energy-Communities-in-the-EU-2.pdf.

CEER (2018): ‘Status Review of Renewable Support Schemes in Europe for 2016 and 2017’, Report, December 2018, accessed on 27 March 2021 at https://www.ceer.eu/documents/104400/-/-/80ff3127-8328-52c3-4d01-0acbdb2d3bed.

Clastres, C., Percebois, J., Rabenaque, O., & Solier, B. (2019): ‘Cross subsidies across electricity network users from renewable self-consumption’ *Utilities Policy*, 59, 100925.

Consentec (2020): ‘Netzentgeltreform: Netzentgelte verbraucherfreundlich gestalten’, Study for VZBV accessed on 27 March 2021 at https://www.vzbv.de/sites/default/files/downloads/2020/06/22/consentec_vzbv_netzentgeltreform_bericht_20200605.pdf

Cramton, P., Shoham, Y., & Steinberg, R. (2005): *Combinatorial Auctions*, MIT Press.

Cumpston, A. & Khezr, P. (2020): ‘Multi-Unit Auctions: A Survey of Theoretical Literature’, doi.org/10.2139/ssrn.3596663.

EEG (2020): Erneuerbare Energien Gesetz – Renewable Energy Sources Act, §§14–15, last changed by Act 8.8.2020 I 1818, Art. 6.

Furusawa, K., Brunekreeft, G. & Hattori, T. (2019): ‘Constrained Connection for Distributed Generation by DSOs in European Countries’, *Bremen Energy Working Papers*, No. 28.

Gomez, T., Cossent, R., & Chavez, J.P. (2020): ‘Flexible network access, local flexibility market mechanisms, and cost-reflective tariffs: three regulatory tools to foster decarbonized electricity networks’, *Oxford Energy Forum*, Nr. 124.

Greve, T. & Pollitt, M. (2012): ‘Designing electricity transmission auctions: an introduction to the relevant literature’, EPRG Working Paper Nr. 1221.

Helm, D. (2003): ‘Auctions and Energy Networks’, *Utilities Policy* 11 (1), pp. 21–5.

Keay, M. & Robinson, D. (2019): ‘The Limits of Auctions: reflections on the role of central purchaser auctions for long-term commitments in electricity systems’, OIES Paper EL 34, Oxford Institute for Energy Studies.

Khezr, P. & Menezes, F.M. (2019): ‘A semi-uniform-price auction for multiple objects’, *Economic Theory Bulletin* 8, pp. 139–48.

Klemperer, P. (2004): *Auctions: Theory and Practice*, Princeton University Press, accessed at www.nuffield.ox.ac.uk/users/klemperer/VirtualBook/VBCrevisedv2.asp.

Klemperer, P. (2018): ‘Product-Mix Auctions’, Nuffield College Working Paper 2018-W07.

Klemperer, Paul (1999): ‘Auction Theory: A Guide to the Literature’, *Journal of Economic Surveys* 13 (3), pp. 227–86.

Kwasnica, A.M. & Sherstyuk, K. (2013): ‘Multiunit Auctions’, *Journal of Economic Surveys* 27 (3), pp. 461–90.

LiCalzia, M. & Pavan, A. (2005): ‘Tilting the supply schedule to enhance competition in uniform-price auctions’, *European Economic Review* 49, pp. 227–50.

McDaniel, T. (2003): ‘Auctioning access to networks: evidence and expectations’, *Utilities Policy* 11 (1), pp. 33–8.

Nedelec, T., Calauzènes, C., El Karoui, N., & Perchet, V. (2020): ‘Learning in repeated auctions’, arXiv – CS – Computer Science and Game Theory, arxiv-2011.09365

Newbery, D.M. (2003): ‘Network capacity auctions: promise and problems’, *Utilities Policy* 11 (1), pp. 27–32.

Picciariello, A., Reneses, J., Frias, P., & Soder, L. (2015): ‘Distributed generation and distribution pricing: why do we need new tariff design methodologies?’, *Electric Power Systems Research* 119, pp. 370–76.

Pollitt, M.G. (2016): ‘Electricity Network Charging for Flexibility’, EPRG Working Paper No. 1623 / Cambridge Working paper in Economics No. 1656, University of Cambridge, Energy Policy and Regulation Group.

Rosellón, J. & Kristiansen, T. (2013): ‘Financial Transmission Rights - Analysis, Experiences and Prospects’, Springer.

Schittekatte, T. & Meeus, L. (2020): ‘Least-Cost Distribution Network Tariff Design in Theory and Practice’, *Energy Journal* 41(5), pp. 119-152.

Simshauser, P. (2016): ‘Distribution network prices and solar PV: Resolving rate instability and wealth transfers through demand tariffs’, *Energy Economics* 54, pp. 108–22.

Steiner, P.O. (1957): ‘Peak loads and efficient pricing’, *Quarterly Journal of Economics*, 71 (4), pp. 585–610.

Stern, J. & Turvey, R. (2003): ‘Auctions of capacity in network industries’, *Utilities Policy* 11 (1), pp. 1–8.

Xu, Z. (2019): ‘The electricity market design for decentralized flexibility sources’, OIES Paper EL 39, Oxford Institute for Energy Studies.

Yarrow, G. (2003): ‘Capacity auctions in the UK energy sector’, *Utilities Policy* 11 (1), pp. 27–32.