How can nodal pricing engage consumers?

Karsten Neuhoff[1], Franziska Klaucke[1], Mats Kröger[1], Christian Nabe; Luis Olmos[2], Anthony Papavasiliou[3], Lisa Ryan[4], Konstantin Staschus, Silvia Vitiello[5]

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This document presents the discussions and results from the FPM-workshop that took place in Berlin in June 2024 with experts from policy making, academia and business to discuss how consumers can be placed at the center of a nodal pricing design. The discussion took place around the idea of rethinking the market design "bottom-up" from the consumers, rather than top-down from large, centralized generation facilities. The workshop was the third in a series of discussions on nodal pricing as part of the Future Power Market platform. Additional information can be found at www.diw.de/fpm.

Current market design fails to reward the full value of demand side participation

Power markets have historically been designed starting from the needs of large generation companies to match inflexible demand. This neglect of final consumers remains strong in the discussion of wholesale market reforms like zonal or nodal pricing that are technocratic and difficult to access for consumers. Thus, concepts such as nodal pricing have failed to get traction since the implications for consumers were difficult to comprehend. Hence it is time to start with the needs of consumers, and find, how these can be addressed with nodal pricing - by complementing it with an appropriate information and trading interface.

With the increasing share of wind- and solar power in the generation mix as well as the rising capacity of load from electrified production processes, heat-pumps and electromobility rapidly increasing across the EU, demand side flexibility will play an essential part in matching demand and supply at any time,

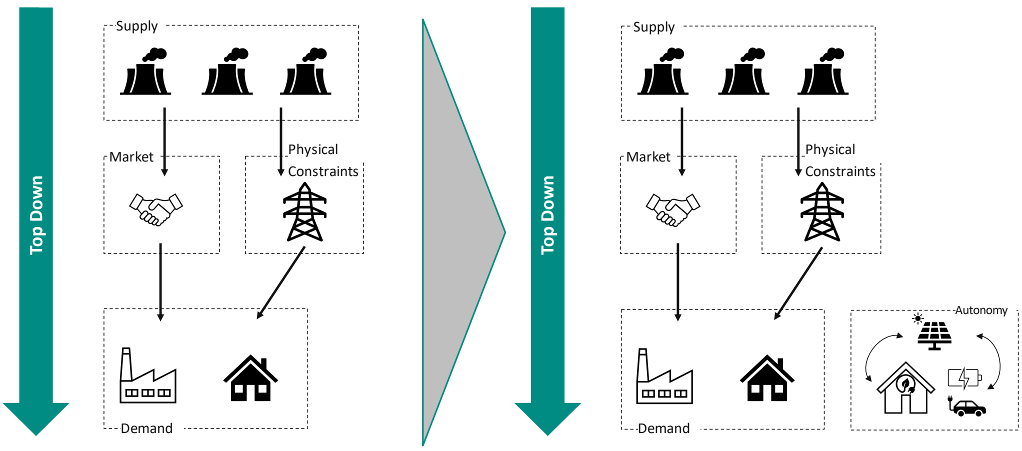

Figure 1 Development from historic power market towards autarky incentives

while respecting operational limits at any point of the network. While traditionally, demand side potentials have been judged to be limited, the potential increases rapidly with grid-connected devices

[1] German Institute for Economic Research, DIW Berlin
[2] Universidad Pontificia Comillas
[3] National Technical University of Athens
[4] University College Dublin
[5] Joint Research Centre of the European Comission in Ispra

such as heat pumps, batteries, or newly electrified production processes and hydrogen electrolyzers that allow for the use of cost-efficient storage for intermediary products and heat, as well as from flexibility of heat-pumps combined with heat storage or electric vehicles.

A variety of barriers that limit the realization of these potentials were identified during the workshop. First, in the specific case of Germany, limited deployment of smart meters for (quarter-) hourly metering and of retail tariffs with time of use rates especially for domestic consumers.[6] Without economic signals, customers do not have incentives to make their demand flexible. Other European countries are far more advanced in their roll-out of the smart meter infrastructure. Second, extensive qualification processes and requirements for the demand side to participate in the various balancing and reserve markets limits revenue potential. In particular, the administrative burden for small demand-side participants can prevent smaller projects from being realized. However, these small units will increase in the future in particular with heat pumps and electric cars. Third, rebates from network charges for industrial consumers with stable consumption patterns discourage flexibility in response to wholesale price developments (e.g., German “7000 hour” rule). Fourth, the current market design does not allow for the use and remuneration of demand side flexibility for congestion management within pricing zones. This leads to inefficient market outcomes and prevents demand side response to capture the full value of their flexibility. Finally, most of the load is located in lower voltage level so that stronger coordination of incentives across voltage levels is required.

As a result, consumers have limited incentives to unlock flexibility potentials and operate them in line with system needs. At the same time, consumers face costs for flexibilizing their load. If they cannot monetarize the value of their flexibility they will not invest in flexibility. Instead, active consumers tend to strive for partial autarky from the grid, i.e. to realize flexibility potentials to minimize the use of electricity from the grid for their building or local energy community, instead of integrating their flexibility into the workings of the market. Thereby, they can capture the (albeit smaller) value of flexibility for themselves instead of optimizing their consumption for the grid. This development creates a set of challenges:

1) **Lower efficiency:** The efficiency potential of an integrated electricity system is foregone if households or firms optimize investment in flexibility and its use for minimizing grid usage. In the absence of efficient time-of-use and locational pricing schemes, the individual optimization can create perverse incentives and does not minimize system costs.
2) **Distributional effect:** Grid cost allocation becomes a great challenge and can become unfair, because flexible households can minimize their payments at the expense of inflexible households. Since the ability to become flexible is lowest among low-income households this can worsen existing unfairness regarding the distribution of energy costs. The more flexible some users become, the more complex become the process to define efficient tariff schemes.
3) **System security:** System security (resource adequacy) could be at risk if decentralized decisions on the operation of flexible loads and storage systems do not respond to signals from the wholesale market or the grid, but only serve to optimize against idiosyncratic preferences and local black-box computer algorithms which are much harder to predict for the system operator.
4) **Producer focus:** If electricity consumers focus their efforts on semi-autarky strategies, electricity producers dominate market design debates and can thus inhibit improvements that reduce their profits.

[6] The experience of rapid escalation electricity costs during the energy crisis further discouraged the deployment of tariffs linked to real-time prices. It is unclear, why electricity tariffs combining a hedge for standard demand profile and exposing consumers to marginal prices for deviations fails to capture attention.

So, given the need for demand side participation, the workshop focused on options to empower consumers to unlock demand side flexibility including how to fully remunerate the flexibility provided to the system.

International experience from markets that unlock demand side participation

Various international examples illustrate successful realization of demand side participation.

In Italy renewable energy communities integrate, at small scale, demand side flexibility and decentralized renewable energy production. They are regionally anchored, and software solutions ensure scalability. Pilot projects have been launched to trigger demand response at distribution level for local congestion management and balancing.

NODES provides a platform for offering local flexibility to distribution network operators in the Nordics, continental Europe and Canada (https://nodesmarket.com/). Factors that were identified as key for creating a well-functioning local market included a small minimum order size, different types of products, interfaces that cater for users with differing degrees of sophistication, dialogue between network operators, market participants and market operator and a sufficient financial return for sellers were. Facilitating learning-by-doing and adjusting the design to consumer needs was also identified as important for the new markets, as was dialogue with stakeholders to ensure their participation and engagement.

EPEX Spot and UK Power Networks created a flexibility platform. It was concluded that it is important that the design of the market focusses on market accessibility, functionality, value, and user friendliness.

Using international experience for the design of Local Energy Marketplaces

Based on the international experience with renewable energy communities and local flexibility markets, the workshop participants explored options to create local marketplaces for electric energy. In contrast to, for example, flexibility markets, these marketplaces should allow for trading electricity, rather than for adjusting demand relative to a baseline. Thus, the local marketplaces could build on the concept of nodal pricing discussed in previous instances of the workshop series[7] and should fulfil the following requirements:

- Create for consumers a clearly defined and easily accessible place to learn about the electricity spot price, and to sell surplus or buy additional electricity.
- Provide for consumers, their retailers, flexibility providers, energy sharing communities and all others a simple interface for demand side automation (e-charging, heat-pumps etc.).
- While retaining the benefits of an integrated power system and the liquidity of the national and European power markets by linking up all local marketplaces with the national power exchange/NEMO to ensure joint price formation and clearing, efficient back-office, etc.

Conceptually, the idea could be described by the analogy to farmers' markets. Farmers' markets offer an opportunity for consumers to acquire locally sourced products they can relate to. This allows small farmers to enter the market, whereas they otherwise could only sell to large food retailers or intermediaries. The idea is to create, in analogy, local marketplaces for electricity in which consumers are happy to engage because they and the market identify with the same home region, and in which the barriers to offer one's local electricity production or flexibility are relatively low. Thereby, the local marketplaces constitute a way of engaging customers with the electricity markets in general.

[7] See previous workshop reports (www.diw.de/fpm).

It remains essential to ensure that the available electricity network is used efficiently to physically move electricity from local marketplaces with surplus power to local marketplaces with insufficient power within each market time unit. All marketplaces must therefore be jointly cleared, easiest in a power exchange algorithm, while considering grid constraints between them. This would work best based on nodal pricing algorithms well established in many parts of the world.

Possible functions of a local energy marketplace

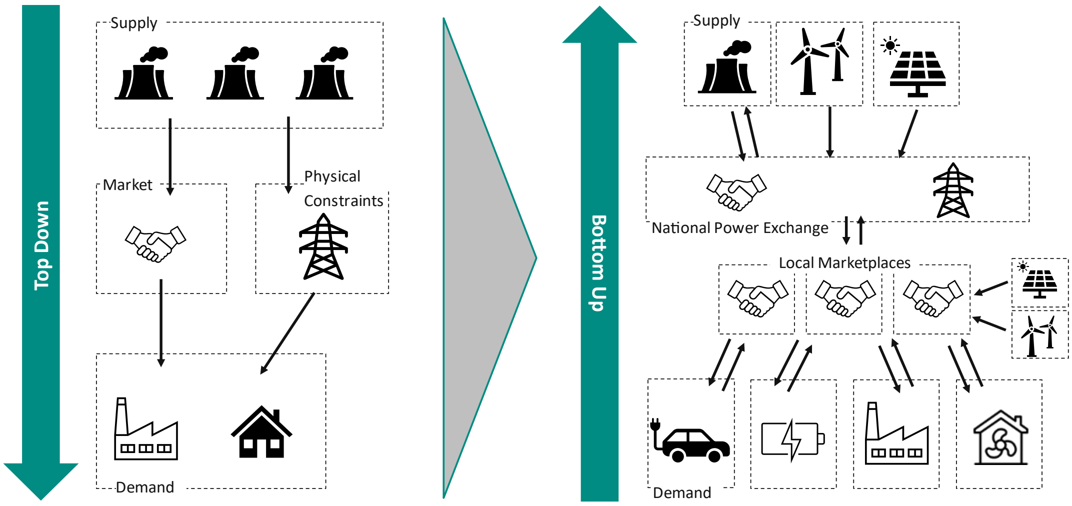

Figure 2 Development from historic to consumer-centric power market design

A local marketplace could comprise various elements, like for example:

- *A consumer interface*, e.g., a webpage which depicts the local marketplace's prices at least for day-ahead and intraday market time units, and which will apply to demand that is not hedged (e.g., through a retail tariff). If some congestion at medium or low voltage exists within the marketplace's boundaries, this and its effects could be displayed as well.
- *A trading interface,* collecting (automated) bids and offers from local consumers, producers and flexibility providers, passes (and potentially aggregates) these to the national power exchange clearing/NEMO, and informs local market participants about accepted bids.
- *A TSO-DSO coordination tool,* for example by screening bids before passing them to the central power exchange clearing, to ensure that they do not violate any DSO constraints at low, medium or high voltage.
- *A clearing platform* for accepted bids and offers.
- *Hosting:* These platforms could all be hosted by the same or by different entities. They could be anchored with the local DSO or largest electricity suppliers in the region, and coordination with a central entity performing the joint market clearing.

Local marketplaces support business models of important stakeholders

- Under these conditions, a local marketplace can support a variety of current business models: Electricity retailers can empower customers to unlock their flexibility, by advice, IT systems, and contract structures to engage with the local market price. The retailer can complement this with hedging offers that provide insurance against electricity price fluctuations and risks.
- Actors facilitating local energy communities and energy sharing can leverage their customer relationships and IT systems to realize the full value of flexibility in their consumer portfolios.
- DSOs, often owned by local electricity suppliers, can strengthen their role in the energy system by serving as hosts or co-owners of the local marketplaces. They can also limit the revenue

risks from vicious cycles that could emerge if autarky strategies escalate the grid costs of remaining customers and thus further accelerate autarky tendencies.

- Power exchanges would benefit from enhanced system integration and thus trading, and could furthermore leverage their market, IT and commercial skills and offer licenses, service contracts or co-ownership for the hosting of local marketplaces.

Small consumers without relevant flexibility-potentials may not envisage direct benefits from their involvement and hence it may be necessary to avoid exposing them to potential costs and risks from the introduction of local marketplaces. In the mid-term these consumers may well be the largest beneficiaries if local marketplaces ensure that all consumers remain connected to the power grid and contribute to sunk grid costs.

Interaction with DSO level congestion management and voltage control

To inform the choice of DSO level congestion management within local market platforms, it needs to be recognized that currently a multitude of approaches are pursued:

- They can comprise auctions for procurement of flexibility (or load reduction) up to one year ahead, for example to reduce constraints during construction periods.
- They can build on local flexibility markets that secure bids for use by DSO and/or TSO.[8]
- There are various concepts of expanding nodal pricing towards nodes of the distribution network, albeit facing challenges as linear approximation of network features is less suitable (e.g. due to binding voltage constraints) and liquidity may be insufficient.
- In California, distribution system operators can nominate flow limits for in/outflows at off-take points from transmission to distribution system to avoid or reduce distribution level congestion. These constraints are then reflected in the nodal pricing clearing algorithm.[9]
- To the extent that local markets aggregate bids prior to their submission to wholesale market clearing, it could also be considered if this could comprise some screening or volume limits.

Given this variety, it was consensus at the workshop that convergence towards one common approach is in the short-term not possible. In the longer-term it depends on network topology, structure of connected load and generation, and scale and capabilities of DSOs. An important argument for a joint approach would be that a scattered approach could lead to inefficient incentives (e.g., inc-dec-game) or limited liquidity in each approach.

Hence, DSOs need to retain flexibility in the local marketplace's design to incorporate a suitable congestion management mechanism. The interface to the wholesale market, however, needs to be standardized for a variety of reasons:

- To avoid complexity for TSOs and power exchanges interfacing hundreds of local marketplaces.
- To reduce the risk of structural changes to the interface, and thus to enhance investment certainty for DSOs and flexible demand.
- For scalability by replication of successful marketplace design across DSOs.

A common interface to address these multiple needs will be of high value. If separate markets and mechanisms are put in place for energy trading at wholesale level and for local (DSO) constraint management, efficiency losses will result from imperfect coordination between the bids/contributions of local agents to the two markets/mechanisms.

[8] FPM report (2018) TSO-DSO-PX Cooperation II, https://hdl.handle.net/10419/180382

[9] FPM report (2017) TSO-DSO-PX Cooperation I, https://hdl.handle.net/10419/167313

What is the regional scope of local marketplaces?

Traditional nodal pricing approaches have defined the geographical coverage by the transfer point from the high voltage [10] to the low voltage network. This could comprise in the German example 834 substations.[11] Some cities comprise several off-take points, and would if this approach is followed, comprise several local marketplaces.

This raises both questions relating to network topology and consumer communication and engagement. From a network topology viewpoint, some cities or rural regions comprise a strong and meshed distribution network, leading to total transfer capacities between the various transmission nodes within the metropolitan area that substantially exceed the capacities calculated based only on the high-voltage transmission lines. In these instances, it is difficult to attribute final demand to a specific off-take point. Also, DSO congestion management might require an integrated perspective extending across multiple transmission off-take points. Furthermore, complexity would increase for consumers, if a city is subdivided into multiple local marketplaces with potentially different electricity prices.

Hence it should be explored to define local marketplaces and thus local prices at the scale of cities or corresponding rural areas, while assessing the risk of structural congestion this may result within these local marketplaces, rather than necessarily for each off-take point from the transmission network as is common international practice so far.

Conclusion

Local marketplaces would offer a variety of opportunities to engage consumers and local stakeholders. They would reflect the consumer centric vision of market design and prioritize the needs of flexible consumers with suitable products. Hosting the local markets with trusted local institutions, such as the DSO, could further reduce hurdles to participate. Alternatively, the local marketplace could also be hosted with other institutions such as the power exchange. Local marketplaces would build on the established nodal market design for wholesale markets that internalizes congestion management at the transmission level.

Thus, local marketplaces facilitate the coordination of storage and flexibility options across the system with price signals and enhance predictability and reliability to ensure system security. This offers consumers incentives to realize a flexibility potential that exceeds their own needs. This can reduce overall system costs and emissions from fossil generation assets currently used to serve flexibility needs. Thereby the concept would avoid excessive costs which could occur if consumers invested towards individual autarky and would avoid escalating costs for the other consumers left to bear the fixed costs of electricity grids (a “social dilemma”). The concept could thus create a benefit to the overall market. At the same time, the identification with the local market could, in conjunction with financial incentives, increase the willingness of consumers to participate in such a flexibility market.

[10] EU voltage higher than 36 kV (DIN EN 50160).
[11] Johannes Knorra, Martin Bichler , Teodora Dobos (2024) Zonal vs. Nodal Pricing: An Analysis of Different Pricing Rules in the German Day-Ahead Market, https://doi.org/10.48550/arXiv.2403.09265