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Flexibility markets: Q&A with project pioneers

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ABSTRACT

Flexibility markets are a promising tool to make better use of existing distribution grids. We analyse four pioneering projects implementing flexibility markets: Piclo Flex, Enera, GOPACS, and NODES. Based on a literature review, we develop a six-question framework. We find that all of the considered flexibility markets are operated by a third party. All projects also engage with multiple DSOs to become the standardized platform provider. Differences among the projects are found in the extent to which the flexibility markets are integrated into other existing markets, the use of reservation payments, the use of standardized products, and the way TSO-DSO cooperation is done. The answers to these questions vary for the projects because of different visions, use cases, or project maturity. Our case study analysis of four pioneering projects enriches the taxonomy and shows that practice is moving faster than the conceptual debate around flexibility markets.

1. Introduction

It is clear that solely relying on grid investments to cope with increasing electricity load and the connection of decentralised generation to the distribution grid will be very expensive. In Europe, flexibility markets are recognised as a tool to make better use of the existing distribution grids and thereby also reduce the need for grid investments. Namely, the newly adopted Clean Energy Package for all Europeans states that distribution system operators shall procure services in a market-based manner from resources such as distributed generation, demand response, or storage when such services are cheaper than grid expansion.[1] Similarly, the Council of European Energy Regulators (CEER) and the respondents to its recent consultation identify market-based procurement as the preferred approach to foster the use of flexibility at the distribution grid (CEER, 2018). Finally, the European Network for Transmission System Operators for Electricity (ENTSO-E) and the major associations for European Distribution System Operators (DSOs) recently published a report in which they emphasize the need for grid flexibility procurement (ENTSO-E et al., 2019). This report also laid out how transmission system operators (TSOs) can coordinate with DSOs as flexibility connected to the distribution grid can be used by both network operators to relieve congestion or for other services.

Most of the existing literature on flexibility markets focuses on their conceptualization. We go a step further by confronting these concepts with the actual projects that are emerging. First, we conduct a literature review to identify the main controversies around the design of flexibility markets, which we summarize as six yes or no questions. We illustrate that the same controversies came up in the debate around the design of other electricity markets, from wholesale to balancing and redispatching markets. Second, we analyse the four pioneering flexibility market projects with our six-question framework.

The four selected projects are Piclo Flex, Enera, GOPACS, and NODES, chosen because they are, as far as the authors are aware, the most advanced initiatives in terms of implementation.[2] Piclo Flex and GOPACS are since recently fully operational after a piloting phase. NODES is a start-up that currently implements pilots and intends to

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[1] See Art. 32 ‘Incentives for the use of flexibility in distribution networks’ in the Directive for the internal market in electricity (recast) (European Commission, 2019).

[2] SmartEN (2019), the European business association for digital and decentralised energy solutions, shortly introduces five projects in its position paper on the design principles for local electricity markets for system services. These include the four projects covered in this study. The fifth project introduced by SmartEN (2019) is IREMEL. IREMEL was set up by OMIE, the Spanish power exchange, and by IDEA, the Spanish Institute for the Diversification and Saving of Energy. As far as the authors are aware, IREMEL is rather in the design phase at the time of writing. USEF (2018), the Universal Smart Energy Framework, covers GOPACS, NODES, and Enera in their white paper on flexibility markets.

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become commercially operational in the near future. Enera is part of the development program Smart Energy Showcases – Digital Agenda for the Energy Transition (SINTEG) by the German Federal Ministry of Economic Affairs and Energy, and profits from a regulatory sandbox.[3] Enera is an ambitious pilot with the goal to develop scalable solutions. There are also other research projects related to flexibility marketplaces with smaller scale R&D demonstrators, examples of such projects are OSMOSE, SmartNet, and WindNode. An overview is given in ENTSO-E (2018a).

Note finally that flexibility markets refer to peer-to-peer trading or local markets, as well as, to markets that are used by DSOs, and possibly also TSOs, to redispatch their grids. The projects referred to in this study also illustrate how the different types of trading activities can take place on the same platform. The need for redispatching comes from the fact that distribution constraints are not adequately taken into account in the existing wholesale and balancing markets. To the extent that this can be solved, there will be less need for flexibility markets, but that is a discussion beyond our scope. A discussion of so-called nodal pricing for distribution grids can be found in the MIT Utility of the Future report (MIT Energy Initiative, 2016) and a discussion of how zonal pricing could be implemented at distribution level can be found in Hadush and Meeus (2018).

The article is organised as follows. In Section 2, we introduce our six-question framework. In Section 3, we analyse the four pioneering projects using the six-question framework. The six questions are: (1) *Is the flexibility market integrated into the existing sequence of EU electricity markets?* (2) *Is the flexibility market operator a third party?* (3) *Are there reservation payments?* (4) *Are the products standardized? (5) Is there TSO-DSO cooperation for the organisation of the flexibility market?* And (6) *Is there DSO-DSO cooperation for the organisation of the flexibility market?* For each question, we provide an answer and a discussion. In Section 4, we briefly discuss design choices that need to be made regarding market access, settlement, and responsibilities. These choices go beyond flexibility market design; they have to do with the participation of distributed energy resources, individually or through aggregation, to electricity markets in general. Finally, a conclusion is provided.

2. Six controversies around flexibility market design

In this section, we introduce six controversies around the design of flexibility markets based on a survey of existing academic literature and stakeholder reports recently published on the topic. Table 1 maps the documentation for each of the six controversies. There is not necessarily a debate with academia on the one side and practice on the other side, and all of the questions can be controversial from both perspectives. These are so-called regulatory “grey areas”. In the following section, we briefly discuss each controversy and illustrate how it also came up in debates about the design of other electricity markets.[4]

First, the resources connected at the distribution level have multiple uses in terms of flexibility. Their flexibility can serve for congestion management, for system balancing, and for portfolio balancing by Balance Responsible Parties (BRPs). Different market design options are possible. ENTSO-E et al. (2019), Gerard et al. (2018), Ramos et al. (2016), USEF (2018) and Villar et al. (2018) all discuss the option to create a separate flexibility platforms for congestion management, with the network operators (the DSO and possibly the TSO) as single buyers, or to have a so-called integrated market model, with DSOs contracting flexibility for congestion management through the existing markets (day-ahead, intraday and/or balancing). Vicente Pastor et al. (2018) conduct a game-theoretical analysis of the different options. Their analysis suggests that the most effective co-ordination would be regulated cooperative dispatch between all network and system operators, and a separate competitive market for BRPs. This dilemma is not entirely new. For example, the balancing energy market can be integrated with the transmission redispatch market, as is the case in Great Britain and the Nordics. Similarly, in most U.S. and a few EU markets (e.g., Poland), central dispatch is applied, where balancing and wholesale markets are cleared jointly (see for example Dallinger et al. (2018) for a discussion and ENTSO-E (2018b) for an overview).

Table 1
Overview of the six design controversies and mapping of relevant literature.

	Academic work	Stakeholder reports
1. Is the flexibility market integrated into the existing sequence of EU electricity markets?	(Gerard et al., 2018; Ramos et al., 2016; Vicente Pastor et al., 2018; Villar et al., 2018)	(ENTSO-E et al., 2019; USEF, 2018)
2. Is the flexibility market operator a third party?	(Burger et al., 2019a; Gerard et al., 2018; Ramos et al., 2016; Stanley et al., 2019)	(ENTSO-E et al., 2019; USEF, 2018)
3. Is there a reservation payment?	Ramos et al. (2016)	(CEER, 2018; EDSO et al., 2017; ENTSO-E et al., 2019)
4. Are products standardized in the flexibility market?	Villar et al. (2018)	(CEER, 2018; EDSO et al., 2017; ENTSO-E et al., 2019)
5. Is there TSO-DSO cooperation for the organisation of the flexibility market?	(Brunekreeft, 2017; Burger et al., 2019a; Gerard et al., 2018; Hadush and Meeus, 2018; Le Cadre et al., 2019; Ramos et al., 2016)	(CEER, 2018; EDSO et al., 2018; ENTSO-E et al., 2019; USEF, 2018)
6. Is there DSO-DSO cooperation for the organisation of the flexibility market?	(Hadush and Meeus, 2018; Stanley et al., 2019)	/

Second, there is an ongoing debate about who should be the market operator. The market operators' main tasks are setting up the market platform, clear the market, and settle transactions.[5] Burger et al. (2019a), Stanley et al. (2019), Ramos et al. (2016) emphasize that to ensure transparency and prevent foreclosure, the market operator must maintain complete independence from market activities. Gerard et al. (2018) and USEF (2018) note that the party being the market operator will be a function of whether the flexibility market is separated or integrated with other markets. Finally, ENTSO-E et al. (2019) stress that network operators should act as neutral market facilitators.[6] Looking at the existing electricity markets in the EU, it can be seen that the market operator role depends on the specific market. For example, wholesale markets are operated by third-party power exchanges, while balancing markets or other ancillary services are currently operated by the TSO. Very recently, however, EPEX SPOT and National Grid joined forces to develop and operate a platform that will host a brand-new firm frequency response auction trial in Great Britain in 2019 (EPEX SPOT, 2018).

Third, there is the option to include a reservation payment. One of the possible models of flexibility markets envisioned by Ramos et al. (2016) includes long-term contracts used for assuring the availability of

[3] A regulatory sandbox typically enables experiments with new technologies, procedures and business models, by providing for temporary regulatory exemptions. Meeus (2019) describes in more detail the different types of regulatory sandboxes.

[4] For a more detailed description of these different existing electricity markets, please consult Schittekatte et al. (2019).

[5] Ofgem (2019) describes six flexibility platform tasks: coordination, flexibility procurement, dispatch and control, platform transaction settlement, platforms market settlement, and analytics and feedback. Flexibility procurement and platform transaction settlement are core tasks of the market operator. Defining market products can be a task of the market operator in cooperation with the network operators, but might require regulatory approval.

[6] A neutral market facilitator guarantees equal market access for all market parties but does not necessarily take up the role of the market operator.

flexibility reserves with an activation market near real-time. In that respect, CEER (2018) recognises that a lack of liquidity in flexibility markets may lead to a situation where long-term contracts may still be needed in some cases. ENTSO-E et al. (2019) describe that different situations in different Member States might require either more short- or more long-term products or a combination of both. Finally, EDSO et al. (2018) note that long-term contracts are beneficial for the investment security of flexibility providers. Again, the discussion about the need for reservation payments is not new. For example, balancing capacity markets are used to reserve resources for the balancing energy markets. In contrast, market players offering their resources in the wholesale market are not subject to a reservation payment.[7]

Fourth, there is a discussion about whether products that are traded in flexibility markets should be standardized (and how) or whether flexibility providers should be allowed more freedom in characterizing their offers. Villar et al. (2018) classify flexibility products considering its main attributes such as scope, purpose, location, or provider. ENTSO-E et al. (2019) recommend that product standardization is implemented at least at the Member State level to limit the costs for market participants in offering the products. EDSO et al. (2018) list several conceivable product attributes. Besides standardizing products in a flexibility market, there is also a discussion about whether products should be standardized at an EU-level. In that regard, CEER (2018) believes that there is no 'one-size-fits-all' approach. In existing electricity markets, products also vary from market to market. Tailor-made trades can be done in bilateral (over-the-counter) markets. Products in wholesale markets may have less strict design parameters than products in balancing markets.

Fifth, TSO-DSO cooperation is very much debated when discussing flexibility markets. Most of the academic research (such as Brunekreeft (2017), Burger et al. (2019a), Gerard et al. (2018), and Ramos et al. (2016)), and most stakeholder reports (such as CEER (2018), EDSO et al. (2018), ENTSO-E et al. (2019), and USEF (2018)) discuss whether the DSO and TSO should procure flexibility in the same market. If the DSO and TSO organize the flexibility market together, more questions arise regarding whether the DSO or the TSO should have priority over flexible resources connected to the distribution grid. Also, how real-time TSO-DSO coordination should be done when a flexible resource is activated in one of the networks is not yet determined. In that respect, Hadush and Meeus (2018) describe how TSO-DSO coordination could take inspiration from the experiences with TSO-TSO coordination for the organization of wholesale and balancing markets. Finally, Le Cadre et al. (2019) conduct a game-theoretical analysis of TSO-DSO coordination. They observe that in terms of resource allocation, the centralized co-optimization of transmission and distribution network resources are the most efficient, followed very closely by a so-called decentralised coordination scheme in which the TSO and DSO simultaneously clear their local markets estimating the flows resulting from the dispatch of the DSO or TSO respectively. A third tested coordination scheme in which the DSOs act first (anticipating the behaviour of the other DSOs and the TSO) results in lower efficiency. In most current electricity markets, resources from both the distribution and transmission levels can participate through the wholesale markets, balancing markets, and even through capacity mechanisms. However, in principle, all these markets could be separately organized at transmission- and distribution-level. For example, Burger et al. (2019a) and Gerard et al. (2018) discuss the option to have DSOs doing local balancing.

Sixth, the last identified controversy is DSO-DSO cooperation.[8] Hadush and Meeus (2018) provide one of the few studies explicitly mentioning DSO-DSO cooperation. They state that the trend toward local energy systems might make DSO-DSO cooperation as important as the DSO-TSO cooperation, especially when DSOs start to use and organize flexibility markets for local congestion management. Stanley et al. (2019) note that increasingly, the aggregators of distributed flexibility and DER act across whole states, provinces and, in the future, across borders. Therefore, flexibility providers would benefit from streamlined interfaces with different DSOs. In existing markets, the focus was so far on TSO-TSO cooperation. TSO-TSO cooperation can vary to a great degree depending on the market. Strong TSO-TSO cooperation is in place for the day-ahead wholesale market (market coupling), while TSO-TSO cooperation is less developed in balancing markets.

[7] Excluding capacity mechanisms which can be seen as a reservation mechanism to ensure adequacy.

[8] Multiple configurations are possible because DSOs can be connected horizontally but also vertically.

3. Analysing four pioneering projects

This section contains two parts. First, the four pioneering projects are introduced, including a table with an overview of some key characteristics. Second, we review the identified design controversy question. For each, we explain how each project answers the question, followed by a discussion. The approach of each project was derived from structured interviews with the respective project representatives. The arguments are drawn from an online discussion among experts from the Florence School of Regulation (FSR) EU Electricity Network Codes course alumni community, an online panel debate on the April 24, 2019 among project representatives and the cited literature.[9]

3.1. Introducing the four pioneering projects

First, Piclo (previously known as Open Utility) is an independent software company that has been active in the energy industry since 2013. In October 2016, Piclo launched its first energy application, Piclo Match, a peer-to-peer energy matching service (Johnston, 2017). We focus on Piclo's second application, Piclo Flex, which was piloted in June 2018 with funding from the U.K. Government Department of Business, Energy & Industrial Strategy (BEIS) and subsequently launched as a commercial offering from March 2019. All six DSOs in Great Britain participated in the BEIS trials. Subsequently, Piclo has signed commercial agreements with three DSOs to support their ongoing flexibility procurement activities: UK Power Networks (UKPN), Scottish and Southern Electricity Networks, and Western Power Distribution. We mainly focus on how UKPN uses Piclo to procure flexibility as UKPN were the first DSO to use the full functionality of the Piclo Flex service during the BEIS trials (Stanley et al., 2019). In March 2019, the first flexibility tenders to deliver flexibility needs for 2019/20 and 2020/21 were organised by UKPN on Piclo Flex. The tenders are organised per constraint area, so all flexible resources connected within a predefined geographical area can compete in the tender. For one constraint area, multiple tenders can be held for different services (such as reinforcement deferral, maintenance) and different contract periods. Table 2 gives more information about these first tenders.

Second, Enera is a joint project between the power exchange EPEX SPOT, the energy group EWE AG, one of the German TSOs TenneT DE and the German DSOs Avacon Netz and EWE NETZ. A scalable pilot is built up in a showcase region, in this case in the windy Northwest of Germany. The main goal is to enable flexible solutions to avoid uneconomic curtailment of excess wind energy. In Enera, network operators

[9] The contributors are identified in the acknowledgements. Currently, two editions of the FSR course have taken place for a total of 271 alumni come from 30 different countries; 50% are senior professionals having five or more years of work experience in the sector. About 60% of the alumni work for energy companies or utilities, 30% work for public or regulatory bodies, 5% are academics, and 5% elsewhere.

can buy flexibility in the intraday timeframe to proactively alleviate congestion.[10] As congestion is specific to certain locations in the grid, local order books are set up in Enera. The first trade was cleared on the February 4, 2019 at 15h25. Audi (with a Power-to-Gas unit) committed to increasing its consumption by 2 MW at the request of EWE NETZ for delivery on the same day from 17h00–18h00. Table 2 gives more details about Enera.

Third, GOPACS stands for Grid Operators Platform for Congestion Solutions and was launched in January 2019. GOPACS is owned and operated by the Dutch TSO and four DSOs (Stedin, Liander, Enexis Groep, and Westland Infra). GOPACS is different from the other initiatives presented here in the sense that it is not a market platform (no flexibility offers are cleared on GOPACS). Instead, it acts as an intermediary between the needs of network operators and markets. GOPACS is connected to a national intraday platform Energy Trading Platform Amsterdam (ETPA), which is operational in the Netherlands.[11] GOPACS intends to be connected to more market platforms at a later stage. Offers from flexibility providers active on ETPA can be procured by GOPACS if they add a locational tag. There are no static geographical zones defined in ETPA. Instead, GOPACS identifies through its algorithm which assets offer the cheapest solution to solve congestion.[12] At the time of our study, only flexible assets connected to the transmission grid are active on GOPACS. In the near future, also DSO connected assets at lower voltages are expected to participate. Table 2 gives more details about how GOPACS is used.

Fourth, NODES is a joint venture between the Norwegian utility Agder Energi and the European power exchange Nord Pool. NODES was established in early 2018. NODES is active in three pilots. One installation is in place in Norway with the DSO Agder Energi Nett. The other two installations are situated in Germany. One is in use by the German DSO Mitnetz Strom and the other by the German DSO WEMAG Netz (Engelbrecht et al., 2019). Both DSOs are situated in the TSO area of 50 Hz. The pilots are quite different in aim as the Norwegian DSO mostly suffers from growing loads which could require an upgrade of a transformer, while the German DSOs need flexibility to avoid curtailment of renewables (USEF, 2018). The Norwegian pilot will be expanded in 2020 and intends to span over three Norwegian bidding zones. On the NODES platform, BRPs and network operators can procure local flexibility in the intraday timeframe. The offered flexibility, which is not needed locally, will be forwarded to other existing market platforms, more specifically the intraday and balancing market. The interfaces between NODES and the existing markets are not yet in place. In NODES, flexibility providers tag their offers with a grid location (GL). One or multiple GLs constitute a local pricing zone. The local pricing zones can differ depending on whether the TSO or DSO is buying flexibility and can be adjusted dynamically on short notice (cfr. weeks).[13]

3.2. Analyzing the projects based on the six design controversies

3.2.1. Is the flexibility market integrated into the existing sequence of EU electricity markets?

We focus here on the integration of flexibility markets with wholesale and/or balancing markets; the integration of DSO flexibility markets and TSO redispatch markets is discussed in Section 3.2.5. There are two projects that provide separate platforms (Piclo Flex and Enera) and two projects for which the flexibility market is integrated to a certain degree into the existing sequence of markets (GOPACS and NODES).

Piclo Flex is clearly a separate platform from the existing sequence of electricity markets. Tenders are organised on Piclo Flex with a lead-time of six months or more, and the contract duration is between a couple of months and 4 years (UKPN, 2018a). A pre-qualified flexibility provider participating in the tender has to submit both an availability offer (the price in £/MW/h for availability) and a utilisation offer (the price in £/MWh for utilisation) as well as the maximum running time (Piclo, 2019a). Contracted flexible resources on Piclo Flex do not have to adhere to dispatch instructions by the DSO for the full contracted period but only during a service window within the contracted period (e.g., winter week-day evenings), which is predetermined at the time of the tender.

Enera is also a separate platform. Enera runs in the intraday timeframe. Flexibility providers submit offers and network operators submit flexibility demand orders that are continuously matched on the platform. Access to the Enera trading platform is standardized, such that market parties can use the same API which they use to trade in the intraday (energy) market when using EPEX SPOT's services. Market parties have the option to submit offers with the same underlying asset for the different markets. The offers can differ in price. However, if all offers on the different markets were cleared, the activations would be incompatible. The responsibility to avoid double activation lies with the flexibility providers.

GOPACS is integrated into the existing sequence of markets. The integration is achieved by sourcing flexibility from existing platforms. GOPACS is only connected to ETPA but connections with other markets are envisioned. On ETPA, locational flexibility offers for network operators are not placed on a separate platform but instead are seen as a subset of the (wholesale) intraday order book. Network operators and market parties (BRPs) can procure the same flexibility. Flexibility providers have the option to offer the same flexibility at two different prices by placing two orders (e.g., one portfolio offer for the intraday wholesale and a second offer with locational information). The flexibility provider is responsible for avoiding double activations. How GOPACS will connect the other intraday markets and balancing markets remains to be seen.

NODES is integrated into the existing sequence of markets. The integration is achieved in two ways. First, NODES is an intraday platform like ETPA and similar to GOPACS, network operators source their flexibility offers on the same platform as BRPs. Again, flexibility providers can construct different offers with the same underlying assets for different prices and the flexibility provider is responsible for avoiding double activations. Second, the flexibility provided on the NODES platform, which is not needed locally, is also envisioned to be forwarded to other market platforms, namely, the cross-zonal intraday and balancing market (NODES (2018)).

3.2.1.1. Discussion. One argument in favour of separate platforms and three arguments in favour of integrated platforms are identified.

The main argument for using separate platforms is that the differences between the products (locational or not) are highlighted, the market is easy to clear, and transparency on price levels is created. In the debate around central versus self-dispatch, transparency is also used by for example Ahlqvist et al. (2018) as an argument in favour of self-dispatch electricity systems.

[10] At the time of our study, redispatch in Germany is regulated. Audited cost or foregone revenues are paid to the TSO-connected market parties that are activated for redispatch. As long as this is the case, the only way DSO-connected flexibility providers can compete to deliver flexibility to the TSO is by offering flexibility at a lower price than the costs of the TSO-connected redispatch resources.

[11] Besides intraday, ETPA also offers day-ahead, week and weekend contracts.

[12] Finding the cheapest solution to solve congestion is a function of the price of the offer from the flexibility provider and of the location of the flexible asset. Some flexible assets can have a higher offer price but be more effective due to their location relative to the congestion.

[13] For example, congestion at the TSO-level can be solved by flexible assets located in different ''DSO local price zones''. Thus, the TSO when buying flexibility will consider a local price zone which is an aggregate of multiple ''DSO local price zones''.

Table 2
Comparison of the four projects at the time of this study[a].

	Piclo Flex	Enera	GOPACS	NODES
Data	**1st tender (cleared-15/05/2019), flexibility procured by UKPN**[b]	**Status on 09/2019 based on interview**	**Status on 09/2019 based on interview**	**Status N pilot on 09/ 2019 based on interview - to be extended in 2020**[c]
Timeframe	Months ahead	Intraday	Intraday	*Pilot:* Intraday *Extended:* Intraday & near real-time (only for TSO)
Market clearing[d]	Auction	Continuous trading	Continuous trading	Continuous trading
Price zones	28 constraint areas (contracts awarded in 7 areas)	23 local order books, expanded from 11 in September 2019	No static zones, dynamic dependent on congestion needs	*Pilot:* 1 zone *Extended:* order of 7–13 zones (dynamic)
Voltage level flexible units (at present)	11 kV or lower	20 kV or lower	110 kV or higher, soon also 50 kV or lower	*Pilot*: 22 kV or lower *Extended*: 132 kV or lower
Number of flexibility providers	6 successful (19 prequalified, 15 bid)	6	5–10	*Pilot:* 1 *Extended:* 5
Indication of the magnitude of the available flexibility	18.1 MW contracted flexibility on 94.8 MW demand	First trade: 2 MWh, 50 + transactions between feb–oct/ '19	10-100 MWh per trade	*Extended:* projection of ±10 MW available flexibility

[a] Disclaimer: this is a snapshot of the status of the projects, the projects are constantly evolving.
[b] Main sources used are UKPN (2019, 2018b, 2018a). At the time of writing, more than 200 flexibility providers offering over 4.5 GW of flexibility are registered to Piclo Flex; more than 100 auctions are organized for 73 constraint areas (Piclo, 2019c).
[c] More information about the two German pilots (assets connected to 110 kV) can be found in Engelbrecht et al. (2019).
[d] Enera, GOPACS, and NODES are also considering including the possibility to reserve assets (month-ahead or longer). In that case, auctions would be used.

The first argument in favour of integrated markets is liquidity pooling. However, products differ on the integrated platform (locational or not) and flexibility providers have the option to place separate offers for the same underlying assets. This argument would be stronger if auctions were used instead of continuous trading (as in Enera, ETPA, and NODES). With auctions, the needs of the market parties and network operators would be combined at one point in time; as such, the flexibility could be allocated more efficiently.[14]

The second argument in favour of integrated markets is the simplicity of making one platform available to which smaller market parties can connect and submit just one offer that can serve for congestion management, balancing or for a BRP to balance its portfolio. This reduces complexity and access costs to different platforms.

The third argument in favour of integrated markets is that by allowing other market parties (BRPs) to procure locational flexibility in the same market as network operators, that market can de facto function as a secondary market for flexibility providers.

3.2.2. *Is the flexibility market operator a third party?*

In all four cases, a third party operates the platform. Piclo Flex is developed and operated by a new entrant in the energy business. In the case of Enera, EPEX SPOT built up the platform, one of the two largest power exchanges in Europe. Similarly, for NODES, Nord Pool, the other large European power exchange is backing up the development. Besides Nord Pool, the other party owning NODES is Agder Energi. Agder Energi holds both distribution network assets and generation assets. The NODES (2018) white paper states that if NODES is in full operation, it will need to be an independent party. As such, Agder Energi will not be a major owner of the marketplace. In the case of GOPACS, the platform provider (ETPA) is a new independent power exchange. GOPACS is an intermediary between the network operators and the market platform.

3.2.2.1. Discussion. It is important to emphasize that the answer to this question is not black and white. Several market operation tasks (such as clearing and settlement) could be allocated to third parties while other tasks could be the responsibility of the DSO (e.g. validating offers and product design). More generally, we identify three arguments in favour of having a third party as the market operator and one argument against.

First, in the case of DSOs, the know-how might not always be present in-house to build up market platforms from scratch. Stanley et al. (2019) point out that engagement with a specialised third party can allow for faster development of the procurement mechanisms of new services.

Second, an argument often brought up by power exchanges is that by letting the market operation function over to a third party, neutrality between buyers and sellers is ensured. For example, in the case both DSOs and the TSO use the same platform to procure flexibility, or the flexibility market is integrated into a local wholesale market, the neutrality among buyers is assured by having a third party as market operator. Burger et al. (2019a) emphasize that neutrality is even more important if the network operator would own distributed energy resources, such as batteries.

Third, if network operators (DSO or TSO) operate the market platform for flexibility procurement, the platform will be monopolistic by nature. However, if a third party operates the platform, this is not necessarily the case. The question of whether market operation is a monopolistic activity or whether it can be a competitive activity is discussed in depth by Meeus (2011) for wholesale markets. In that paper, we argue that due to network effects, it is hard to have well-functioning competition between market platforms but that allowing competition may still have benefits, such as stronger incentives for innovation.

An argument against having a third party as a market operator is the cost of interface management between the grid operator and the market operator.[15] In general, there is always a cost to manage interfaces between different parties when formerly integrated activities are unbundled. A typical example of the trade-off between removing conflicts of interest and the costs of interface management beyond flexibility market design is the debate about the unbundling of TSOs or DSOs in network asset owners (TNO or DNO) and a system operator (ISO or IDSO) as documented by Pollitt (2012) for TSOs and more recently debated in

[14] However, in the case of low liquidity, there are also arguments in favour of continuous trade.

[15] This argument only applies to platforms operated and used by one network operator. In case a platform is operated by one network operator but used by multiple network operators, there will also be a cost of interface management.

Burger et al. (2019b) for DSOs.[16]

3.2.3. Is there a reservation payment?

Looking at the four projects, for now reservation payments are only used in Piclo Flex. An important feature of the flexibility tenders organised on Piclo Flex is that revenue stacking (contracting with multiple other services) is allowed.[17] Enera, GOPACS, and especially NODES all mention that in the future they intend to set up or integrate longer-term reservation markets.

3.2.3.1. Discussion. Two arguments in favour and two arguments against reservation payments are identified.

First, long-term contracts are a way to manage the risk between the grid operator and the market parties, guaranteeing that there will be flexibility at all times. An issue with services for very specific locations is that there are not necessarily many parties present that can offer the service in need. One of the possible remedies for such an issue is long-term contracts with a sufficiently long lead-time and contract duration. As such, flexibility providers are given enough time to make the necessary investments and enough certainty about future revenue streams. This is also what UKPN (2018a) mentions in its Flexibility Roadmap. For reinforcement deferral (due to an increase of load), the lead-time between the tender and the start of the contract is 6 months or 18 months. Reinforcement deferral is the main use case of UKPN at this moment.[18] In the future, the lead times might be reduced significantly, for example, to one week. For Enera, the use case is the avoidance of curtailment, which can explain why no reservation is in place yet.

Second, long-term contracting is a way to mitigate gaming. Long-term contracting reduces or eliminates the incentive to game prices in short-term markets as the impact of short-term price fluctuations on a flexibility provider's revenues are reduced. An elaboration of this argument in the context of electricity wholesale markets can be found in Léautier (2018). Two situations in which gaming is possible can be distinguished: gaming within a market and gaming between markets. In the first situation, players can make use of market power to elevate prices above competitive levels, for example when there are very few market players that are able to offer flexibility at a specific location at a certain point in time. In the second situation, market players have the possibility to strategically adapt their bids on wholesale markets when they can anticipate congestions that will be solved in a subsequent market. This can happens when there is a wholesale electricity market with large geographical coverage and subsequently redispatch markets at a more local level. As such, market players can consciously aggravate (expected) congestions and then be paid in the redispatch market to solve the problem they created themselves. This is possible under the condition that market players have a good idea of the bottlenecks in the grid. This strategy was coined as the incremental-decremental (inc-dec) game by Stoft (1999). Holmberg and Lazarczyk (2015) and Hirth and Schlecht (2019) show that inc-dec gaming is an arbitrage strategy that can even be successful in the absence of market power. Besides long-term contracting, there are other possible remedies to limit gaming in flexibility markets. As also discussed in Neuhoff et al. (2018), examples are extensive (automatic) market monitoring and enforcement of anti-trust law, price caps and introducing temporary administrative prices in locations where there are few players or where structural congestion is present.[19]

The first argument against reservation payments is that short-term efficiency is sacrificed to a certain extent. However, this is only true if the utilisation payments are determined at the time of the (reservation) tender. The moment that there are enough market parties competing to offer flexibility near real-time, the requirement to determine the utilisation payment at the time of the (reservation) tender could be discarded. This is similar to the practice in balancing markets in the EU and advocated by for example Müsgens et al. (2014).[20] Namely, balancing capacity is procured solely based on the balancing capacity offers submitted by the Balancing Service Providers (BSPs). In real-time, there is competition for activation between contracted, who have the obligation to bid in the balancing energy market, and non-contracted balancing resources (EC (2017), Art 16 (5–6)).

The second argument against reservation payments, especially with long contract durations, is that it can be harder for certain resources (such as demand response) due to forecasting difficulties to guarantee availability for a long time horizon. Thus, reservation can act as an entry barrier for these flexible resources.

3.2.4. Are products standardized in the flexibility market?

For three of the projects (Piclo Flex, Enera, and GOPACS) it can be said that products are standardized. However, the designs of the standardized products differ substantially between the projects. Products in NODES are not standardized.

In Piclo Flex, standardized products are in place. The short-term activation product is determined per constraint area at the time of the tender. At the time of writing, UKPN has 73 constraint areas defined in Piclo Flex. Besides location and voltage level, the key operational parameters are the service window (and the contract duration during which this service window holds) and the minimum and maximum running time (see also the upper left image in Fig. 1). All other technical parameters are validated during the prequalification process.

In Enera, standard product definitions are determined by EPEX SPOT in cooperation with the network operators procuring the flexibility. The products look similar as in the intraday with blocks of energy up or down for a certain duration (such as 1 h or 15 min) for a certain location as shown in the lower-left image in Fig. 1. In terms of locational tagging, each order belongs to a certain node predefined by Enera. The local order books consist of orders from one or more nodes.

GOPACS, as currently in place, procures standardized products from ETPA to which a locational tag is added. The locational tag is called an EAN-code. Unique to GOPACS is that it always procures a combination of two orders (a buy and a sell order). This product is called an Intraday Congestion Spread (IDCONS) (GOPACS, 2019). The buy and sell orders

[16] Please note that with a third party market operator and a DSO, there is an interface between the market on one side and the grid assets and operation on the other side. With an IDSO as the market operator and a DNO, an interface would be created between the market and operation on one side and the grid assets on the other side.

[17] One exception applies, flexibility contracted on Piclo by the DSO to defer reinforcement cannot offer additional services that require an increase in active load, unless outside of contracted service windows.

[18] Other use cases are maintenance and dealing with unplanned interruptions (pre- and post-fault). Depending on the use case, the exact tender design can differ.

[19] Another way to avoid gaming is to completely regulate redispatch and remunerate instructed redispatch actions based on the audited costs or forgone revenue of the called-up resource. However, it is believed that market-based redispatch can bring gains by driving redispatch costs down due to competition and can provide better price signals for where to locate future flexibility generation or demand. Another issue with a regulated approach for redispatch is that it is very hard to estimate the costs to redispatch the new generation of flexible resources such as demand response and storage. As such, these resources would be hard to deploy for such purpose, even though they could be of great value for the system. Overall, there is a trade-off between benefits from possible competition and costs from possible gaming.

[20] The German balancing market is an interesting case in that regard. Namely, in July 2019, the ''mixed pricing rule'', which bases the selection of providers of balancing reserve on a mix of their capacity and energy bid, has been annulled by a court ruling (Higher Regional Court of Düsseldorf, 2019). The mixed pricing rule was in place in Germany since October 2018. At present, the balancing reservation is only based on the capacity bid and competition for balancing energy activation near real-time is possible.

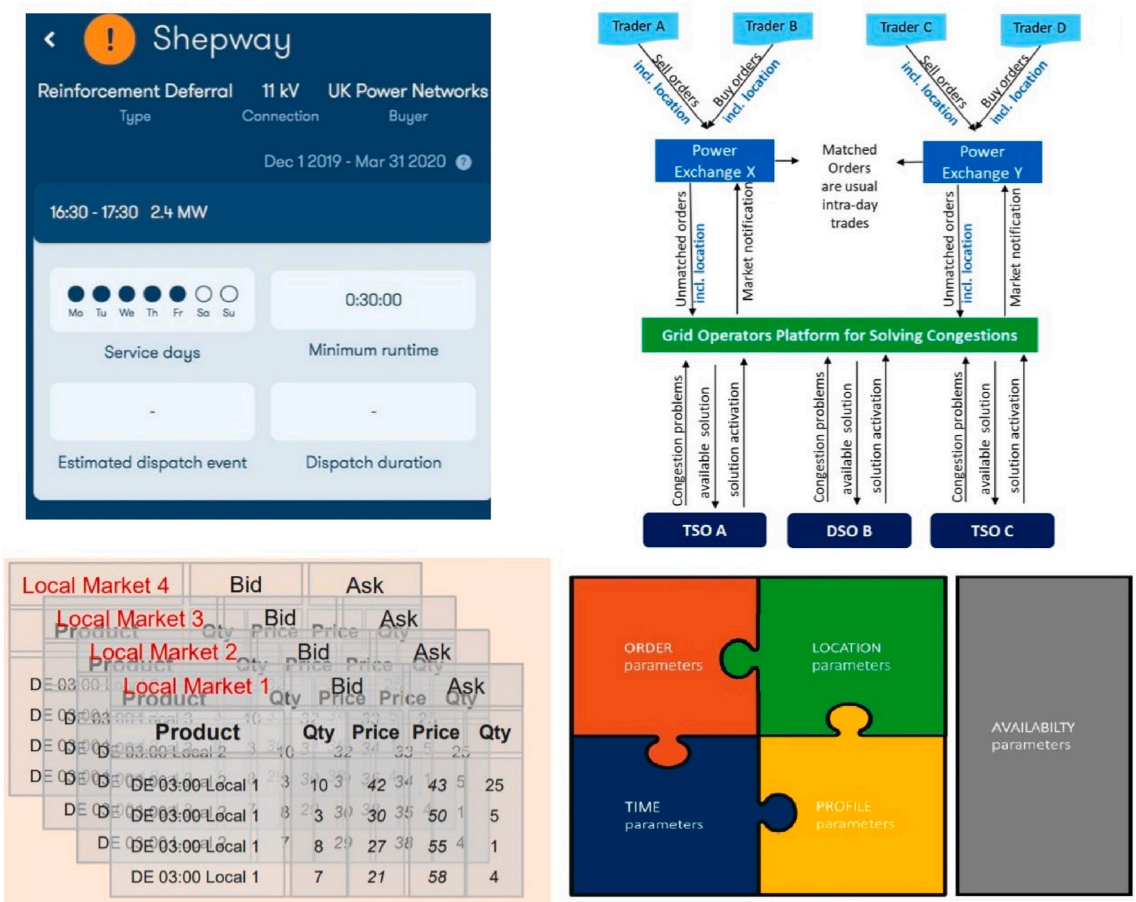

Fig. 1. Illustration of the different short-term market products in Piclo Flex (service window) –upper left, Enera (locational orders) –lower left, GOPACS (IDCONS product) – upper right, and NODES (different types of parameters) –lower right. Sources: Piclo (2019b), USEF (2018), Hirth and Glismann (2018) and NODES (2018).

have the same format as intraday wholesale orders (simple bids of 15 min or 1 h), and orders match in starting time, volume and duration but are located in a different area. The upper right image in Fig. 1 illustrates the IDCONS product. If congestion occurs in one part of the network due to high load, one energy sell order will be procured by GOPACS in that part of the grid. At the same time, in a non-congested area, an energy buy order will be activated. As such, an energy imbalance is avoided. The price of the energy sell order will be higher than the price of the energy buy order. The network operator who requests the flexibility pays the price difference (or spread) between the orders.

In NODES, no standard product definitions are set. Instead, flexibility providers have the choice to specify their offers using a wide range of parameters. Examples are technical and financial parameters, but also the generation source can be specified. The lower right image in Fig. 1 shows the different groups of parameters. As such, a catalogue of flexibility offers is built up. Flexibility buyers can filter offers from the catalogue and then select the cheapest offer that fulfils their needs. NODES also allows network operators to create a template with the parameters they would like to see specified. In terms of location, flexibility offers can indicate in which grid locations (GL) they are connected. DSOs and TSOs determine the delineation of GLs, which are smaller for DSOs than TSOs and always smaller than bidding zone areas.

3.2.4.1. Discussion. We identified one argument in favour of and two against standardized products.

The main argument in favour of standardized products is to allow for a sufficient level of liquidity, whereby standardized products allow for building up a merit order to organize the competition. As a result, with standardized products price transparency is promoted. It is more difficult to compare the value of offers in case of unstandardized products. The number of different flexibility offers that can be made increases exponentially as a function of the possible product parameters. Similarly, in the debate around the European platforms for balancing energy liquidity is also the argument brought forward to have (a limited number of) standard products (ENTSO-E, 2016).

The first argument against standardized products is that with standardized products it is hard to meet very specific flexibility needs of network operators.[21]

A second argument against standardized products is that a catalogue approach has the advantage for flexibility providers that specific characteristics of their flexibility (e.g. reaction time or emissions) can be better valued. Flexibility providers can customize their offers and ask for premiums when an asset has valuable attributes that would otherwise not be valued if they were not part of the product definition.

3.2.5. Is there TSO-DSO cooperation for the organisation of the flexibility market?

The projects differ in how TSO-DSO cooperation is dealt with. GOPACS is built-up and used by one TSO and four DSOs. Enera and NODES allow for TSOs to procure flexibility on the same platform as DSOs. In the case of NODES, the TSO is not active yet. Piclo Flex is solely used by DSOs.

[21] To draw the parallel with balancing, for this reason, European TSOs are allowed to introduce specific balancing products if they can show to their regulator that their balancing needs cannot be satisfied only through the European platforms with standard products (EB GL, Art. 26).

GOPACS is very relevant in this regard. GOPACS is one of the first implemented TSO-DSO coordination platforms. In its current version, GOPACS assures that no conflicting activations occur. In the future, the idea is also to identify synergies between the needs of different network operators.

For Enera, one DSO is procuring flexibility and the TSO became an active buyer since recently. In the first step of the Enera project, so-called Enera 1.0, the DSOs and the TSO are expected to communicate bilaterally when activating an offer to avoid conflicts. In the future, the idea is to have a 'vertical coupling' in place so that offers will be filtered on the market platform in a way that no conflicting activation can occur, similar to how cross-zonal offers or bids are not accessible if cross-zonal links are congested in (horizontal) market coupling.

No TSO is currently active in a NODES installation. Soon the TSO will be active in the extended Norwegian pilot. In the future, TSO-DSO cooperation is intended to be dealt with by filtering out the offers available to one network operator if they would cause problems for other network operators. How grid locations (GLs) are defined, which are nothing more than clusters of physical points, can also help to make actions of one network operator more transparent for other network operators in order to avoid conflicting activations.

At present, Piclo Flex is solely used by DSOs and the cooperation with the TSO is limited at the moment. When a DSO activates a resource for congestion management, the DSO has to notify the TSO.

3.2.5.1. Discussion. We identify three arguments in favour of TSOs and DSOs using the same platform to procure flexibility and one argument against.

First, using the same platform limits the number of platforms that must be built and take into account by a flexibility provider when marketing its flexibility.

Second, liquidity increases in case TSOs and DSOs procure flexibility on the same platform; one asset connected at the distribution level can be procured by either the TSO or the DSO to solve congestions.

Third, by using the same or a similar platform, real-time coordination between the TSO and DSOs could be facilitated. For now, real-time TSO-DSO coordination is focused on avoiding conflicting activations by the different network operators. In the future, finding synergetic activations is expected to be developed, with the activation of one flexibility resource able to solve issues in both networks.

An argument against introducing a platform where both DSOs and TSOs procure flexibility is speed. It costs time to set up the collaboration with a TSO and by starting with a platform only for one or more DSOs, initial experience can be gained.

3.2.6. Is there DSO-DSO cooperation for the organisation of the flexibility market?

All platforms are intending to engage with more DSOs in the future in order to position their (customisable) flexibility market platform as the standard solution in Europe. In the case of Piclo Flex, all six DSOs in Great Britain participated in the BEIS trials. Subsequently, Piclo has signed commercial agreements with three DSOs to support their ongoing flexibility procurement activities. Two DSO are currently active on Enera (EWE NETZ and Avacon Netz). The case of Enera is different from Piclo Flex in the sense that DSOs are vertically connected; EWE NETZ is connected to Avacon Netz, which in turn is connected to the TSO TenneT DE. In the case of GOPACS, four DSOs besides the TSO are using the same TSO-DSO coordination platform. At present, in each NODES installation, only one DSO is active. More DSOs are expected to join the platforms soon.

3.2.6.1. Discussion. Three arguments in favour of DSOs using the same platform to procure flexibility are identified and one argument against.

The first argument in favour is that when DSOs cooperate and use the same platform, the learning costs for flexibility providers with assets in different DSO areas to use the platform can be limited. This is also described by Stanley et al. (2019) who discuss the Piclo Flex platform in more depth.

Second, when DSOs use the same platform, the difficulty for the TSO to create a different TSO-DSO interface with all DSOs and other relevant companies could be reduced.[22]

Third, from an operational point of view, activations near the boundaries of two DSOs could affect each other networks if they are horizontally (or exceptionally, vertically) connected, similarly as is the case between two TSOs at the transmission level. For example, it could be that there is a congestion issue in the area of one DSO, but that cheaper flexibility that could solve that problem is available in the area of another DSO. In such a setting, coordination and cost-sharing agreements between DSOs need to be developed which are easier to develop if the same or similar flexibility platforms are used.

An argument against DSOs using the same platform to procure flexibility is that standardizing the DSOs platforms to some extent (such as winner-takes-it-all) could limit benefits from innovation and competition between platform providers.

4. Market access, settlement, and responsibilities

In order to make flexibility markets work, several choices need to be made regarding market access, settlement, and responsibilities. These choices go beyond flexibility market design; they have to do with the participation of distributed energy resources, individually or through aggregation, in electricity markets generally. Studying these choices in depth is out of the scope of our study but we highlight five aspects in Table 3 and illustrate what choices have been made in the different projects.

First, participation in all flexibility markets is voluntary and no technology is excluded. However, in NODES there is the possibility for buyers of flexibility to filter flexibility offers depending on the technology type.

Second, all projects have a pre-qualification procedure. In almost all cases, the pre-qualification is done by the so-called connection network operator, meaning the DSO or TSO to which the flexible asset is connected. The pre-qualification procedure is in most cases similar to the procedure in place to obtain access to balancing markets.

Third, there is no harmonized approach in calculating the baseline.[23] UKPN (2018b) describes the use of a baseline methodology based on representative historical data when activating flexibility. GOPACS makes use of the transport prognoses (t-prognose), whereby flexibility providers have to communicate day-ahead schedules that serve as baselines.[24] The applied baseline method in Enera and NODES depends on the connecting network operator and technology. For example, there can be a different baseline method for renewable generation than for demand response. Setting an adequate baseline is challenging, as discussed by Rossetto (2018).

Fourth, at present, none of the projects specify a penalty for non-delivery. UKPN (2018c) does describe that in the case of three or more default events, the contracting DSO has the right to remove the flexible asset from the contract. The general idea behind not having penalties is to lower the entry barriers for new entrants. Once experience with the flexibility markets has been gained, penalties for non-delivery

[22] An example of another company is a Balancing and Settlement Code (BSC) company which can take over some tasks of the TSO related to the imbalance settlement (e.g. as is the case in GB with Elexon).

[23] The baseline represents the counterfactual generation or consumption level of the flexible asset had it not been providing flexibility services. The baseline is needed to measure the effective performance of flexible resources and to properly compensate the flexibility provider.

[24] In the future, with assets also connected to lower voltage levels, a similar procedure might be developed.

Table 3
Overview of a selection of design choices beyond flexibility markets.

	Piclo Flex	Enera	GOPACS	NODES
Data	**1st auction (cleared- 15/05/2019), flexibility procured by UKPN**	**Status on 09/2019 based on interview**	**Status on 09/ 2019 based on interview**	**Status pilot on 09/2019 based on interview**
Participation	Voluntary, no restrictions	Voluntary, no restrictions	Voluntary, no restrictions	Voluntary, no restrictions, but buyers can filter offers per technology
Pre-qualification	Yes, done by the connecting DSO	Yes, done by the connecting SO	Yes, done by the connecting SO	Yes, collaboration between NODES and the connecting SO
Baseline	Default baseline is based on representative historical data	Depending on the connecting SO and technology	T-prognose (schedule communicated D-1 by flex provider)	Depending on the connecting SO and technology
Penalties for non-delivery	No, but DSO can remove a flex unit from the contract after 3 "default events"	No, but considered when expanding	No, not for now	No, but considered when expanding
Balance responsibility	The flexibility provider has to self-rebalance	The flexibility provider has to self-rebalance	The flex provider is automatically rebalanced	The flex provider may self-rebalance or allow NODES do it

are considered.

Fifth, flexibility providers can either act as a BRP themselves or can trade on behalf of (or with agreement from) their BRP (USEF, 2018). Contractual arrangements between (independent) aggregators, suppliers, and BRPs are a topic of debate and dependent also on the national regulatory framework. A recent discussion can be found in Poplavskaya and De Vries (2018). In all flexibility markets except for GOPACS, the flexibility providers have to self-rebalance after activation of a flexible unit. Thus, the cost of self-rebalancing will be reflected in the flexibility offer. In NODES, the flexibility providers can choose whether to re-balance themselves or to pass it on to the NODES platform to do so. In the case of GOPACS, the TSO is directly informed, and the position is adjusted in case of an activation.

5. Conclusions

The TSO-DSO report from the European TSO and DSO associations (ENTSO-E et al. (2019)) introduces three models for flexibility markets: DSOs could source flexibility via balancing markets, TSO and DSOs could jointly source flexibility for congestion management as a separate grid service, or they could do so independently from each other. We show that flexibility markets can operate as intraday markets, rather than grid service markets. We also show that the integration of flexibility markets into existing markets and TSO-DSO cooperation are only two of six equally important market design choices for flexibility markets. In other words, our case study analysis of four pioneering projects enriches the taxonomy and demonstrates that practice is moving faster than the conceptual debate around flexibility markets. Table 4 summarizes the answers of the four projects to our six-question framework. We observe two trends and four key differences among the projects.

Table 4
Project answers to the six design controversies.

	YES	NO
1. Is the flexibility market integrated into the existing sequence of EU electricity markets?	GOPACS and NODES	Piclo Flex and Enera
2. Is the flexibility market operator a third party?	All projects. GOPACS is not a market platform operator but an intermediary. The market platform is ETPA.	/
3. Is there a reservation payment?	Piclo Flex	Enera, GOPACS, and NODES (all projects envision to integrate reservations)
4. Are products standardized in the flexibility market?	Piclo Flex, Enera, and GOPACS (IDCONS product)	NODES
5. Is there TSO-DSO cooperation for the organisation of the flexibility market?	GOPACS (TSO and DSOs use the same intermediary). Enera (DSOs and TSO active) and NODES (DSO and soon also the TSOs will be active).	Piclo Flex is solely a DSO platform
6. Is there DSO-DSO cooperation for the organisation of the flexibility market?	Piclo Flex (3 DSOs), GOPACS (4 DSOs), Enera (2 DSOs) and NODES (one DSO active per installation, soon more will join)	/

The first trend is that all the considered platforms are operated by a third party. This is relatively new in the sphere of ancillary service procurement (e.g., balancing and redispatch) in the EU where these markets are currently operated by the TSOs. Having a third party operating the market platform allows for neutrality between buyers and sellers of flexibility. Third parties, such as EPEX or Nord Pool, can be more experienced in setting up market platforms than DSOs. Two points are important to be added regarding this trend. First, the degree of integration of the flexibility market with other (existing) electricity markets has an impact on who can be the market operator. Both design controversies are hard to decouple. Second, it is important to emphasize that the market operator role consists of multiple tasks of which several market operation tasks (such as clearing and settlement) could be more easily allocated to third parties while other tasks (such validating offers and product design) could be the responsibility of the DSO.

A second trend is that all projects engage or tend to engage with multiple DSOs. By doing so, the different platforms providers try to become the first-choice flexibility platform provider and establish themselves as the lead player that can replicate its solution across the EU and further. Having one platform covering multiple DSOs makes it easier for flexibility providers who can have flexible assets connected to different DSOs. Having one platform for several DSOs can also facilitate a more standardized way for the TSO and DSOs to coordinate. Depending on the configuration of the networks, DSOs also have to coordinate in terms of operations (the two DSOs active in Enera are vertically coupled). The pilot projects covered here are deployed in countries with several medium-sized DSOs in place. In countries such as France, Italy, and Portugal with one dominant DSO, there is less possibility for DSO-DSO coordination in the organisation of flexibility markets.

There are also four key differences among the projects. The responses of the projects for these four controversies vary because of different visions, use cases, or the maturity of the projects.

First, the difference in the way the flexibility markets are integrated into the existing sequence of EU electricity markets is a clear choice made due to the different visions of the projects. On the one hand, Enera and Piclo Flex opt for separate platforms to provide transparent price levels. On the other hand, by integrating the flexibility market into existing markets, GOPACS and NODES try to foster liquidity pooling and give market parties the option to formulate one offer that can be used for multiple services. At this point in time, it is too early to say whether one approach is favourable over the other. It remains to be seen whether and how NODES and GOPACS will be able to be integrated or linked to other markets, as they are planning to do. Barriers exist not only from a technical but also from a regulatory point perspective. Discussions about these are ongoing.

Second, only Piclo Flex works with a reservation payment. The main identified reasons for the differences among the projects in this respect are the use cases. Reinforcement deferral is the main use case of UKPN (using Piclo Flex) at this moment. Being sure of delivery is key in this respect. For Enera, the use case is the avoidance of curtailment, which is less critical and can explain why no reservation is in place yet. When projects mature, it is expected that all will implement a form of reservation payments, while Piclo Flex will open its short-term activations for more competition.

Third, the choice for non-standardized products used in NODES is deliberate. Allowing for tailored flexibility offers is an innovative practice; it makes it possible to value specific characteristics of flexible units and makes it possible to meet the specific needs of grid operators. However, not standardizing products comes at the expense of liquidity and transparent competition between flexibility providers. It is also to be seen whether non-standard products are in line with the recently adopted Electricity Directive.[25]

Fourth, Piclo Flex is the only project where there is no TSO active in the flexibility market. Establishing TSO-DSO coordination within a flexibility market takes time. Piclo Flex decided to move fast by implementing a DSO-only solution. However, flexible resources contracted by Piclo Flex are allowed to engage in revenue stacking (for example by also offering services to the TSO). The other three projects allow both DSOs and the TSO to procure flexibility, even though the way the cooperation between the grid operators is implemented differs. GOPACS is an innovator in this respect as it is a true TSO-DSO intermediary that allows for dealing with the coordination of grid operators outside of the market platform. Through GOPACS, network operators can co-optimise their needs. Enera and NODES apply a more traditional approach; network operators make more decentralised decisions and the market platform deals with the TSO-DSO coordination through the filtering of offers or 'vertical coupling'. TSO-DSO coordination for these projects is not yet mature; it remains to be seen which approaches work best in practice. Overall, the border between the regulated and commercial domain needs further consideration.

Regarding future work, it will be interesting to revisit this analysis in two to three years to see whether or not the answers to the six design controversies consolidate. As more market data become available, quantitative analysis could also extend this work.

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[25] In Art. 32(2) of Directive for the internal market in electricity (recast) (European Commission, 2019) it is stated that: *"Distribution system operators, subject to approval by the regulatory authority, or the regulatory authority itself, shall, in a transparent and participatory process that includes all relevant system users and transmission system operators, establish the specifications for the flexibility services procured and, where appropriate, standardized market products for such services at least at national level."*

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