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Market integration of local energy systems: Is local energy management compatible with European regulation for retail competition?

Cherrelle Eid [a, *], L. Andrew Bollinger [b], Binod Koirala [a], Daniel Scholten [a], Emanuele Facchinetti [c], Johan Lilliestam [d], Rudi Hakvoort [a]

[a] Delft University of Technology, P.O. Box 5015, 2600 GA, Delft, The Netherlands
[b] Urban Energy Systems Laboratory, Empa, Duebendorf, Switzerland
[c] Lucerne Competence Center for Energy Research, Lucerne University of Applied Science and Arts, 6048 Horw, Switzerland
[d] ETH Zurich, Department of Environmental Systems Science, Universitätstrasse 16, 8092 Zürich, Switzerland

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ABSTRACT

The growing penetration of distributed energy resources is opening up opportunities for local energy management (LEM) – the coordination of decentralized energy supply, storage, transport, conversion and consumption within a given geographical area. Because European electricity market liberalization concentrates competition at the wholesale level, local energy management at the distribution level is likely to impose new roles and responsibilities on existing and/or new actors. This paper provides insights into the appropriateness of organizational models for flexibility management to guarantee retail competition and feasibility for upscaling. By means of a new analytical framework three projects in the Netherlands and one in Germany have been analysed. Both the local aggregator and dynamic pricing projects present potentials for retail competition and feasibility of upscaling in Europe.

1. Introduction

In the European Commission, parallel attention is given to the introduction of competition in the electricity sector and the ambitious targets for sustainability. The process of electricity sector liberalization was formally finalized in 2007, inciting competition in the wholesale and retail electricity markets and the unbundling of network activities. The retail competition markets in Europe are largely based on an assumption of centrally managed electricity systems, whereas wholesale markets are increasingly coordinated or merged [1]. Starting in 2015, all interconnected European power exchanges are coupled, which represents a large step towards the creation of a European internal energy market, the European Energy Union [2].

With regard to sustainability, achieving the ambitious 2020 and 2030 European climate targets relies on both the market penetration of large- and small-scale renewables and the deployment of energy efficiency measures [3]. The recently established Energy Union strategy strongly supports a new market design that would support the integration of higher shares of renewable energy and foster energy efficiency measures contributing to demand moderation [4]. Especially Germany can be recognized with favourable policies for renewables with priority connection and priority grid access for generation units that produce electricity from renewable sources [5]. The supportive feed-in-tariffs in Germany have incentivized the widespread installation of small solar panels in the residential and commercial sector with in 2014, 38 GW capacity of solar PV installed, with more than 60% located at low voltage levels [6]. Other examples of rapidly developing residential solar PV segments are found in Belgium, where 1 in 13 households has a PV system, but also in for example Greece and the United Kingdom [6]. Further, Denmark in particular has seen an increased penetration of decentralized combined heat and power (CHP) [7–9]. Previous analysis showed that liberalized electricity markets hindered the

* Corresponding author.
E-mail addresses: C.Eid@tudelft.nl (C. Eid), Andrew.Bollinger@empa.ch (L.A. Bollinger), B.P.Koirala@tudelft.nl (B. Koirala), D.J.Scholten@tudelft.nl (D. Scholten), Emanuele.Facchinetti@hslu.ch (E. Facchinetti), Johan.Lilliestam@usys.ethz.ch (J. Lilliestam), R.A.Hakvoort@tudelft.nl (R. Hakvoort).

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adoption of small CHP units in other places like the United Kingdom (UK), due to the discrimination of the liberalized electricity market towards smaller electricity generators [9]. For many CHP plants in the UK it would only be beneficial to sell electricity to a third party, providing lower pricing schemes than the actual electricity markets [8]. Differently, regulation in Denmark supported adoption of CHP units by allowing aggregations of those units to bid in the Danish electricity markets. Analysis showed the economic viability of using electric flexibility from CHP units for national balancing purposes and therefore improving the overall integration of wind power in the sector [7].

At the distribution grid level new challenges are arising due to the penetration of electric vehicles (EVs), especially in Norway and the Netherlands [10]. To respond to these changes in supply and demand, system operators and suppliers have started to develop new strategies for handling a more decentralized system. Among the more radical solutions is *local energy management* (*LEM*) – the coordination of decentralized energy supply, storage, transport, conversion and consumption within a given (local) geographical area. Combined with automated control and demand-side management strategies, local energy management, especially with the use of local heating production, holds the promise to significantly increase the efficiency of energy use, reduce carbon emissions and enhance energy independence [7,9,11]. Many of these benefits have already been realized in the context of numerous local energy projects initiated worldwide [12,13].

As countries across Europe seek to effectively and efficiently manage the large-scale integration of distributed energy resources, it is important to consider the effect of actor roles and responsibilities for managing the electric flexibility from resources locally in the regulatory context of energy retail competition. Different authors have expressed the difficulties associated with the unbundling of network and market functionalities [14,15]. For example, due to the fact that the DSO is a monopoly party, it is generally not allowed to trade electric flexibility with end-users.

Because the internal market policy process imposes constraints on how the electricity system can be organized, there may be conflicts between these flexibility management approaches and market regulation. The aim of this paper is to give insight into the compatibility of the organizational structure for flexibility management with the European electricity retail competition context. This is done through analysis of different real-life LEM cases and their organizational structures, comparing them to the traditional organizational structures and possibilities for retail competition and lastly discussing the aspect of scalability of those projects.

We analyse four cases – three Dutch and one German case – drawing both on publicly available material such as [16–20] and interviews with involved project partners and managers.

The paper is structured as follows. Section 2 describes background information on organizational structures for flexibility management, together with the framework for flexibility management used in this analysis. Section 3 describes the method used to analyse the cases, and Section 4 presents the results of the analysis. This is followed by a discussion and conclusions in Sections 5 and 6.

2. Background

2.1. Organizational structures and electricity market integration

The organization and coordination of energy transactions on local electricity distribution level has been explored by numerous scholars for different local energy management concepts. Some analyses focus only on electricity and refer to the terms smart grids, virtual power plants and microgrids [21–24]; and others include thermal and chemical energy carriers with multi-energy carrier systems and refer to the terms energy hubs or smart energy systems [11,25]. As described in the introduction, in this paper we define local energy management (LEM) as *the coordination of decentralized energy supply*, *storage*, *transport*, *conversion and consumption within a given* (*local*) *geographical area*.

This paper aims to present the possibilities for integration of local energy systems into the traditional regulatory context of Europe. Specifically, the focus here is on the aspect of electricity management integration and therefore this paper leaves out the integration of heat or gas supply due to the fact that deserves analysis by itself see Fig. 1 for a conceptual presentation. In the figure, the aspect of electric flexibility is presented as central. Electric flexibility can be defined *as a power adjustment with a specific size and direction*, *sustained at a given moment for a given duration from a specific location within the network*[26]. Due to the fact that for reliability of supply a constant balance between supply and demand is required, the role of electric flexibility and the management thereof is crucial. This flexibility can be used for multiple purposes, ranging from network congestion management, supply portfolio optimization and renewable integration. In this research, the aspect of flexibility management is analysed from an organizational perspective instead of a technical perspective only. This organizational structure can provide insights in whether a flexibility management method is closely related to the traditional organizational structures to manage flexibility in the electricity sector in Europe.

2.2. Framework for flexibility management

When discussing organizational structures and their impacts on the arrangements of (electricity) markets, the theory of institutional economics is relevant. The Williamson framework represents how economic transactions are embedded in layers of formal organization, governance and informal institutions [27]. Künneke proposed a technical counterpart of this framework, which has been further elaborated by other researchers [28,29]. This comprehensive framework shows how technical and economic transactions are embedded in their technical and economic environment. For example, for economic transactions, the rules for (spot) market design provide the possibilities for actors to bid in the markets. Alternatively, from a technical perspective, operational control mechanisms manage the way in which technical transactions take place in real-time. Annex 1 presents the techno-economic framework. For the analysis in this paper the framework has been adapted to focus on the management of flexibility in electricity systems and provide insight into the most suited design for the European context. The framework includes three layers, a techno-institutional layer, an economic layer and an operational layer. Flexibility management is defined as the application of the four flexibility management variables; *the division of responsibilities* (***who***) *for specified management of flexibility of appliances* (***what***) *by specific means* (***how***) *and for specific time-dependent system purposes* (***why***), and two organizational variables, *the****number of actors****involved and the****nature of transactions***. Fig. 2 presents the framework used to analyse the LEM cases in this paper. The next

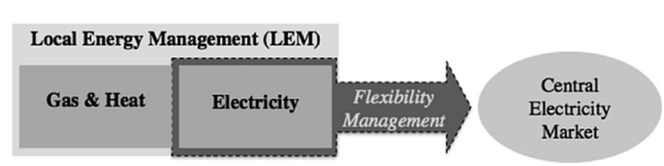

Fig. 1. The emphasis on electric flexibility management in this work.

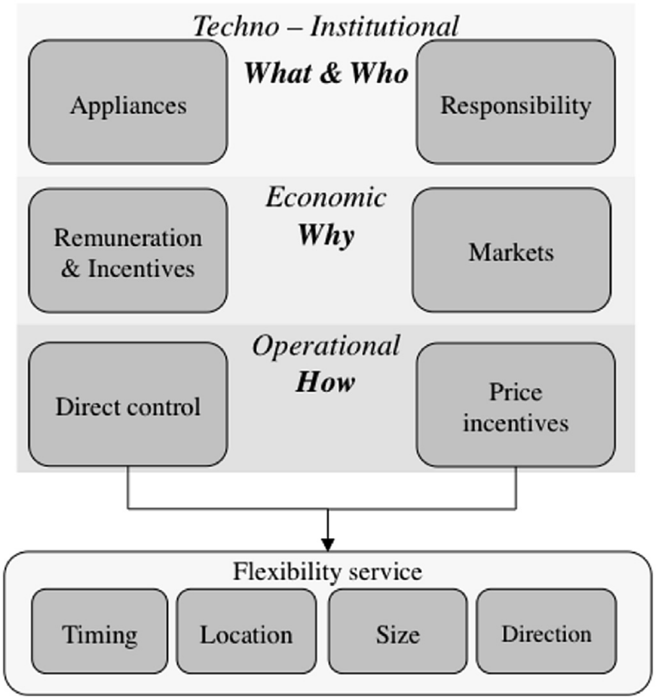

Fig. 2. Framework for flexibility management in electricity systems.

subsections present a description of the different variables.

2.2.1. Responsibilities (who)

The actors who assume responsibility for the management of flexibility at the low voltage level include the DSO, retailer, aggregator and/or other actors like the TSO. Depending on which actor assumes this responsibility, and its current business model, the flexibility is used for the specific market activities in which this actor is involved and/or the services that this actor provides. For example, the transmission system operator (TSO) is the chief entity responsible for ensuring balance between the electricity supply and demand in the system. This is done through settlement of various markets, i.e. ancillary service market and balancing markets [26]. In those markets, large generators and industrial customers are eligible to place offers for the provision of upward or downward flexibility. At the distribution network level, there are currently no markets for such flexibility (outside of pilot projects). Still, different actors might have specific interests involved with the use of flexibility; the retailer could use flexibility for portfolio optimization, while the distribution service operator (DSO) could use flexibility to reduce congestions for example as it is done in Sweden [30]. The level of engagement in activities for flexibility management by DSOs, however, remains dependent on the regulated remuneration for the activation of flexibility. In Europe, most DSOs are subject to incentive regulation, which means that their expenses should reduce with an efficiency factor each year. However, the procurement of flexibility through smart grid solutions can increase the operational expenses in a manner which counteracts the tendency of the DSO to embark on this route [31].

2.2.2. Appliances (what)

An actor can assume responsibility for managing the flexibility of a specific (set of) appliance(s). This could include specific, in-home appliances like washing machines, electrical heaters or an EV, solar PV units and CHP units. Differently, flexibility could be provided by the entire household consumption (for example with the provision of a time-based tariff for the entire household consumption). Each appliance has specific technical abilities providing specific flexibility services [26].

2.2.3. Signals (how)

There are different ways to activate flexibility. The most common signals for flexibility activation are direct control, semi-direct control and indirect signals (also named price signals). **Direct control** provides direct access from a central actor (like an aggregator) to control the operation of contracted devices. Direct control provides secure flexibility within a specific time and location for the procuring actor and provides ease to the end-user due to the fact that the end-user does not have to manually activate its units. Differently, **semi-direct control** refers to the ability of end-users to predefine time bands for which the devices are providing flexibility, and after which the operations of the devices are automatically adjusted. Semi-direct control is often used for a price signal (explained hereafter), in order to automate the activation of devices at low-price time periods.

Differently, **indirect signals** refer to price-based signals. The flexibility obtained from those types of arrangements refers to “changes in electric usage by end-use customers from normal consumption patterns in response to changes in the price of electricity over time” (DOE, 2006). There are multiple time-based pricing options available ranging from real-time pricing (RTP), critical-peak pricing (CPP), time-of-use pricing (TOU), and peak-time rebates (PTR) [32]. The price options differentiate from each other mostly based on the price variability that they represent in time. Real-time prices change very frequently (from around every 15 min to hourly basis) while time-of-use prices can change on a time basis of 4 h. Different from direct control, indirect control give end-users the freedom to participate in the provision of flexibility services. Therefore those signals do not provide security on the expected capacity of flexibility.

2.2.4. Markets (why)

Markets provide the organizational environment for economic trading. For flexibility management, markets can exist for specific timeframes before real-time (for example ancillary service and balancing service markets) and also include the location dependency of that specific market (for markets for congestion management are organized from a multi-node perspective).

Flexibility management in the electricity system requires different types of flexibility services, defined by different timeframes before real-time (ancillary services are traded very close to real-time versus capacity markets which are much longer from real-time). Furthermore, beside the time-dependency, the electricity system also has a location dependent need for flexibility in case of network congestions. Therefore, balancing markets are typically centrally organized while markets for congestion management are organized form a multi-node perspective of the system. The organization of markets in which actors are allowed to trade provides a financial incentive for flexibility management in the system. The already existing markets for flexibility are those managed by the TSO and partly by the market operator.

2.2.5. Number of actors involved and nature of transactions

Beside the diverse flexibility design variables presented here, furthermore organizational variables are of interest, which are related to the way in which the market is organized. These variables are the number of actors involved and the nature of their transactions [33]. The nature of transactions can be horizontal, hybrid or hierarchical. When a single actor is managing the flexibility, it naturally presents a hierarchical nature of transactions between end-user and the central deciding actor. However, when two or more actors are involved with flexibility management, the nature of the transactions can be horizontal or hybrid. With a horizontal organization, all of the actors have equal influence on the management of flexibility. With hybrid transactions, it can be the case that the transactions are not entirely horizontally arranged but one specific actor is appointed to manage the flexibility on behalf of other actors.

3. Method

In this work, four cases are analysed. The results of this analysis are summarized in Table 1 which is based on the framework presented earlier in this paper. For each case, the four flexibility management variables and the two organizational variables are described. The information from these cases comes from publicly available material and from interviews with the project managers involved.

Together, the insights in the separate the flexibility management variables can provide an indication of how well the organizational approach suits to the European regulatory context and the possibilities for upscaling of this approach. The situation as it is currently the case in most European countries is presented in the last column of Table 1.

The degree to which the cases provide possibilities to adhere to a retail competition context and allow for upscaling relates to: (1) the way in which multiple retailers can trade in such system, (2) the roles that the traditional actors like the DSO take within the case, and (3) the possibilities for upscaling. The possibilities for upscaling are related to the nature of the transactions; the more hierarchical the nature of transactions, the less complex it is to scale the respective approach due to the fact that the transactions are managed according to a singular method. Differently, generally the more actors involved, the more competition a case includes (less monopolistic) and therefore the better suited it may be to the retail competition model in Europe.

Given that this work aims to show what type of organizational structures are most suited to the European context, this paper focuses mainly on the specified variables and organizational aspects for flexibility management. Of course, within each case, there are many more indicators that provide insight into the technical and economic performance of the system. This includes, for example, the cost of electricity within various time-scales for each case, the power of the installations for each case and the mathematical model underlying each approach. Even though this information is interesting from a techno-economic view, it is not relevant to the aim of this work in terms of assessing the suitability to the European context. Therefore the focus remains on the arrangement of flexibility management and the organizational structures involved.

4. Results

The following sections present the different organizational models for flexibility management. The names (e.g. Multi-Objective Optimization and Dynamic Pricing) have been chosen to illuminate the central flexibility management concepts used in the examples. The cases are summarized only briefly in order to remain focused on the most important aspects of the organizational structures for flexibility management. Please see the indicated references for detailed information regarding each case.

4.1. Case 1: multi-objective optimization

Power Matching City (PMC) is a project located in Hoogkerk, a city within the Netherlands. There are three actors involved for the management of flexibility: the consumer, the DSO and the retailer (flexibility variable **who**). The project includes 40 households with installations of Solar PV, EVs, heat pumps, micro CHP and a Powermatcher device (flexibility variable **what**). This Powermatcher manages the operations of the appliances and interacts with the local market, taking into account actor preferences. In this project, direct control is applied for the heat pump and the micro CHP (i.e. controlling electricity production). The operations of the washing machine can be pre-defined and therefore semi-direct control is provided to those appliances (flexibility variable **how**). All other household consumption units are not controlled, nor is any price incentive given for general consumption. Each of three involved actors bids (in an automated manner) in the market via which a non-monetary "balance price" is determined at each moment in time (flexibility variable **why**). This local market takes into account the day-ahead spot market price, balancing market price, local transformer loading and consumer preferences for electricity consumption (see Fig. 3).

4.1.1. Nature of the transactions and number of actors involved

In this case, the retailer, DSO and consumer play an important role in the transactions for flexibility. The IT system acts as a real-time trading platform for local transactions between the different trading agents (DSO, retailer and consumer) which can bid within the local market, providing a non-monetary market price. Consequently, due to the fact that there is not a central actor making the decisions, the nature of the transactions in this case is horizontal.

4.1.2. Comparison to base case

Firstly, the DSO, retailer and consumer take up different roles

Table 1
Flexibility management variables used in this paper.[1]

Variables	Options	Base case[3]: flexibility management in electricity sectors in Europe)
Who is responsible?	DSO, retailer, aggregator and/or other actor	At high voltage level: TSO *At low voltage level: no specific responsibility for flex management*
What appliances are managed?	E.g.: CHP, PV, EV, customer appliances and/or consumption	At high voltage level: large generators and customers *At low voltage: none*
How is flexibility activated?	Price incentives or direct control	At high voltage level: through direct control & price incentives *At low voltage: normally no flexibility activated, sometimes if retailer/DSO provides a (price) incentive*[38]
Why is this flexibility activated?	Balancing, day-ahead, ancillary services and/or for local market, etc.	Existing TSO markets: e.g. ancillary services, balancing market, congestions markets etc. At low voltage: no specific market available
Number of actors involved	1 or more	Single buyer (TSO), many sellers of flexibility *At low voltage: not specified due to absence of market*
Nature of transactions	Hierarchical, hybrid or horizontal	Horizontal *At low voltage: not specified due to absence of market*

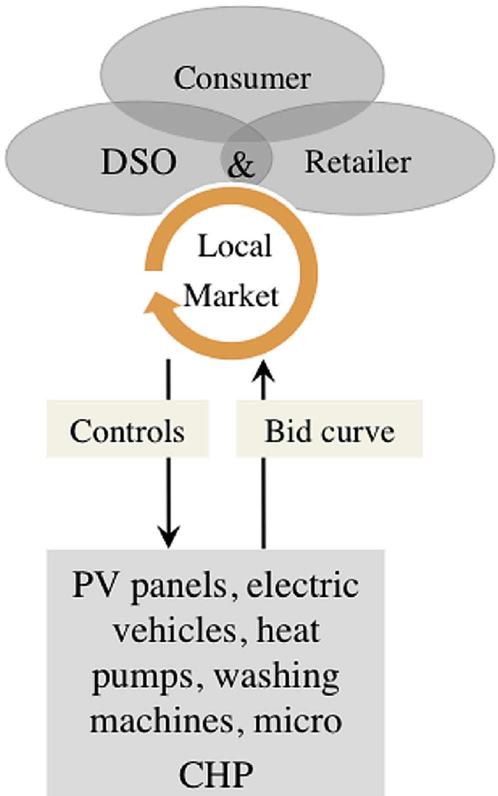

Fig. 3. Organization of flexibility management in Multi-Objective Optimization project "Power Matching City".

within this case compared to the traditional retail competition context. In the daily operations of the multi-objective optimization project, the retailer, DSO and end-user have been permitted to procure flexibility for individual economic objectives locally. However, in the current retail competition context in Europe, markets are not located at the distribution level but only at the transmission level. Traditionally the DSO, retailer and end-users do not assume this role and do not have permission to trade flexibility at the local level.

Secondly, within PMC an issue exists for the coordination of flexibility between actors. In PMC, the different interests of the actors regarding flexibility management have been arbitrary divided; all agents received a certain measure of flexibility. Experience showed that at certain moments in time conflicts could arise in the procurement of flexibility. Often, for instance, one party needs all available flexibility but could only use its own part from the resident, or two actors would need the flexibility at the same time. Therefore, in PMC, the energy supplier assumed the role of deciding who will receive what type of flexibility [17]. However, in a retail competition context as in Europe, where end-users should be able to choose their supplier, this case can even become more complex due to the fact that coordination is required between multiple retailers, the DSO and the consumer.

4.1.3. Possibilities for upscaling

Therefore, in order to make this case possible within the retail competition model in Europe, a readjustment is needed regarding the roles and responsibilities of actors together with a method for the set-up of local markets, which allows for multiple retailers to be integrated. Next to the definition of those two important steps, furthermore a settling method is required to locally divide the flexibility between different agents when this is procured simultaneously, also referred to as the coordination problem [34]. Appointing an actor to take care of the distribution of flexibility could support this, however it should be taken into account that this actor might be biased towards specific market objectives (instead of efficient network utilization) when involved in market activities. Therefore an important aspect is the definition of fairness [17] from a social perspective for an unbiased division of flexibility that supports overall objectives of the sector. Lastly, in order to motivate the DSO to procure flexibility, adjustments in the regulated income of DSOs are required.

[3] A more comprehensive overview of the use of flexibility in traditional markets can be found in Ref. [26].

4.2. Case 2: dynamic pricing

Within The Netherlands, the project "Your Energy Moment" is a pilot within an apartment block and a group of semi-detached houses in the city of Breda. Within this project, a time-dependent 2-h varying tariff (€/kWh) is presented to the consumer via an in-home energy display (flexibility variable **how**). This final tariff includes both a price component of the retailer and of the DSO (flexibility variable **who**). Each of the households owns a PV unit and net-metering with the time dependent electricity tariff takes place for remunerating the PV production. The retail tariff is based on the price variation in the day-ahead market while the time-dependent transport tariff is a peak-pricing scheme, which is related to the daily network peak-hours [19] (flexibility variable **why**).

The time-dependent tariff stimulates customers to shift their total household electricity consumption in time. However, to support this load shifting, the customers are equipped with a smart appliance, that, if programmed by the consumer, will automatically turn on the 'wet appliances', namely the washing machine, dishwasher and tumble dryer (flexibility variable **what**) at the cheapest moments in time (see Fig. 4).

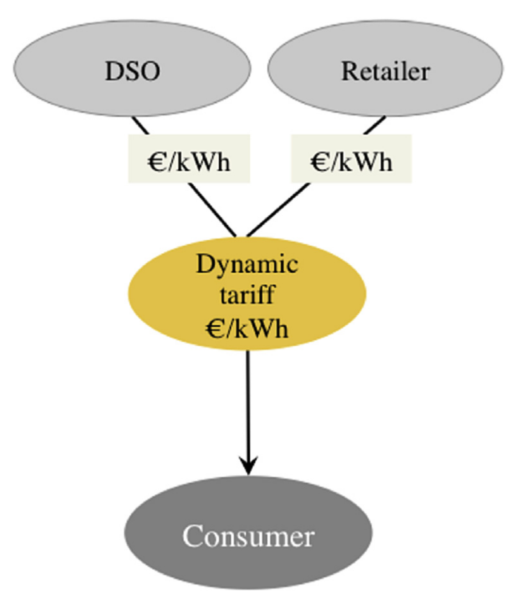

Fig. 4. Organization of flexibility management in Dynamic Pricing project "Your Energy Moment".

4.2.1. Nature of transactions and number of actors involved

In this case, the nature of the transactions in the market is horizontal due to the fact that the DSO and retailer both have the possibility to present their tariff to the end-user. However, if compared to the multi-objective optimization case, this case represents a less horizontal market arrangement due to the one-directional price signal provided to the end-user by the DSO and retailer. The consumer is not involved in the bidding process but merely exposed to this signal. Therefore in this project the nature of the transactions is horizontal, but in a reduced form than in the Multi-Objective Optimization case.

4.2.2. Comparison to base case

In the Netherlands and most other European countries, the DSO is obligated to provide non-discriminatory third party access with flat pricing schemes. Traditional regulation could hamper the time based pricing from the DSO due to market power risks, especially when at some moments the distribution price is higher than the retail electricity price. The price signal given by the DSO in this case however might lead to discrimination in time and location regarding the use of electricity. The regulation of DSO price settlement is therefore an important conflict with the retail competition model for the DSO.

4.2.3. Possibilities for upscaling

An important adjustment firstly is the allowance of the DSO to provide time-based tariffs, and the provision of regulatory incentives for DSOs to do so. If the DSO is not being remunerated to reduce investment expenses by slightly increasing operational costs for the procurement of flexibility, the DSO will remain uninterested in development towards price-based flexibility activation.

Secondly, guidelines are required for the price signals given by the retailer and DSO, which will then be forwarded to the consumer through a settled formula. In order to fit within the retail competition context, multiple retailers should be able to provide their specific price signal, which then is combined with the local distribution price. The possibilities for upscaling in this case are less difficult than in the Multi-Objective Optimization case, due to the fact that only the price signal is the activator of flexibility, and not a simultaneous bidding process between multiple actors, as with the PMC case.

4.3. Case 3: local aggregator

The Local Aggregator is a case referring to the project "Energy Frontrunners" (Energie Koplopers in Dutch) in the municipality Heerhugowaard, in the Netherlands.[1] The applied flexibility management method is described as Universal Smart Energy Framework (USEF).[2] In this project 240 households have a device installed that is remotely controlled by which direct control is applied on appliances (flexibility variable **how**) by the local aggregator (flexibility variable **who**). In this project, the aggregator is the Dutch retailer Essent. Essent controls the operation of the heat pumps, electric boilers, fuel cells and PV curtailment (flexibility variable **what**). Besides being the aggregator, Essent is also the balance responsible party (BRP), in charge of trading flexibility on the national balancing markets (**why**). However, in this pilot project, the trading transactions are simulated and do not take place in reality.

The DSO buys flexibility from the aggregator in order to reduce the solar peak from the PV panels and reduce the evening peak consumption in the local distribution network. Eventually, at the end of the month, the (simulated) revenue that has been created from trading activities in the balancing market and from the network optimization is divided among the participating households (see Fig. 5).

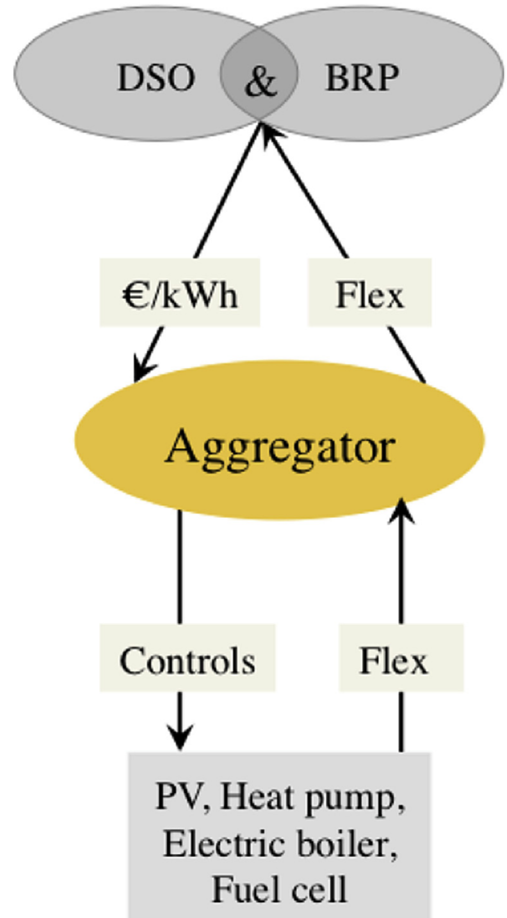

Fig. 5. Organization of flexibility management the Local Aggregator project "Energy Frontrunners" adapted from Ref. [18].

4.3.1. Nature of transactions and number of actors involved

The aggregator assumes a central role in this case, and trades on behalf of the balance responsible party and the DSO. Due to this central role of the aggregator, the nature of the transactions can be seen as a hybrid due to the fact that a single actor is responsible for operations but takes into account the requests of the DSO and BRP.

4.3.2. Comparison to base case

In the pilot project, all the households had the freedom to choose their own retailer, independent of whether this retailer was the one responsible for aggregation and balance responsibility. However, in a retail competition environment, it would not be beneficial for retailers that have supply contracts with customers when an independent aggregator is able to make changes in their supply programs to the end-users [35,36]. This would reduce their revenues due to the penalties that need to be paid when unexpected changes in overall end-user consumption take place.

Secondly, next to the issue of balance responsibility, furthermore also in this case the role of the DSO is different from that in the traditional liberalized model in Europe. As described in the previous cases, the DSO as natural monopoly is generally not incentivized nor allowed to procure flexibility.

[1] See for more information https://www.energiekoplopers.nl/contact/.
[2] See for more information: www.usef.info.

4.3.3. Possibilities for upscaling

Due to the monopoly role of the aggregator, firstly a clear definition of its role and degree of freedom with regard to the management of flexibility is required. For this aggregator, which could be a regulated party, it should be clearly defined what transactions are allowed with the DSO and BRP while safeguarding customer desires with the direct control of appliances.

Secondly, an important adjustment here is the allowance and incentives for the DSO to procure flexibility. If the DSO is not being remunerated to reduce investment expenses of the grid by slightly increasing operational costs for the procurement of flexibility, the DSO will remain uninterested in the development towards price-based activation of flexibility.

Lastly, in order enable the possibility to have retail choice for customers, specific compensation mechanisms should be set up for retailers affected by adjustments in their customers' consumption by the independent aggregator.

4.4. Case 4: local integrated utility

The village of Feldheim (Germany) represents an example of a co-operation between private households, the municipality and project developers for the management of a decentralized renewable energy system [20]. This system is managed by a cooperative, which is both the retailer, the owner of the electricity network and the manager of flexibility (flexibility variable **who**). The project includes 37 households, two businesses, two local government entities as well as three agricultural enterprises. The cooperative uses direct control (variable **how**) to activate flexibility from a lithium-ion battery storage, biomass plant, wind power plant and solar PV farm (variable **what**). Net production from the PV, wind and biomass is sold back to the grid and is remunerated via a feed-in tariff. The flexibility from the battery storage is being sold for the provision of flexibility services for frequency control and the operation of the devices are controlled in order to abide to network constraints [20] (flexibility variable **why**) (see Fig. 6).

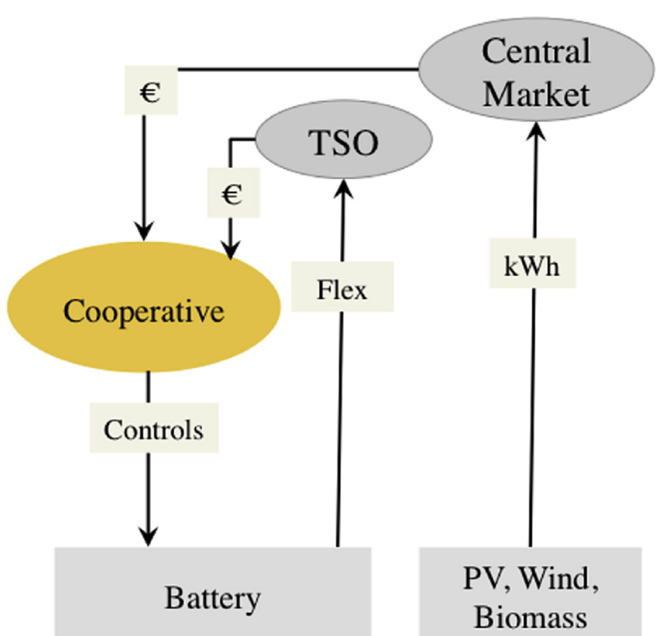

Fig. 6. Organization flexibility management the Local Integrated Utility project "Feldheim".

4.4.1. Nature of transactions and number of actors involved

The cooperative as a single monopolistic actor takes all decisions regarding the operation of devices locally. Consequently, the nature of the transactions that take place in the Feldheim project take a hierarchical form. There is no involvement of a DSO or retailer due to the fact that the cooperative is the owner of the local network and responsible for the reliability of supply.

4.4.2. Comparison to base case

The locally owned and operated electricity system presented in the integrated utility could be seen as conflicting with liberalization rules due to the fact that network operator is not unbundled from the electricity supply. Local customers in theory are then not eligible to choose their supplier. However, due to the fact that the local customers are mostly also shareholders in the cooperative, this retail choice does not affect their interest for another retailer. However, some customers still decided to choose another retailer administratively (probably due to the fact that they are not part of the cooperative) while the cooperative is still responsible for ensuring overall reliability of electricity supply.

A risk of this development is that if all customers choose to be administratively contracted with another supplier than the local cooperative, this would lead to cost recovery problems for the local supplier and eventually reduced reliability of supply. The end-users however, in this project are shareholders within the cooperative, which acts as an incentive for contracting with the local cooperative. In long term, if many cooperatives emerged (without local shareholders) there is a risk that all users are willing to contract only with the cheapest retailer available in the country.

4.4.3. Possibilities for upscaling

This project inherently does not provide possibilities for retail choice, due to the fact that the Local Integrated Utility is both network owner and supplier of retail services. This goes against the regulation for unbundling of network operations (the monopolistic activities) from supply activities in the retail competition context. In the retail competition context it is assumed that retail choice will foster efficiency in the sector. In the case of a Local Integrated Utility with local shareholders, however, the drive for efficiency results directly from the community both owning the cooperation and being end-users of its services. This case therefore inherently provides an alternative to the retail competition through self-regulation.

5. Discussion

The presented cases show a range of different approaches to flexibility management in LEM projects. The results are summarized in Table 2. The next sections summarize the findings and conclude on the most suitable approach for scalability in the European context.

5.1. The possibilities for retail choice

An important benefit of the retail competition model is that customers have the freedom to choose their retailer. The different cases feature different levels of complexity to ensure retail choice for customers. The easiest method to provide retail choice is the Local Aggregator model (case 3), due to the fact that household electricity consumption is not controlled by the aggregator, but only specific appliances. When the aggregator changes the consumption levels of end-users with diverse retailers, a compensation mechanism is required to make up for the changes in the balancing responsibility program.

Differently, the dynamic pricing and multi-objective

Table 2
Overview of flexibility management and organizational structures in the LEM case studies.

Case	Case 1	Case 2	Case 3	Case 4
	Multi-objective optimization	Dynamic pricing	Local Aggregator	Local integrated utility
Project name	Power Matching City	Your Energy Moment	Energy Frontrunners	Feldheim
Who is responsible for flexibility management?	DSO, retailer and customer preference	DSO and retailer	Aggregator	Co-operative
What is managed?	PV panels, electric vehicles, heat pumps, washing machines, micro CHP	PV panels, smart washing machines and heat pumps	PV panels, heat pump operation, electric boiler and fuel cell	Wind, solar PV, battery, and biomass plant
How are the appliances managed?	**Direct control**	**Dynamic pricing**	**Direct control**	**Direct control**
Why (for what purpose is flexibility used)	Reduction of network peaks & supply optimization in time-steps of 5 min	Reduction network peak & day-ahead market optimization with time-steps of 2 h	Reduction network peaks & balancing services in time-steps of 5 min	Reduction network peaks & frequency control in time-steps of 15 min
Number of actors involved	3	2	1	1
Nature of transactions	Horizontal	Horizontal	Hybrid	Hierarchical

optimization cases represent more technically complex projects due to the fact that the retailers and DSOs are actively involved (in an automated manner) with the management of flexibility. In those projects, guidelines are required to make sure that multiple retailers are allowed to access a part of the flexibility of the end-users by means of direct control (Case 1) or present their individual (standardized) pricing schemes to the customer (case 2).

With the Local Integrated Utility case, the cooperation is both owner of the local network and retailer of electricity. End-users in this case are customers of this local retailer and shareholders in the local cooperation. In order to make sure a similar project would adhere to the requirements for retail competition, it might be a risk that some end-users will chose to become customers of other retailers instead of the local one, if the local electricity price is higher. This risk could be avoided by making sure (just as in the Feldheim case) that a specific amount of end-users are contracted locally and others are free to choose. However, this does not fully constitute retail competition.

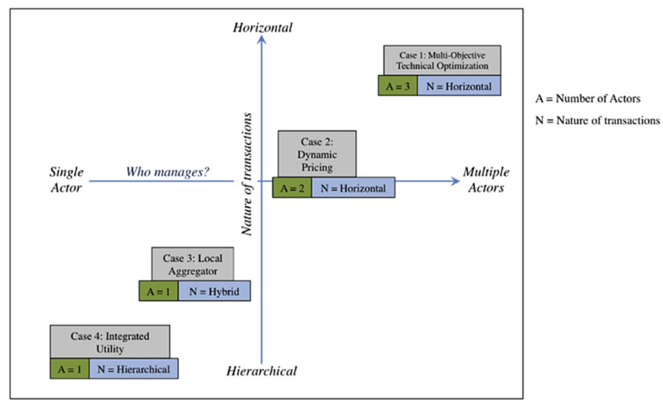

Fig. 7. Conceptual presentation of cases and nature of transactions.

5.2. Possibilities for upscaling in Europe

The number of actors involved in the management of flexibility ranges between one and three in the different cases. In the Multi-Objective Optimization project the transactions between the DSO, retailer and consumer were of horizontal nature. Due to the fact that the transactions between those actors take place in real-time, the Multi-Objective Optimization represents a project with the highest level of operational efficiency, however also the highest complexity and related transaction costs, especially when integrating diverse retailers within this project [37]. In the Dynamic Pricing project, both the DSO and Retailer are involved with flexibility management by means of a time-based price signal. This represents horizontal nature of transactions, but in a lower scale than that of the Multi-Objective-Optimization due to the fact that the consumer is not involved in determining but merely exposed to a price signal. In the Local Aggregator project, a single actor is responsible on behalf of the DSO and balance responsible party, representing a hybrid nature of transactions. Lastly in the Integrated Utility Model one central actor is responsible for flexibility management, representing a very hierarchical nature of transactions. Fig. 7 represents the cases conceptually and the nature of the transactions between the different actors.

In order to discuss the scale at which the cases would fit within the European retail competition context and thus provides possibilities for upscaling, two points are of interest. First, to what degree are multiple retailers able to offer their electricity to end-users simultaneously? And secondly, what is the degree of complexity involved with upscaling this methodology for further development in Europe?

All cases except for the Integrated Utility theoretically provide the possibility for retail competition. However, the more horizontal the nature of the transactions and the number of actors involved, the more technically complex the system becomes for retail competition. This is mostly the case for the Multi-Objective Optimization approach in which an iterative process of demand bidding is used for the management of flexibility. Such an algorithm for an iterative grid capacity market may solve congestion in an economically efficient way, but its implementation requires frequent exchange of information between the DSO agent, retailer agents and consumer agent, increasing the required complexity and transaction costs for this specific approach to adhere to retail competition.

The dynamic pricing model provides a simpler method for multiple retailers to compete for flexibility by formalizing the computation of the final dynamic tariff to the end-user, before real-time. Therefore this is a less complex method than the Multi-Objective Optimization approach and probably more feasible for upscaling.

The aggregator model is another approach suitable for upscaling. Due to the fact that transactions are managed by a single aggregator that is operating on behalf of the DSO and BRP, the integration of multiple-retailers is simple due to the fact that end-users can choose any supplier. However, principles need to be set for the compensation between the BRP and retailers for the imbalances that have been created by the aggregator. Furthermore, in order to ensure that market activities do not overtake network activities (and the other way around), the aggregator should be a regulated party or this activity could be fulfilled by an actor that is already regulated, e.g. the DSO.

The needs for flexibility provision and management have everything to do with the purpose for which this is used in the system. In the presented projects, trading of flexibility has been used to manage network peaks (in all projects), to align with the day-ahead market price variations (in the Dynamic Pricing Model and Technical Optimization Model) and to trade flexibility in balancing markets (Local Aggregator and Integrated Utility Model).

When trading of flexibility takes place within already existing markets, the involved traders receive monetary value for the flexibility procured. However, in traditional retail competition markets no market model exists for trading of distribution network capacity. Therefore, as discussed earlier in the paper, such type of trading cannot be made monetary at this moment without adjusted regulations and market design, especially for the DSO within cases 1–3. Currently, there is no rationale for DSOs in Europe to procure flexibility due to the method by which most DSOs are remunerated. Incentive based regulations, which are currently most widely used in Europe, motivate DSOs to reduce operational expenses (OPEX) and/or capital expenses (CAPEX) in line with an efficiency factor. Generally, the costs related to flexibility trading would be considered OPEX on which efficiency measures apply. Therefore, it would not be beneficial for a DSO to procure flexibility since this would increase the operational expenses. By allowing the costs related to the procurement of flexibility (CAPEX and OPEX) to remain outside the regulatory benchmark, policy makers could support the DSO to utilize flexibility of end-users. An important issue with flexibility management for DSOs is that due to their monopoly position within their geographic area of service, the price of flexible demand cannot be competitively set. Therefore, such trading, without sufficient pricing transparency, might lead to excessively high benefits for the DSO.

To conclude, due to the feasibility of those projects and possibilities to include retail competition, the Local Aggregator and the Dynamic Pricing projects would be most suited for upscaling in the European context.

Beside the organizational structures presented in this work, also other organizational structures could be designed including aspects from different cases. An example is a Local Aggregator utilizing an ex-ante defined time-based price from the retailer after which the aggregator takes into account DSO requests for direct control at moments of network congestions. This approach decreases the need for frequent compensation mechanisms between a BRP and the retailers but still provides incentives for efficient use of flexibility taking into account network limits.

6. Conclusions

This paper presented an analysis of four organizational models for flexibility management. We study these models using cases from the Netherlands and Germany. The case studies have been categorized as *Multi-Objective Optimization*, *Dynamic Pricing*, *Local Aggregator* and *Local Integrated Utility*. The analysis utilized four flexibility management variables (*who*, *what*, *how* and *why*), and two organizational variables (*the number of actors involved* and *the nature of transactions*).

The different approaches impose new roles on traditional actors, especially on the distribution service operator (DSO) and the retailer. Traditionally, in the retail competition model, the activities of the DSO are limited to ensure a level playing field for all market participants. According to the DSO's current investment rationale, which is based on incentive based schemes, DSOs would not be incentivized to increase operational expenses in order to procure flexibility. Therefore to change the DSO's investment rationale from mainly that of upgrading network capacity towards one in which the DSO focuses on the efficient use of network capacity through flexibility management requires that the regulated income of the DSOs include the increased operational expenses for procurement of flexibility.

The cases show that the nature of transactions for flexibility management can vary from more horizontal arrangements to more hierarchical arrangements (with a local coordinating actor like a utility or aggregator). Horizontal arrangements are inherently more complex. On the other hand hierarchical structures provide greater feasibility for upscaling and also the possibility to incorporate multiple retailers, given that the central actor is not a Local Integrated Utility. Our analysis shows that the Dynamic Pricing and Local Aggregator approaches would be better suited to the retail competition context in Europe. The issue that remains is the aspect of financial compensation between retailers and the balance responsible party (as shown in the Local Aggregator case). Besides the organizational structures presented in this work, other approaches for organizational structures could also be designed. An example is a combination of the Local Aggregator and Dynamic Pricing approach in which each retailer provides an ex-ante defined time-based price for electricity after which a Local Aggregator or the DSO itself takes responsibility for flexibility management to avoid network congestions.

This work provides insight into the impact of organizational structures on the roles of the actors and on the feasibility of large-scale deployment of these arrangements in the European regulatory context. Both the local aggregator and dynamic pricing projects present potentials for retail competition and feasibility of upscaling in Europe due to the fact that multiple retailers can be integrated in a relatively simplified way. With the dynamic pricing model multiple retailers compete for flexibility by formalizing the computation for the final dynamic tariff to the end-user, before real-time. With the aggregator model, the transactions are managed by a single aggregator that is operating on behalf of the DSO and BRP. The integration of multiple-retailers is simple due to the fact that end-users can choose any supplier. However, principles need to be set for the compensation between the BRP and retailers for the imbalances that have been created by the aggregator. Furthermore, in order to make sure that market activities do not overtake network activities (and the other way around), the aggregator should be a regulated party or this role could be fulfilled by an actor that is already regulated, such as the DSO.

An important next step is to quantify the costs of activating local flexibility for diverse organizational approaches. A comparison between activating flexibility locally versus centrally in the system along with analyses of the impact of appointing the DSO as a central coordinating actor for flexibility management according to metrics of transaction costs and economic efficiency would provide interesting insights. Lastly, the authors recommend that future work should be conducted on the economic viability of various socio-institutional and technical alternatives for self-regulation in local energy systems.

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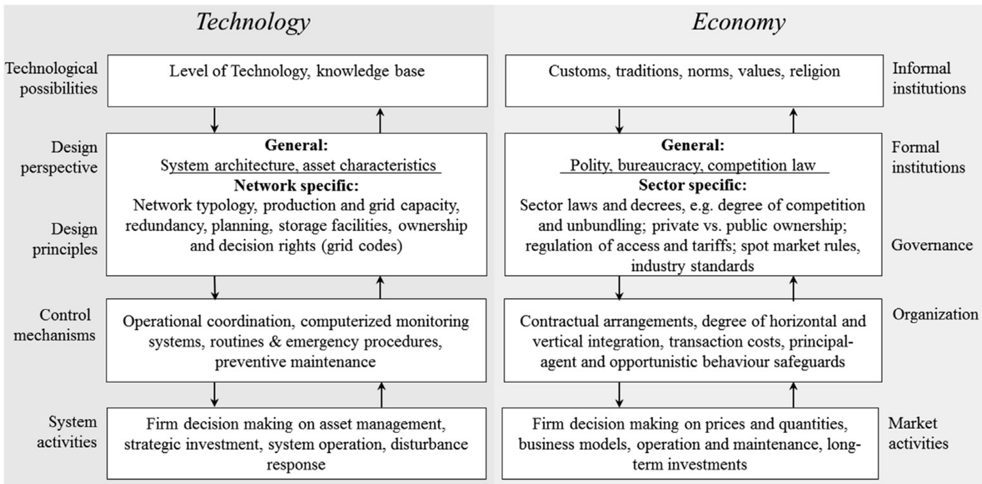
Annex. 1Technical and institutional design in energy infrastructures.



A design framework for energy infrastructures; as presented in [29]

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