DOMINOES – DELIVERABLE

D5.4 Roadmap to integrated energy market operation and management

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Executive Summary

Local markets (LM) are appearing at the moment all over Europe. The purpose of the deliverable is to provide a roadmap of how the integrated operation of local markets in the energy market environment would be possible. DOMINOES-project has a vision for user-centric energy markets of the future, where prosumers are empowered to participate in energy markets by influencing the valuation of their energy resources as well as the distribution of that value. Customer engagement is incentivized via a more direct role in local marketplaces and through the promotion of energy communities' role. In the local decision-making, the available value should be considered both from what is available locally within the local community and distribution network, as well as on the broader wholesale markets. The information must thus be available from all levels in order to make rational decisions that enable globally optimal behaviour. The goal is to enable aware distributed decision-making. Key elements in the vision are compatibility, distribution grid management, accountability for flexibility, bottom-up flexibility, incentivization for customer engagement, the active prosumer role of the customer and changing market participant roles.

In the roadmap, issues about the regulation and market structures are identified. The Clean Energy Package introduces the roles of the citizen energy communities, renewable energy communities and peer-to-peer trading of renewable energy. From the distribution system operator perspective, the regulation is also very important on how DSO can participate in the local market and what are the regulatory possibilities to purchase flexibility.

Local market and open market structures should be compatible in such a way that compatible operation is possible. This includes transparent information, information exchange between market levels and market participant and compatible structures. For the technology development is needed in many of the IT-tools but also high automation level is needed for effectively managing a high number of small-scale distributed assets. Besides the general roadmap, roadmaps for countries participating in the project (Finland, Portugal, Spain, UK) are presented.

The deliverable describes three alternative scenarios on the local markets' possible roles and related market development. The local market might remain as isolated markets and trading energy and possibly also flexibility by themselves. This would leave value for the distributed energy resources and the energy system unused. Partly, the trading of flexibility could be enhanced when the existing market operators extend their role in the direction of flexibility trading and location related flexibility. One scenario is related to alternative ways to handle network access from the distribution grid perspective.

Key conclusions from the roadmap are the role and the regulation of the distribution system operator in flexibility procurement, transparent market information, the high automation level of the related IT systems and services, compatible market structures between the local and overarching markets.

List of Acronyms

aFRR	automatic Frequency Restoration Reserve
BaU	Business as Usual
BRP	balance responsible party
CEC	Citizen energy community
CEP	Clean Energy Package
DA	Day ahead
DSO	Distribution System Operator
ERSE	Energy Sector Regulatory Authority
EV	Electric vehicle
FCR-D	Frequency Containment Reserve for Disturbances
FCR-N	Frequency Containment Reserve for Normal Operation
FFR	Fast Frequency Reserve
ID	Intraday
ISP	Imbalance settlement period
LM	Local market
LV	Low voltage
mFRR	manual Frequency Restoration Reserve
MV	Medium Voltage
NRA	National Regulatory Authority
P2P	peer to peer
PV	Photovoltaic
REC	Renewable energy community
RES	Renewable Energy Sources
TP	Technical Provider
TSO	Transmission System Operator
WM	Wholesale market

1 Introduction

The purpose of this deliverable is to provide a roadmap to integrated energy market operation and management in the energy market environment where distributed energy resources and local markets are present.

Section 1 introduces the scope of the deliverable. Section 2 describes the DOMINOES-project vision about the future user-centric energy markets and the solutions that the DOMINOES-project is delivering for the vision. Section 2 also identifies the roadmap needed to achieve the vision considering regulation, market structures, market participant roles, and market facilitation by the distribution system operator and technology. Country roadmaps, especially for countries participating in DOMINOES-project, are developed. Section 3 introduces a few possible future scenarios as an alternative for the proposed DOMINOES vision. The alternative scenarios include isolated local markets, the extension of the existing market operator role and alternative ways to handle network access. Section 4 concludes the deliverable and gives some recommendations for the future work.

1.1 Purpose and scope of the deliverable

This deliverable aims to describe a roadmap on how the local markets could be established working in parallel with the current markets. The deliverable also describes alternative approaches to how the local market environment could evolve and the possible implications of those types of local market developments. The deliverable considers the regulatory environment concerning the local markets and energy communities coming from the Clean Energy Package. The analysis will use the country environments represented in the project, namely Finland, Portugal, Spain and the UK.

2 Roadmap of DOMINOES solution

This chapter outlines the roadmap for introducing the DOMINOES local market model to relevant markets. At first, the vision and components of the market model are described. The general roadmap is then outlined and finally, specific roadmaps for studied market areas (Nordics, Iberian and UK markets) are provided.

2.1 Targeted solution and vision

This section describes the main components of the DOMINOES market vision. First, the vision and requirements for the market model are described. Then, the market model is defined.

2.1.1 Driving forces and assumptions

The European Commission (European Commission, 2021a) has set a proposal to raise the 2030 greenhouse gas emission reduction target at least 55% compared to 1990: "Key targets for 2030 are at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 32% share for renewable energy and at least 32.5% improvement in energy efficiency". The electricity directives and regulation enable consumers to participate in the energy market and put the consumer at the centre of the clean energy transition (European Commission, 2021b).

The amount of renewable energy sources is growing, which causes also challenges to the traditional electricity grids since the network should be reliable at the same time. The local market could facilitate the increasing share of renewable energy generation, such as wind and solar power.

Also, the distributed generation is increasing, which means that network needs in local and system level are also increasing. For example, congestion management and balancing could be facilitated by local markets. Local markets also bring benefits to the customers. Through the local market, customers can have a more active role in the energy market and gain new benefits.

Distributed renewable energy sources, electric vehicles (EV) and storages are expected to increase. In addition, energy communities and the more active role of the end-user may become more common. The question is how to integrate these to the energy market, meanwhile ensuring reliability and efficient operation all the time. According to (CEDEC et al. 2019) Active system management report, active distribution system management could be used for the secure management of the electricity systems at distribution system operator (DSO). Active system management consists of strategies and tools used by DSO like operational processes, information, data exchange and interaction with market parties. The aim is to integrate renewable energy resources and distributed energy resources with energy markets.

The growing number of distributed energy resources also increases the resources able to participate in the local market and to contribute to system benefit.

Electricity markets have been liberalised in most of the European Union countries. In the retail electricity market, this means for the end-customers possibility to select the retailer of their choice and thus increase competition and market effectiveness. Also, the development of local markets must consider the principles of liberalised open markets in order to be successful in the future.

2.1.2 Vision: User-centric energy markets of the future

DOMINOES-project has a vision for user-centric energy markets of the future, where prosumers are empowered to participate in energy markets by influencing the valuation of their energy resources and the distribution of that value. In the envisioned user-centric energy markets, customer engagement is incentivized via a more direct role in local marketplaces and the promotion of energy communities' role.

In the local decision-making, the available value should be considered both from what is available locally within the local community and distribution network, as well as on the broader wholesale markets. The information must thus be available from all levels to make rational decisions that enable globally optimal behaviour. The goal is to enable aware distributed decision-making in support of existing centralized decision-making.

This vision described in Table 1 would enable local resources participation in distribution grid management and easy wholesale market uptake of said resources. The realization of the vision requires changing roles for existing energy market stakeholders, easy tools and services for end-customers as well as compatibility with existing market structures for scalability.

Table 1 DOMINOES market model vision

Compatibility	• For scalability • Market model compatibility • Technological compatibility to meet market technical requirements or standards (i.e., information content)
Distribution grid management	• DSO access to flexibility • Availability of flexibility for its best use in case of no congestions • Role of DSO on transaction validation • Sharing of locational information of the resources
Accountability for flexibility	• Settlement per metering point • Validation of flexibility • Local trading with locational information • Transparency of costs

Bottom-up flexibility	• Local sharing of resources for communities and increased use of renewables • Incentives for use of flexibility for system benefit
Incentivization for customer engagement	• The new role of end-customer in local markets • Energy community role promoted • Incentives for demand response • Customer benefit and value for all stakeholders
Active prosumer role of the customer	• Easy access and participation, simple tools • Transparent information on the prices at all levels available for the prosumer. Customer can make their own decisions
Changing market participant roles	• Old participants providing new services • New participants providing new services • Interactions with market and each other

2.1.3 Solution: DOMINOES market model

Next, it is described how the aforementioned vision can be approached with a local market, where energy resources connected to the distribution network can trade energy and services with each other and the DSO. This section describes an overview of the DOMINOES market model, while more details can be found in the referenced project deliverables (D2.1, D2.3, D2.4). DOMINOES local energy market concept is illustrated in the figure 1 below.

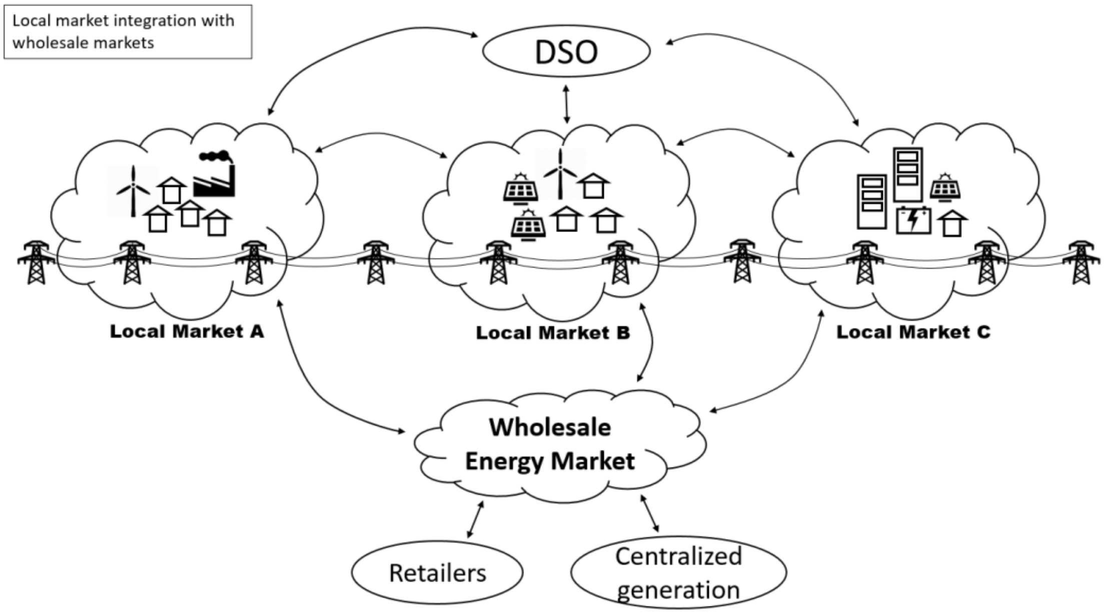

Figure 1 DOMINOES local energy market concept

The main elements for the DOMINOES local market model comprise maximizing **compatibility** with existing structures by extending the existing market sequence with local markets, establishing **local balance responsibility**, and trading of separate **products for energy and flexibility**. These elements enable increased accountability, transparency and incentives for participation of distributed energy resources ranging from **distribution network management** up to **wholesale markets uptake**.

2.1.3.1 Compatibility

Compatibility with existing market structures is most evidently achieved by placing the local market within a sequence of existing wholesale markets (WM). The local market can be split into several sessions. Potential sessions that were identified include long-term flexibility procurement, day-ahead (DA) trading (for energy and flexibility) as well as intraday (ID) trading (for energy and flexibility). In addition, compatibility with existing information exchange interfaces and information content should be maximised.

In the deliverables D2.3 and D2.4 of the DOMINOES project, the placement and timing were analysed in general as well specifically for Finnish and Portuguese markets. Figure 2, Figure 3 and Figure 4 illustrate the market sequences.

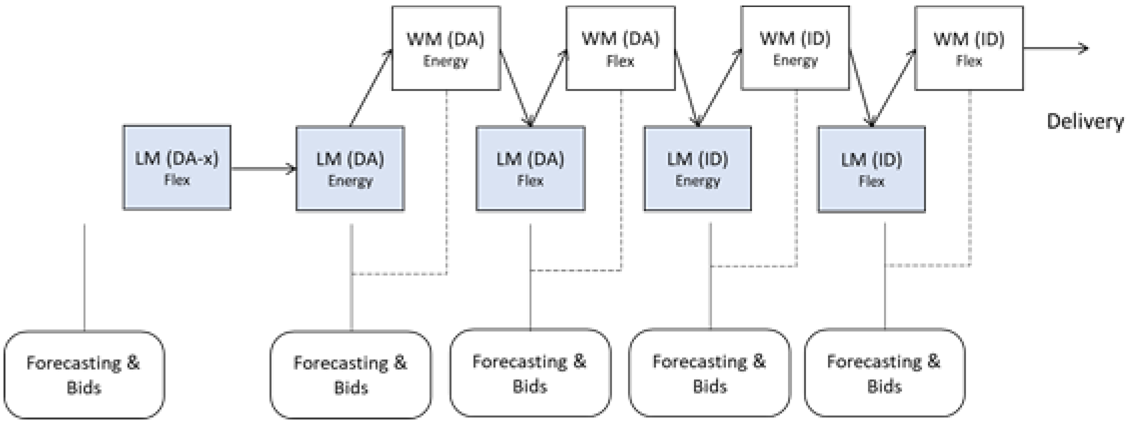

Figure 2 General sequence of markets (DOMINOES 2.3)

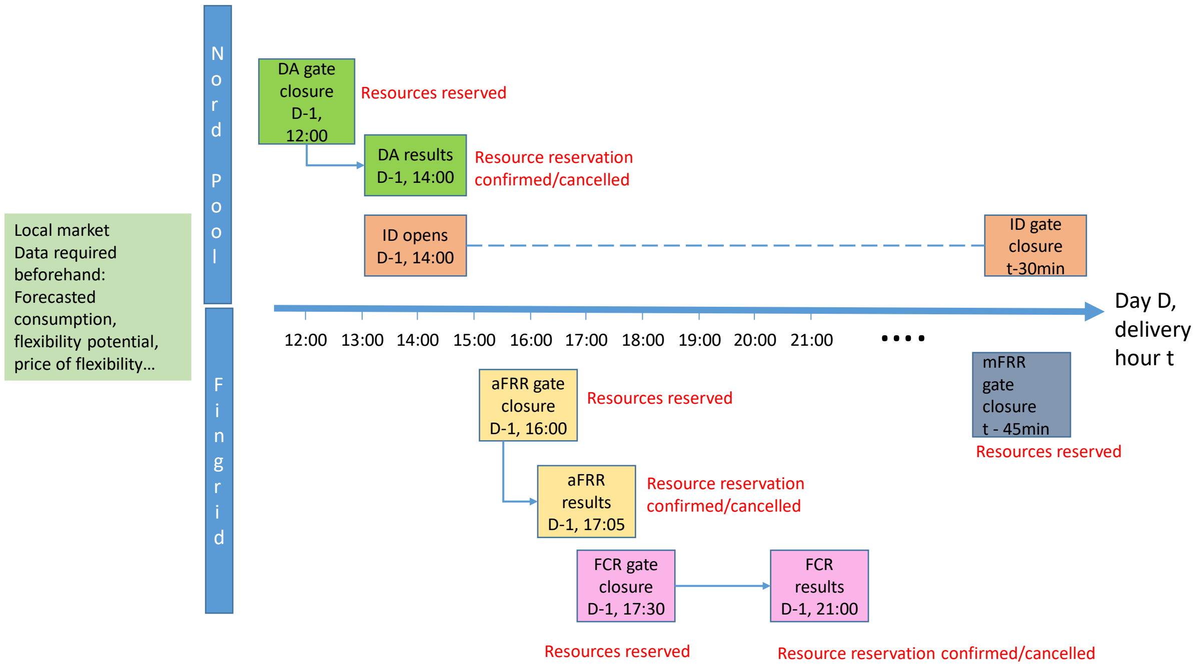

Figure 3 Sequence of markets in Finland (DOMINOES 2.4)

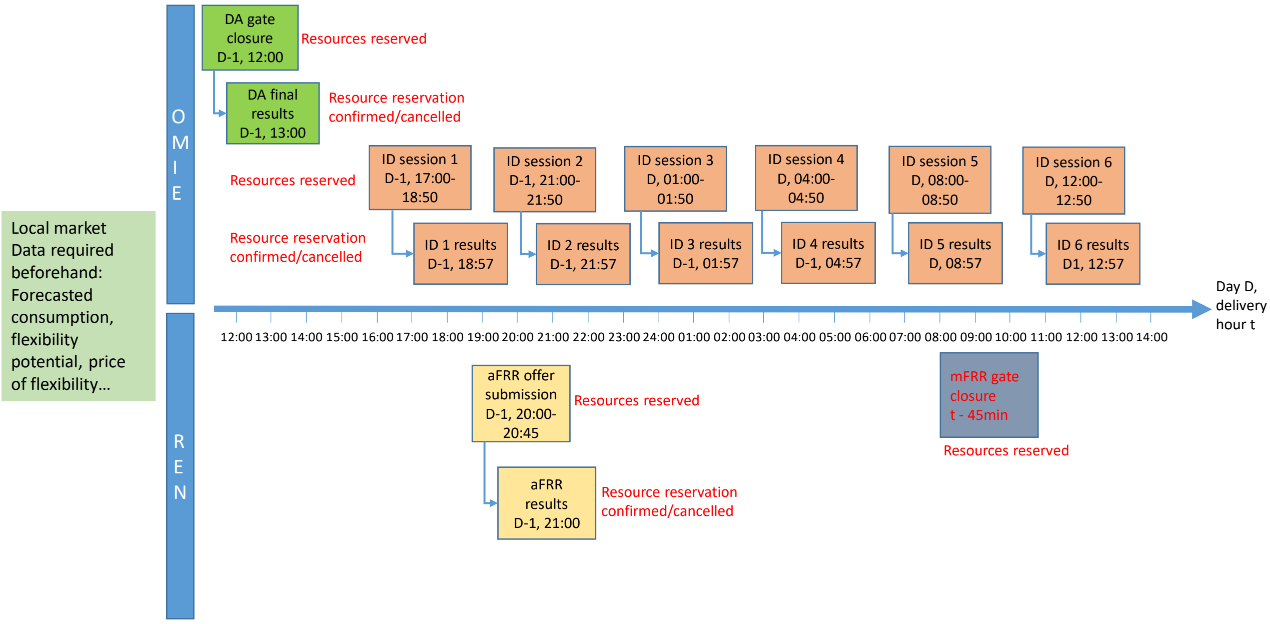

Figure 4 Sequence of markets in Portugal (DOMINOES 2.4)

Furthermore, compatibility can be enabled by considering the settlement processes of energy by defining the local balance responsibility concept.

2.1.3.2 Local balance responsibility

Local balance responsibility implies extending balance responsibility to the smallest possible granularity, i.e., the metering point level. Proposals of alternative balance responsibility models for implementation were established in the DOMINOES deliverable D2.3: a complementary model with compatibility to existing balance responsibility and a full model with existing system balance responsibility extended to metering point level.

Local balances support the validation of flexibility activations, enable local intra-community trading and transparency of costs. For more accurate validation of flexibility, separate products for energy and flexibility can be established and they can be considered in the balance settlement.

2.1.3.3 Products in local market

The DOMINOES local market considers energy and flexibility as separate products. Flexibility can be used in the energy markets (local and wholesale) or within the local flexibility market for DSO congestion management.

The local market could also consider energy in general as a non-homogeneous good, enabling the expression of individual preferences while trading (i.e., between trading partners within or outside their community, or between generation types).

2.1.3.4 Market uptake

With a separate market and product for flexibility in the local market, the distribution network operator can also access flexibility services. The DSO has the transaction validator's role with the inclusion of the traffic light model (described in CEDEC et al.), further enhancing the reliability of the network. With the sequence of markets, the availability of flexibility for its best use in case of no congestions is ensured.

2.1.4 Examples of local market compatibility

This section briefly describes a couple of cases where an end-consumer could derive value from participating in the markets' sequence. In the following examples, it is assumed that there could exist an incentive for local trading. The incentive could be financial or other, such as social. The participation in the wholesale markets is done as part of an aggregated bid.

Example 1: Local market & Elbas wholesale level intraday trading

In this case, an energy producer first evaluates the current situation and estimates the following capabilities and price levels:

- Expects to produce 2 kWh of energy
- Expects energy price on wholesale (DA spot) market to be between 0.05 €/kWh - 0.07 €/kWh

The producer then participates on the following markets:

- Day-ahead: Local market trading
  - Sells 2 kWh at minimum price 0.05 €/kWh, which is then accepted as 2 kWh at a price 0.06 €/kWh
- During the operating day: Elbas intraday trading
  - Able to only provide 1 kWh
  - To cover the difference, procures 1 kWh from Elbas at a maximum price of 0.08 €/kWh. Is awarded 1 kWh at a price 0.07 €/kWh

This example illustrates how a producer could take part in multiple levels of markets and take advantage of local incentives by trading on a local level.

Example 2: Local co-operative power-sharing & reserve markets

In this case, a consumer-first evaluates the current situation and estimates that it

- Expects to consume 2 kWh of energy
- Expects energy price on wholesale (DA spot) market to be between 0.05 €/kWh - 0.07 €/kWh
- Has flexible resources with the ability to reduce consumption 1 kWh

The consumer participates then on the following markets:

- Day-ahead: Local market trading
    - Buys 2 kWh at maximum price 0.06 €/kWh, awarded 2 kWh at a price 0.06 €/kWh
- During the operating day: mFRR balancing energy
    - Able to reduce consumption 1 kWh
    - Sell 1 kWh to mFRR at minimum price of 0.07 €/kWh. Is awarded 1 kWh at a price 0.08 €/kWh

This example illustrates how a consumer could participate in power-sharing on a local market. The consumer could also participate in reserve markets (potentially as a part of an aggregated bid).

We have also identified what is required for the compatibility between two different markets, what data should be exchanged and how the information should be handled so that the end-customer can make justified decisions. The identified required information for making informed decisions include:

- End-customer (or the end-customer services) should have access to
    - Prospective markets depending on resource capabilities and existing contracts
        - Expected market prices and risks / uncertainties involved
    - Forecasts providing expected consumption & production patterns
    - Other costs & incentives, such as network tariffs
- To be able to validate flexibility & to provide capability information, shared information for flexible resources in for example a flexibility resource register should be available

2.2 General roadmap

Local markets are many times seen as local solutions for the market participants to trade between themselves. DOMINOES aims to increase awareness of how the local market can add value to the overall energy markets and how the DSOs could be connected to the local market solutions.

This roadmap identifies the actions required to introduce the local market concepts in real market environments. Local markets may have a local role, but the market structure and regulative environment should create a framework where local markets can connect to other markets and provide value for the markets, the DSO and the local market participant. The connection with the DSO is very important in providing the local benefits of flexibility.

Local market development should also consider the viewpoint of the end-customers and actively encourage their market participation. Local markets, local market operators and energy community service providers need to design easy and understandable products and services. Interactive tools and applications are needed to provide easy market participation.

2.2.1 Regulation

Regulative aspects in the proposed DOMINOES market model are mostly related to identifying the value of flexibility for the networks and the role of system operators in purchasing flexibility.

Also, the role and definition of energy communities are important. An energy community is not a synonym for a local market, but there could be a local market inside the energy community. The energy community is defined in the Clear Energy Package (CEP) (European Commission, 2020d) and will have a legal role in the future when the CEP is implemented in the national regulatory framework. The energy community framework enables a good environment for a local market and thus is worth studying. After the possibilities of energy communities are identified, suitable local market mechanisms can be defined. The local market, as non-regulated market activity, can’t be strictly regulated.

Existing market structures are not yet suitable for the small-scale resources market participation. The threshold of being a market participant is too big (market entering mechanisms, bid sizes, etc.), and aggregation practices are not in place. The local market should lower the barrier of market entry and enable market participation. Also, there are restrictions on what type of resources (generation, consumption, storage) can participate in the markets in some countries. Examples of which type of resources contribute to different reserves can be found from (ENTSO-E, 2020).

2.2.1.1 Network Codes: Flexibility

Although flexibility and local energy markets can significantly support the integration of renewable energy sources and can be used to reduce grid constraints potentially resulting from peak generation and peak load, electricity network codes do not have specific binding rules for these topics, particularly focusing instead on the connections of generators and demands. There only regulation that mentions the importance of flexibility as a demand response tool is the Code (EU) 2016/1388.

2.2.1.2 Valuation of network flexibility

It is crucial for the “success” of local markets in an open energy market environment that the locational aspect of the flexibility is valued outside the local markets as well. Otherwise flexibility for the networks won’t be valued. Locational value of the flexibility is important for the system operators, both DSO and transmission system operator (TSO) since flexibility could be a solution to locational related network issues, like congestion management. System operators are regulated entities, and thus their targets are affected by the regulation.

As stated in article 32 of the Recast Electricity Directive, DSO’s are required to procure flexibility services to improve their future efficiency. A regulation framework should promote the procurement of flexibility from open marketplaces that are already existing, like wholesale trading and the upcoming local markets. This would require that locational information should be added to the trading information properties. When the regulation encourages the DSO role as flexibility procurer in the open flexibility markets, the DSO can utilise the resources that are anyway participating in the energy/flexibility markets already.

If the flexibility resources are not yet participating in open markets (like wholesale or reserve markets), when they become participants of the local market, their potential in flexibility is recognised and published. Customers at low and medium voltage networks are typically not yet active market participants. By connecting to local markets, DSO's would have the capability to procure these resources' flexibility. Since the DSO needs for flexibility are at the local level, providing resources should be local. The traditional providers of flexibility in system-level are not adequate for DSO purposes.

Creating one system operator, specific marketplaces or buying portals might lead to a situation where not all the potential flexibility service providers find the marketplace at all or the flexibility service provider is locked to this one specific marketplace. For instance, the congestion management needs are typically relatively seldom and locking the flexibility value to this one purpose would be inefficient for the whole system. When DSO would be a procurer of flexibility in the local market, that is an open and transparent way to purchase the flexibility.

A regulative framework should enable a flexible market operation environment so that it incentivises to use the flexibility for the most valuable part of the system at each moment.

From the distribution system operator perspective, transparent co-operation with the local market is beneficial. If the local market operates behind one metering point without visibility to the connecting network. In that case, this might negatively impact the DSO when the demand from the network is a sudden change. For example, the local community mostly operates behind the metering point, but then in exceptional cases relies on the network, and the network must prepare for that occasion as well.

2.2.1.3 Clean energy package

The Clean Energy for All Europeans package and especially the transposition of the recast Electricity (2019/944) and Renewable Energy (2018/2001) directives into national legislation should alleviate many of the concerns related to local markets. For example, Article 17 of the Electricity directive addresses demand response through aggregation and states that:

- *"Member States shall allow final customers, including those offering demand response through aggregation, to participate alongside producers in a non-discriminatory manner in all electricity markets."*
- "*Member States shall ensure that transmission system operators and distribution system operators, when procuring ancillary services, treat market participants engaged in the aggregation of demand response in a non-discriminatory manner alongside producers on the basis of their technical capabilities."*

At the moment, the list of eligible resources (generators, loads, pump storages, batteries) in ancillary service markets varies widely between European countries and in some cases, only generators are eligible (see ENTSO-E 2020). Thus, transposing these requirements should help to level the situation of demand response providers and aggregators in Europe. However, regardless of the list of eligible resources, requirements concerning minimum bid sizes and symmetricity may complicate demand response and aggregators' participation.

Although the package does not directly address local energy and flexibility markets, it introduces the definitions for two types of energy communities, i.e., renewable energy community (REC) and citizen energy community (CEC) and peer-to-peer (P2P) trading as shown in Table 2.

Table 2 Energy communities and P2P trading in recast Electricity (2019/944) and Renewable Energy (2018/2001) directives

Citizen energy community	Renewable energy community	'Peer-to-peer trading' of renewable energy
a legal entity that: (a) is based on **voluntary and open participation** and is effectively **controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises**;	a legal entity: (a) which, in accordance with the applicable national law, is based on **open** and **voluntary** participation, is autonomous, and is effectively **controlled by shareholders or members that are located in the proximity of the**	the **sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or**

(b) has for its **primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates** rather than to generate financial profits; and (c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders;	**renewable energy projects** that are owned and developed by that legal entity; (b) the **shareholders or members of which are natural persons, SMEs or local authorities, including municipalities**; (c) the **primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates**, rather than financial profits;	**indirectly through a certified third-party market participant, such as an aggregator**. The right to conduct peer-to-peer trading shall be without prejudice to the rights and obligations of the parties involved as final customers, producers, suppliers or aggregators;

The key differences between CECs and RECs relate to (CEER, 2019):

- membership:
  - REC: additional requirement that for private undertakings, their participation does not constitute their primary commercial or professional activity
- geographic limitation:
  - CEC: no limitation
  - REC: proximity of renewable energy projects owned and developed by the REC
- allowed activities:
  - CEC: only electricity sector activities
  - REC: all energy sectors
- technologies:
  - CEC: technology neutral
  - REC: only renewable energy technologies.

Energy communities should be entitled to share the electricity (CECs) or renewable energy (RECs) produced by the production units owned by the community and to access all electricity/suitable energy markets directly or through aggregation in a non-discriminatory manner. One challenge is that according to the Electricity Directive, energy community members do not lose their rights and obligations as household customers or active customers. Thus, the community members should be able to purchase electricity from the supplier of their choice. Simultaneously they should be able to benefit from the energy community's resources (e.g., generation). Hence, the members have to have market access also as individual customers, and the community cannot be a single customer as a whole.

According to the Recast Electricity Directive, market participants engaged in aggregation (Article 17), citizen energy communities (Article 16), and active customers (Article 15) shall be "*financially responsible for the imbalances that they cause in the electricity system; to that extent they shall be balance responsible parties or shall delegate their balancing responsibility in accordance with Article 5 of Regulation (EU) 2019/943*". Furthermore, according to Article 17, "*Member States* ***may*** *require electricity undertakings or participating final customers to pay financial compensation to other market participants or to the market participants' balance responsible parties, if those market participants or balance responsible parties are directly affected by demand response activation*."

Thus, the directive allows developing and implementing a compensation mechanism. National approaches to this may vary as only the main principles of such mechanism are mentioned in the directive (e.g., the mechanism shall not create a barrier to market entry of aggregators).

Article 32 of the Recast Electricity Directive addresses incentives for the use of flexibility in distribution networks. It requires the Member States to provide a regulatory framework that allows and incentivizes DSOs to "*procure flexibility services, including congestion management in their areas, in order to improve efficiencies in the operation and development of the distribution system*." DSOs must be able procure these services from providers of distributed generation, demand response or energy storage.

The directive does not give guidelines on how the DSOs should be remunerated for the use of flexibility services. Thus, national remuneration mechanisms may differ from each other.

Overall, the Clean Energy for All Europeans package improves the opportunities to create local markets. However, while it defines the basic principles for new stakeholders such as aggregators and energy communities, there is room for national consideration. The potentially differing arrangements may cause challenges e.g., for energy community service providers wishing to scale up their business model. Coordination between national regulators and TSOs and harmonization of essential rules could help in creating a common framework for local markets.

2.2.2 Market structures

Local markets are part of the energy markets. It should be considered how the current market structures prevent or enable the establishment of local markets and how the local market can provide value to the whole energy market.

The basic principle is that market operation is a free domain and not regulated. In theory, anyone interested can join the markets. Local markets can also join other markets, and the establishment of local markets is a free domain.

The local market should incentives the end-customers to share the energy and flexibility, not only to optimize their own consumption/production. For the whole system benefit, it would be cost-effective to use all the existing resources.

Pricing and tariffs have the potential to influence peoples' consumption of electricity and the attractiveness of the local market. Benefits compared to the costs of participation should be higher. For these reasons, the distribution pricing structure should support the local markets.

One key element is that the end-customer has transparent information on the prices at all market levels (local, wholesale, balancing) and the other potential value available, like green or renewable energy, community sharing or the network aspect of locational trade. This would make the price formation also more transparent. Some of the price information is publicly available but not yet collected and presented for the end-customer in an easy format.

Information sharing is one way to engage end-customers to participate in the local markets. Price information or potential benefits are also important when making the investment decisions on the generation capacity or demand response enabling technologies. This way, there will be more and more flexible resources.

2.2.2.1 Additional information needs

Currently, the electricity market system assumes that the electricity network is a copper plate, and there are no physical limitations in the trading. The locational information at the existing wholesale trading is included in the pricing zone. In the future, this will not be sufficient in increasingly more situations and networks. Flexibility trading needs to provide more detailed locational information in order to take into account locational flexibility needs.

To provide the value for the locational flexibility, locational information of the flexibility resource should be identified and included in the trading information. Locational information is not necessarily only geographical information but also network topology-related information, like connection point ID and location of the network's connection point.

When more than one party procures the flexibility from the one resource, there will be a need for shared information about the flexibility resource.

Active System Management -report (CEDEC et al., 2019) introduces the flexibility resource register concept. Flexibility resource register would contain the structural information of the flexibility resources (including locational information). Flexibility resource register enables the information exchange between the different market operators. In the future flexibility, resource register could be used for prequalification of the resources and settlement. By implementing such a national register, all the system operators (and other market parties) could have the visibility to the flexibility resources.

Flexibility resource register could contain detailed information about the resource capabilities to be utilised in the flexibility trading as well. These include technical information like power, capacity, ramping properties, recovery time, rebound etc. There are also other possible ways to include this information in trading besides flexibility register like trading based on attributes. The resource might be trading energy but has properties that would also enable flexibility trading, but the resource will not be utilised if these properties are not known.

The table 3 describes based on (DOMINOES 2.4) the overview of local markets' information exchange with the stakeholders.

Table 3. Information exchange from stakeholders of Local Market based on (DOMINOES 2.4)

From Local Market	To Local Market	From Local Market	To Local Market	From Local Market
Consumption & generation forecasts Flexibility forecast Flexibility activations Technical validation Market schedules & prices	Grid and local market constraints Flexibility procurement offers	Technical validation Flexibility offers Flexibility activations	Grid constraints DSO validation Emergency signals Acceptance of bids Flexibility procurement	Metering data Settlement Data Deviations Reports Invoicing
Before the operational time frame		Operational		After operational time frame

2.2.2.2 Retail markets

End customers are able to produce energy. Therefore, there should be an opportunity to sell the surplus energy to the retailer or other than the retailer. Selling the surplus to the retailer is already existing practice.

The alternative way to activate end-customers is the retailer's products to the end-customers. The product should consider the wholesale market value and show it to customers. One example of this could be retailer products based on wholesale market prices at the hourly level or an advanced version. The end-customer can also decide based on the market prices securing the price levels.

Retail electricity products can activate the end-customers and be an interim stage. These alternatives do not necessarily require or enable a very active role. Thus, more favourable option would be if the end-customer could be part of the energy market through a new market participant, as a local market. In any case, the structure should be as transparent as possible.

2.2.2.3 Local market

One way to organise the local market is the energy communities. Depending on the national implementation of Clean Energy Package (see chapter 152.2.1.3) there might be differences in the community's requirements or limitations. For example, in Portugal, the maximum generation capacity for the energy community is 1 MVA. There might be differences in the management of the renewable and non-renewable generation in the communities. It should be noted that the energy community doesn't necessarily mean also a local market.

For the benefits of the local markets, it's important that there is a link to the distribution system operator. In some cases, the local markets establish themselves for internal reasons, and a DSO connection could be formed afterwards. Another type of local markets is the DSO flexibility markets where the main driver is the flexibility need from the DSO and the market start to develop from that need.

One critical aspect to consider in local markets is the balance settlement and its coherence with the overall balance settlement. Trading outside the balance settlement chain causes imbalances for the balance responsible parties (BRP). The responsible balance party might not be aware of the changes and cannot take it into account. For one end-customer, the effect on balance is not big, but summing up might become significant. If the responsible balance parties cannot keep the balances, it will increase balancing costs and costs for the end-customer in the long run.

2.2.2.4 Other markets

Wholesale or balancing market operation does not necessarily require changes. Still, the markets could lower the overhead of being a market participant, e.g., by lowering the minimum volume or reducing the requirements for information requirements, guarantees and financial capabilities, pricing and matching product structure. The market structure should enable the aggregation of resources. If independent aggregation is allowed, it will create even more opportunities for new market participation and for new market participants.

The local markets should be aware of the possibilities on the wholesale and other markets for the local market operators and participants, so the provision of information is important. In addition, the sequential operation of the markets should be ensured and "enabling" the temporal space for the locational market.

Balance settlement and related information exchange should be organised in such a manner that it doesn't cause an overwhelming burden to the new participants.

Changes in the energy markets do not happen suddenly, and the local market's active role could enlarge by a stepwise approach. Below there is a suggestion on how the shift for the local markets could happen.

1. Selling excess renewable electricity for a retailer (not yet a local market)
2. Establishment of an energy community so that the legal requirements are in place in the respective countries
3. Energy trading is enabled so that the community members (or local market participants) are trading between themselves (peer-to-peer trading or isolated local energy market)
4. Flexibility trading is enabled so that the community members (or local market participants) are trading between:
    a. Peer-to-peer flexibility trading
    b. Local market trading
    c. Flexibility trading for the distribution system operator
5. Energy community can be part of the retail or wholesale trading through a retailer
6. Energy community is an energy market role who has a defined role in the trading
7. Energy community or local market operating in power exchange markets (energy trading)
8. Energy community or local market operating in national flexibility markets (flexibility trading) and trading flexibility for the transmission system operator

2.2.3 End-customer role

In order end-customer to be an active energy market participant, they need more information on the opportunities and prices in the energy markets. At the moment this information is typically not available in an easily digestible format so that the end-customers would really take an advantage out of it. Besides transparent information, the end-customer also need easy tools, applications and services to be active market participants and engage in local markets.

One of the challenges that the electricity sector will face has to do with new services that can be provided to residential electricity consumers. In Portugal, the average residential consumer pays approximately 50€/month of electricity. The provision of bill-saving services to these consumers by energy-service companies will require a high level of aggregation, due to the low potential of savings that can be provided in Portugal, because average consumption is lower than in many other European countries, which translates into a relatively low monthly bill (in euros) and a low potential of significant energy savings. Flexibility services will be more easily established with large consumers, which have a deeper knowledge of their energy costs and sometimes have dedicated staff to optimize electricity bills.

In Finland, the kWh price of electricity is relatively low compared to other European countries, and thus the financial incentives are hard to find for some customer groups. Customers in apartment buildings or living in detached houses with the main heating method other than electricity have relatively low electricity consumption on average. Especially the heating season in Nordic countries provides the potential for the provision of flexibility and demand response. With 20000 kWh yearly consumption, the average monthly electricity costs are around 230 €.

2.2.4 Market facilitation

The goal of decarbonisation and transition towards an electricity sector with a lower level of Greenhouse Gas Emissions has led to a deep change in the European electricity sector structure. There is a growing level of renewable generation in the energy mix, and renewable generators connect themselves not only to the transmission but also to the distribution networks. More than 60% of renewable generation (excluding large hydro) is connected to the distribution grid in Portugal. This change represents a challenge in terms of DSO management, given that DSOs must assure that the grid has enough capacity for both consumption and generation. Another aspect that must be assessed by DSOs is the impact of new Renewable Energy Sources (RES), such as self-consumption or Electric Vehicles (EV), in the distribution grids. While self-consumption will significantly change the shape of the typical load diagrams of LV customers, EV charging may cause new peaks of electricity consumption, which must be taken into account by the grid operator.

The effort to increase the level of renewable generation and the challenges that the new RES bring to the DSOs raise the importance of new agents and roles, capable of supporting these two goals.

The new Electricity Directive 2019/944 already establishes some rules regarding:

- Self-consumption;
- Electricity storage;
- Flexibility.

All these new resources are recent in the sector, and they directly affect the distribution grid operation.

Self-consumption has the potential to reduce the volume of electricity flowing through the distribution grid. This will bring more uncertainty in terms of network planning, especially because of the unknown evolution of self-consumption installation and the unknown amount of non-registered self-consumers. Also, as distribution charges are mostly recovered by energy-related terms (€/kWh), it is important to rethink the distribution tariff structure, in a manner that allows for sustainable and fair revenue recovery.

Electricity storage may be used at the consumer level by consumers or as a DSO tool for grid management purposes. Consumer-level storage has the potential to foster the profitability of self-consumption, as it guarantees a higher amount of self-consumed electricity. Also, storage may be used as a tool for customers to buy electricity when its price is low and inject it when the price is higher. On the other hand, DSO-level storage may be a useful tool to support the DSO, for instance, in case of grid failure. According to Article 36 of the Electricity Directive, the DSO shall be allowed to own and operate storage assets, in case they are part of the DSO grid. In other cases, the DSO will only be allowed to operate storage when there is no market offer available directly. The National Regulatory Authorities (NRA) will have the responsibility to supervise storage ownership and operation, as well as regularly assess the market conditions of storage services.

Regarding flexibility, this resource is expected to become an alternative to investment in the distribution grid, whenever this reveals to be the most effective option. The DSO shall include flexibility options in its planning decisions. The Electricity Directive establishes that the DSO's costs to procure flexibility services shall be accepted and recovered through the distribution tariffs. Member-States shall also create incentives to promote the use of flexibility.

According to the Electricity Directive, the role of "neutral market facilitation" in the electricity sector corresponds to the role of procuring losses in the electricity sector. On the other hand, all major changes in the electricity sector involve the DSO and will impact the operation of the distribution grids. As such, the DSO will be a key element to foster and facilitate the energy transition. One of the main principles DSOs shall respect is the non-discrimination between agents, that is, the DSO shall be neutral concerning the choices it makes. This gives the DSO a role that is sometimes also called "neutral market facilitation" of new RES.

The future of the electricity sector is expected to have the following features:

- More decentralised generation, with a significant part being installed at LV level;
- Considerable weight of self-consumption;
- Wider use of electricity storage.

New agents will be able to aggregate consumption and/or generation and offer flexibility services. The DSO is one of the agents that interested in making its grid operation more efficient and effective by procuring these services, whenever they represent the best alternative.

However, the facilitation of new RES and the procurement of flexibility services require the DSO to have a high LV grid knowledge level and a close to real-time grid supervision. Given the LV networks' granularity, the transition to a more digitalised grid may require the DSO to invest heavily in IT systems and equipment. It will be important that the NRA and DSOs assess in which cases the benefits of flexibility and RES are higher than the costs of making these alternatives possible.

In what concerns the Portuguese electricity sector, the first self-consumption regime was published in 2014, while the current regime has existed since 2019, established by the Decree-Law 162/2019. The self-consumption code was published in 2020, following a public consultation promoted by Energy Sector Regulatory Authority (ERSE). The 2019 Decree-Law already establishes some dispositions regarding individual and collective self-consumption, as well as renewable energy communities. The rules under which storage shall operate are not defined yet. However, the main Portuguese DSO, *EDP Distribuição*, has already tested the use of storage assets in a pilot project in Valverde, Évora (H2020 Sensible Project). The rules for DSO procurement of flexibility services have not been established. The main flexibility tools that already framed and in place are the interruptible contracts, which are managed by the TSO, REN (although the DSO can request its use for customers connected to the distribution grid) and the pilot for the participation of large consumers in the tertiary reserve generation market, which is managed by the Global System Manager (in Portugal, this role is played by the TSO). In this pilot, large consumers can offer to increase or decrease consumption, according to the System Manager's needs to assure the equilibrium between generation and consumption. Although the DSO is informed about the offers and the amounts of electricity involved, this pilot does not establish any active participation of the DSO.

Main recommendations and guidelines:

- All new market solutions that impact the distribution grid shall be supervised by the DSO. Whenever safety of supply is in risk, the DSO shall be able to disconnect RES;
- Cost-benefit analyses shall be taken, regarding the benefits of new RES alternatives, compared to business as usual (BaU) options;
- There should be a financial assessment of the IT development needed by the DSO to facilitate new RES;
- There should be a future impact assessment of how storage, EV and self-consumption will impact maximum peaks and energy flowing through the distribution grids;
- Distribution tariffs shall be changed, in order to promote a fair distribution of the distribution costs among customers, without discrimination against customers that do not have self-consumption or storage.

2.2.5 Technology

The efficient local market operation also requires advancements in technology. The development of the distributed energy technology, controllable and related control and telecommunication infrastructure are fundamental parts of the local market development. Without cost-effective end-customer solutions, there are no resources for the local markets.

From the end-customers' point of view, another crucial aspect is the transparent information needs and interaction possibilities to enable the local market participation based on informative decisions.

Implementation of the local market needs production, consumption, forecasting, data handling and system management. Table 2 presents the main needed technologies in more details. Remote data technology is required for implementing local energy markets. In addition, the data should be collected remotely, and information exchange infrastructure should exist. Forecasting, in turn, facilitating with planning and operating of electrical grids. It is good to consider long-, mid- and short-term forecasting. Inverter-driven technologies are used for energy storage and renewable generation. Implementation and connection devices are needed between them and between devices and the electric grid. The challenge is including the requirements of the local market concept. The management system allows transactions, utilizes the flexibility best possible way in the energy market and use the available information to gain the best market performance (DOMINOES D2.1).

Table 2. Technology development requirements for local markets (DOMINOES 2.1)

Remote data technology	• Collection • Information exchange • Remote monitoring and controlling • Data analysis
Forecasting technology	• Prediction of energy consumption • Prediction of renewable generation • Prediction of market prices
Inverter-driven technologies	• for renewable generation and energy storage.
Implementation and connection devices	• enabling local trading • energy harvesters (several devices that work together) • communication
Management system	• enables transactions • information use • use of flexibility

Especially focus should be on the technologies and solutions that enable the participation of small customers.

In the DOMINOES deliverable 2.1, it is described how the E-broker could be the solution for the control and management of the local market level. Its objective is to match consumers and prosumers in the best way possible, ensuring stable and proper performance and that priorities are met. E-broker can also be implemented as a management system for the resources of individual end-users. In this scenario, each of the devices or groups act as an agent with a given priority that interacts with the rest.

Blockchain is also a hot topic in peer-to-peer trading. Blockchain or other similar technologies could provide solutions in the local markets for recording transactions, contributing to a more open market, P2P-transactions, security and smart contracts. (DOMINOES D2.1.)

As a part of the exploitation of DOMINOES-project, some technical elements of the local markets have been identified that need to be developed further after the project. These are part of the technological development needs for establishing functioning local markets.

Different IT-platforms need to be developed to meet the local market requirements, besides the trading mechanisms and systems connecting the local market to other market and distribution system operator management systems. Improved simulation models and demand response models should be developed to ensure efficient operation. In distributed systems, cybersecurity must be ensured.

2.3 Country roadmaps

This section provides country roadmaps for those participating in DOMINOES-project, Finland, Portugal, Spain and the UK focusing especially on Finland and Portugal, where the project validation sites are.

2.3.1 Finland (Nordic)

Finland is considered to be among the most active markets for demand-side flexibility (smarten, 2019). Demand response resources are eligible in all markets operated by the Finnish TSO Fingrid. At the moment, independent aggregators can provide frequency-controlled reserves (FCR-N, FCR-D and FFR) and a pilot project tests their participation in the balancing energy markets (mFRR) (Fingrid, 2020a). Other upcoming changes in the mFRR markets include lowering the minimum bid size to 1 MW (compared to current 5 MW) and shortening the product duration to 15 minutes (compared to current 60 minutes) (Fingrid, 2020b).

Especially in the FCR-D market, DR has become a significant competitor to flexible generation. For example, in the yearly FCR-D market, DR represented over 70 % of contracted flexible capacity for 2018 (Fingrid, 2017). Even residential loads such as water heaters have been utilised as resources in the FCR markets (Sähköala, 2018). The increased supply has led to lower prices, especially in the yearly FCR-D market (Fingrid, 2020b). Both in FCR-N and FCR-D, the prices in the hourly markets are higher than in the yearly market, and in the FCR-N, the volumes acquired from the hourly market have grown during recent years (Fingrid, 2020c).

While the Nordic countries trade electricity in the same organised market (i.e., Nord Pool), the system balancing is handled by the national TSOs. Thus, there are some differences in the ancillary service market rules. For example, in Norway, independent aggregation is not permitted, and load participation in FCR markets is very little (Sáez Armentero et al., 2020). However, Nordic Energy Regulators published in 2020 their recommendations for a Nordic regulatory framework for independent aggregation (NordREG, 2020a). Furthermore, despite the common wholesale market, there are some national differences to consider. While Finland forms one bidding zone in the power exchange Nord Pool, all other Nordic countries are divided into several bidding zones, making the customers' location especially relevant.

The imbalance settlement model (eSett, 2020) currently applied in the Nordic countries is based on two imbalances: production imbalance and consumption imbalance. However, due to the harmonisation of the imbalance settlement in Europe, the Nordic countries will adopt a single price, single position model. The target go-live date is 1st of November 2021 (Nordic Balancing Model, 2020). This change is expected to simplify the imbalance settlement process and unify the position of different flexible resources. Furthermore, the imbalance settlement period (ISP) will shorten from the current ISP of one hour to the 15 minutes ISP required in Regulation 2017/2195. However, the Nordic TSOs have requested derogation of this requirement until 22nd of May 2023 (Fingrid, 2020d). Nevertheless, the shorter ISP may increase BRPs interest in flexibility services.

The governments and regulators in Nordic countries have obligated the TSOs to develop and operate data hubs that will facilitate wholesale and retail market processes (NordREG, 2020). The functionalities of each data hub include, for example, customer moving and switching, meter value management, and third-party access to metering data. Denmark and Norway have fully implemented data hubs, whereas the Finnish TSO Fingrid expects to launch the data hub in February 2022 and the Swedish TSO Svenska kraftnät in 2022 or 2023 (depending on legislation) (NordREG, 2020b).

Due to cold winters and wide use of electric heating, LV networks' distribution capacity is relatively high in the Nordic countries. Thus, even significant increases in installed PV capacity do not widely affect peak powers (Lassila et al., 2019). However, other changes, such as the fast increase in the number of electric vehicles (EVs), would significantly impact peak powers in the Nordic environment. Furthermore, overlapping high-power EV charging or high PV generation during low-loaded seasons would increase the risk of under and overvoltages (Lassila et al., 2019). A more pressing challenge for the Finnish DSOs is the tightening requirements for the security of supply. According to the Electricity Market Act 588/2013, by the end of the year 2028, outages caused by storm or snow may not cause may not last longer than six hours within town plan zones and no longer than 36 hours in rural areas. Due to the regressive population, fulfilling the new requirement in sparsely populated rural networks through traditional infrastructure investments can be risky (Lassila et al., 2020). Alternatives for the traditional approach include ensuring the security of supply via the purchase of services from external service providers or agreeing on a lower security level with the customer (Lassila et al., 2020).

The current regulatory framework for DSOs (Energy Authority, 2015) will be applied until the end of 2023. This model encourages investments over the purchase of services such as flexibility. Thus, the model needs to be updated before the next regulatory period starting in 2024 to meet the requirements of the Electricity Directive 2019/944.

Finland and other Nordic countries Norway, Sweden and Denmark have completed the large scale roll-out of smart electricity meters (ACER, 2020). This has enabled offering of tariffs with DR incentives also for residential customers. For example in Finland, 11 % of retail customers had at the end of 2019 a dynamic electricity price contract where the price varies hourly according to the day ahead spot prices (Energy Authority, 2020). Due to the early smart meter rollout (Decree 66/2009 set the end of the year 2013 as the deadline in Finland, but many DSOs had started installations earlier), the second generation smart meters will be largely installed during the 2020s. Thus, it would be important to establish these meters' functionalities soon (Ministry of Economic Affairs and Employment, 2018).

Legislation for enabling 'local energy communities', i.e., communities whose members or shareholders' consumption points and generation/storage assets are located within the same property or a group of properties and whose members are connected to the distribution network through the single connection point, was published in December 2020 (update of Decree 66/2009 concerning balance settlement and measurement). Apart from the more detailed locational requirement, local energy communities' definition is mostly consistent with the CEC definition introduced in Directive 2019/944. In practice, this legislation enables energy communities, e.g. within apartment buildings. In addition, Decree 66/2009 allows end-users who generate or store electricity or participate in flexibility or energy efficiency schemes to form a group of active customers for the settlement of electricity deliveries. Similar locational restrictions as for local energy communities are applied.

The main focus of the new legislation is on energy sharing and imbalance settlement arrangements. The local energy community or group of active customers must register with the DSO responsible for its electricity measurements. It must inform the DSO about the consumption points which belong to the community/group, allocation guidelines for the generation or discharge from a storage, allocation guidelines for electricity injected to the grid, and changes in this information. In practice, consumption point's consumption and its share of the community/group generation/discharge are summed within each imbalance settlement period, and the resulting value must be used in billing.

In sum, independent aggregation is already allowed in most markets operated by the Finnish TSO. Independent aggregators' situation is expected to improve soon also in other Nordic countries. This enables additional revenue streams for the local resources.

Datahubs may facilitate the information exchange related to local market services, although this has not been a key goal in developing the first versions of the datahubs. Furthermore, the harmonisation efforts in the Nordic countries will facilitate scaling up of services for distributed resources. However, questions still remain related to the arrangements concerning communities not connected through a single connection point and P2P trading.

2.3.2 Portugal

Regarding the specific Portuguese legal and regulatory framework, the public policy strategy has been to increase the level of consumer flexibility and to make flexibility more relevant in terms of grid management. On the one hand, the Portuguese regulator has developed two pilot projects, in 2018 and 2019: one pilot had the goal of improving the network access tariff structure, which leads to a more effective benefit associated to demand-shifting, while the other involved consumption in providing ancillary services (tertiary reserve). Although this pilot was focused on flexibility at generation markets level, it is a clear sign towards involving customers in the sector's management decisions. On the other hand, the Portuguese government published a new self-consumption regime (Decree-Law 162/2019, Diário da República, 2019), both individual and collective, and which already opens the door to Renewable Energy Communities (RECs).

By introducing these new players – self-consumption and REC - in the sector, the public policy-makers are making a solid effort to accelerate the transition to a sector with a significant amount of local renewable generation. However, they will represent a big challenge in terms of distribution network management, as the DSO will have to plan and operate its grid in a way that can accommodate these new generation solutions, without compromising quality and safety of supply. This will make flexibility tools even more relevant, as they can provide quick and effective responses by consumers compared to conventional investment alternatives.

2.3.2.1 Future Pathway

One of the challenges regarding Portuguese regulation is the sustainability of the current tariff structure, given the expected impact of self-consumption and renewable energy communities. The majority of network costs are recovered through energy-related (€/kWh) tariffs, which means that consumers pay according to the amount of electricity used from the grids.

The first self-consumption regime was published by the Decree-Law 153/2014, and it established a payment of part of the energy policy costs (the so-called "CIEG"). However, this piece of legislation didn't involve the payment of any network costs by self-consumers, apart from the network costs paid due to their consumption from the grid. The current self-consumption regime was published in 2019. It establishes some rules for individual and collective self-consumption, and also for renewable energy communities. The self-consumption code, published by ERSE in 2020, specified the rules for individual and collective self-consumption. The current framework establishes that only self-consumption using the grids should pay network and policy costs. There is also the possibility that the government exempts self-consumption through the grids from policy costs.

It is unlikely that self-consumption will have a significant impact on network cost recovery in the short term. However, as self-consumption rises, the amount of electricity coming from the grid may significantly decrease. A volumetric network tariff structure could make network cost recovery less sustainable and less fair because consumers without self-consumption would pay a higher bill. It is key that the tariff structure for network charging has a transition towards a more stable and consumption-independent cost-recovery. This could be made either by including a fixed (€/month) charge, where consumers would pay for the fixed part of network costs, or by charging consumers according to their used load / contracted power.

Another challenge has to do with new services that can be provided to residential electricity consumers. In Portugal, the average residential consumer pays approximately 50€/month of electricity. The provision of bill-saving services to these consumers by energy-service companies will require a high level of aggregation, due to the low potential of savings that can be provided in Portugal, because average consumption is lower than in many other European countries, which translates into a relatively low monthly bill (in euros) and a low potential of significant energy savings. Flexibility services will be more easily established with large consumers, which have a deeper knowledge of their energy costs and sometimes have dedicated staff to optimize electricity bills.

Another challenge that will exist in the following years will be the DSO’s need to adapt its systems to increase the level of visibility of its LV grids. The traditional BaU model of DSO management had a very low level of LV real-time supervision and monitoring. By 2010, almost all consumption meters were conventional, and even MV/LV substations had no telemetering installed. In the last years, however, the main Portuguese DSO has installed telemetering in all MV/LV substations, and nearly half of LV consumers are already equipped with smart meters. The next steps will involve the DSO’s ability to provide a large set of remote operations and services, using the smart meter infrastructure (connecting / disconnecting consumers, changing the consumer’s contracted power or even providing information regarding real-time consumption). The DSO shall adapt its systems to collect and treat a very large amount of data. This requires a higher level of investment in IT systems, which energy authorities (regulator and government) should allow fostering energy transition. The Portuguese DSO has also created a supervision centre, which has the goal of tackling non-technical losses. The Portuguese regulator accepted this supervision centre costs. This centre collects a high level of LV network status. Despite the DSO's effort, the amount of fraud and electricity theft is still high. In the future, the DSO will have the challenge of creating new tools and use new technologies to control and further decrease network losses. However, this effort requires a change in the electricity loss legislation in Portugal, which hasn't changed since 1990 and does not significantly penalize the agents responsible for fraud and theft. New legislation should be able to help reduce non-technical losses, whose costs already represent several millions of euros, and are borne by the DSO (through the losses incentive mechanism) and by electricity consumers.

2.3.2.2 Business Models & Market Strategy

The currently dominant energy market structure is based on a simplified and high-level energy value chain mainly explored by incumbents operating in energy generation, energy transmission, energy distribution, and energy retail. In many countries, markets are regulated by public authorities, meaning that electricity prices don't follow demand and supply. In one hand, the price regulation limits the competition. It discourages investments and the emergence of new market players. On the other, electricity consumers are often passive customers that purchase electricity at regulated prices that do not reflect market signals.

Nonetheless, in the context of the Fourth Industrial Revolution, overarching advances in technology aligned with the fast-paced integration of distributed renewable generation sources, electric vehicles and energy storage systems in the energy grid, are changing the way customers are procuring, perceiving and consuming energy-related products and services, and the way companies are exploring new competitive advantages to create better experiences to meet customers' expectations (World Economic Forum 2017). In view of that, there is at present an ongoing disruption of well-established, traditional energy market structures, and innovative local energy market designs, backed up by progressive legal frameworks, have recently started emerging as a consequence.

Illustratively, as pointed out by the Smart Energy Demand Coalition (Smart Energy Demand Coalition 2015), Demand Response (DR) gained widespread policy support in the EU, as recently seen in the Third Energy Package (European Commission, 2020a), the Energy Efficiency Directive (EED) (European Commission, 2020b) and the forthcoming Network Codes (which stipulates that DR and aggregators shall partake alongside generation within all organised electricity markets) (European Commission, 2020c).

Furthermore, the European Commission approved a comprehensive legislative package named 'Clean Energy for all Europeans' (European Commission, 2020d), which provide guidelines for EU Member States to enforce a more integrated, competitive, customer-centred, flexible, fair, transparent, and non-discriminatory EU electricity market with market-based supply prices, strengthening existing end-users' rights and creating new ones, as well as introducing frameworks for energy communities. Specifically, the Directive (EU) 2019/944 on common rules for electricity's internal market (Official Journal of the European Union, 2020a). Outlines rules on retail electricity markets; on the role, rights and responsibilities of aggregators; on the concept of Citizen Energy Communities (CECs); on the connection of electric vehicle recharging points to the distribution network, among others. Alongside, the recast of the Renewable Energy Directive (2018/2001/EU) (Official Journal of the European Union, 2020b) moves the legal framework to 2030, setting a binding EU-wide renewable energy target of at least 32%, which includes provisions for enabling Renewable Energy Communities (RECs) and self-consumption of renewable energy, and increased 14% target for renewable fuels in transportation, among others.

The bundling of these legislative proposals into the 'Clean Energy for all Europeans' package allows overcoming limitations of existing rigid energy market structures, opening up a plethora of different business models opportunities and market strategies for many energy market players, including Technical Providers (TPs). Illustratively, end-users either self-organised in REC or CEC schemes might benefit from the support of an intermediate actor (TPs playing the roles of aggregators[2] or energy community managers) that will firstly provide guidance to new energy community applicants throughout their administrative permit application and granting processes by means of an administrative contact point, in order to reduce project complexity increase efficiency and transparency, and later on by providing information, technical and legal support for their interactions within local energy markets and with upstream energy markets, namely by facilitating REC or CEC members to partake in demand response programmes, self-production, self-consumption, storage and sale of electricity, as well as cope with balancing compensation and penalty mechanisms.

Furthermore, TPs are able to deliver innovative products and technologies to facilitate the transition to this new energy regime, namely by going beyond the provision of smart consumption/generation monitoring mechanisms and also delivering overarching local energy marketplace platforms or Virtual Power Plant (VPP) platforms, embedded with social engagement mechanisms, as a means to optimise distributed energy assets whilst attracting and retaining end-user's willingness to engage in such markets proactively (namely through the provision of flexibility services or peer-to-peer-energy sharing).

All in all, TPs can base their future commercial strategy towards energy community managers and energy retailers/aggregators with balancing responsibilities aiming to deploy and partner up with RECs or CECs.

2.3.2.3 Guidelines for Implementation

In terms of the guideline for the feasible implementation of the innovative business models & market strategies detailed in the previous section, it is fundamental to firstly analyse the actions required to introduce and establish the local energy market concept alongside existing market structures, whilst considering the EU internal energy market objectives to introduce supporting and compatible solutions.

[2] An aggregator represents a "natural or legal person who combines multiple customer loads or generated electricity for sale, purchase or auction in any electricity market" (European Comission, 2019)

As highlighted by (Krahmann, 2013), the large-scale commodification of low-carbon consumer products and services is only possible with strong public intervention. In Portugal, initial steps towards that have been taken, namely with regards to the transposition of the EU Renewable Energy Directive (RED II) into an enabling national regulatory framework[] (Official Gazette of the Republic of Portugal, 2019) in 2019 for the facilitation of REC initiatives and collective self-consumption schemes in the country – which represents an instrumental step to reach a 47% share of renewables in the gross final energy consumption by 2030 (Official Gazette of the Republic of Portugal, 2019).

On that note, while Portugal represents the EU Member State that most literally transposed the EU RED II provisions as it is (Hannoset et al., 2019), to date it still has not transposed the EMD provisions for the facilitation of CECs.

Annala et al. (2020) carried out a thorough analysis of the context of the regulatory transposition of the EU RED II in Portugal, stating that it was carried out in a partial manner to allow the responsible executive governmental agencies (i.e., the Directorate General for Energy and Geology (DGEG), the Energy Sector Regulatory Authority (ERSE) and the government official for the energy sector) to gradually improve the national legal framework in view of the best practices from the field.

The referred Decree-Law introduced major modifications in the self-consumption regime of electricity, guiding it towards the increased use of renewable energy; modification of net metering requirements; definition of a 15-minute interval for the monitoring and treatment of energy-related data; allowance of collective self-consumption schemes via the association of several production and consumption facilities; facilitation of the development and implementation of RECs, as well as the integration of electrical energy storage infrastructures; and favouring market-based sales of electricity (Official Gazette of the Republic of Portugal, 2019).

Among other things, the Decree-Law formulates that the collective self-consumption scheme must be based on the association of consumers and prosumers that are in geographic proximity for energy sharing. It also introduces a new, dully qualified entity to be appointed by the respective members of the collective self-consumption scheme, entitled *Self-Consumption Management Entity (Entidade Gestora do Auto-Consumo - EGAC)*, that shall legally represent them before operators and administrative entities.

This opens an unprecedented opportunity for energy-related TPs to upgrade their skill sets beyond their traditional service provision schemes and start embracing the role of EGACs due to their technical capabilities. In this first step, the feasible implementation of this new vision, according to (Official Gazette of the Republic of Portugal, 2019) the new role played by TPs as EGACs could be extended to:

- The design and management of an internal collective self-consumption regulation that defines, at least, the access and exit requirements for new and existing members; the required deliberative majorities; the rules and respective coefficients for the sharing the renewable production among prosumers; the rules for sharing the payment of tariffs; the commercial agreement to be adopted with the surplus renewable generation; and the application of the respective revenue

- The responsibility for any articulation with the grid operator (namely to manage the energy sharing activities, the respective coefficients, and making production data available)
- The responsibility for the commercial relationship with any independent aggregator / energy retailer that aggregates production / market facilitator (henceforth called “aggregators“ for the simplification of nomenclature), namely for the purpose of sales of any surplus renewable generation from the collective self-consumption scheme through organised energy markets, bilateral contracting (including power purchase agreements), or peer-to-peer trading regimes
- The operational management of the collective self-consumption activities; the management of any imbalances causes to the national energy grid; the management of any network access charges made by the grid operator whenever the distribution grid network is used; the management of the internal network when it exists; the connection with the distribution grid; definition of the respective representative powers; among other responsibilities.

All in all, ERSE provided a schematic representation of the commercial/legal interplay between the EGAC and other stakeholders involved in such activities.

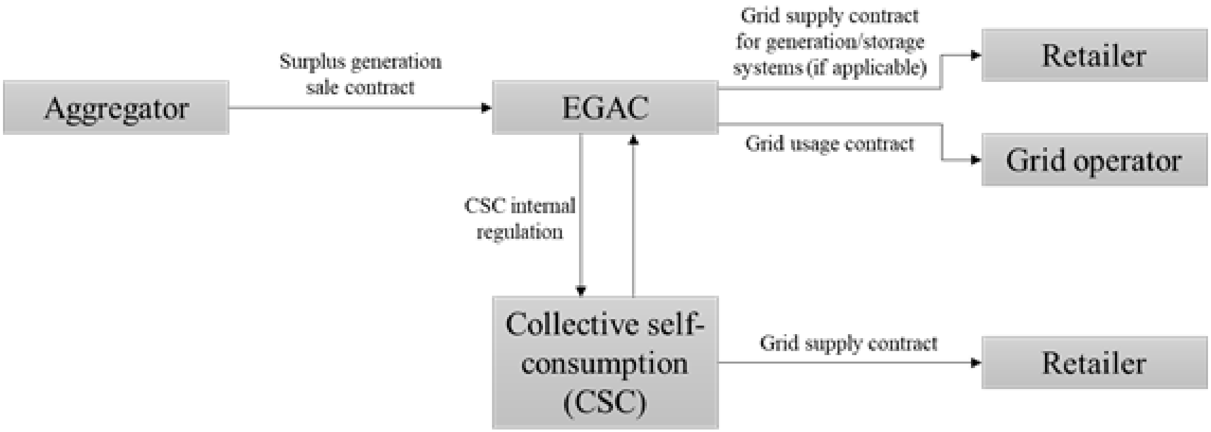

Figure 5 Schematic representation of the commercial/legal interplay between the EGAC and other stakeholders involved in such activities (Adapted from ERSE, 2020)

In terms of rights, duties, monitoring of renewable generation and the commercial relationship of RECs, the same rules of collective self-consumption apply with the appropriate adaptations, such as the power to produce, consume, store and sell renewable energy through power purchase agreements; share their renewable generation within their members; participate in all suitable energy markets, both directly and through aggregation, in a non-discriminatory manner (Official Gazette of the Republic of Portugal, 2019, apud Annala et al. 2020). RECs are also fully responsible for imbalances causes to the national energy grid, being responsible for settling such imbalances or for delegating it to a market participant or its designated representative (Official Gazette of the Republic of Portugal, 2019, apud Annala et al. 2020– which could also be played by TPs. This is reinforced by the referred Decree-Law which states that any natural or legal, public or private stakeholder can openly and voluntarily participate in RECs, emphasising the roles of SMEs (the legal status of most TPs), municipalities and domestic customers in it (Official Gazette of the Republic of Portugal, 2019, apud Annala et al. 2020.

Nonetheless, although Portugal has started taking the first steps to comply with the EU-wide provisions on energy communities, it still needs to be further developed to reach full maturity in this topic. At present, a handful of RECs and collective self-consumption schemes (e.g., in the forms of neighbourhoods, condominiums, private social security institutions, municipal buildings and industrial complexes) started growing across Portugal, which is awaiting the decision of the responsible executive governmental authorities to receive their formal recognition.

As a secondary step towards the feasible implementation of the innovative business models & market strategies detailed in the previous section, energy-related TPs can also tap on the opportunities brought forth by digital transformation to facilitate the introduction of the local energy market concept through the design and implementation of seamless, secure and fully customised digital experiences for any stakeholder involved in such markets - including aggregators and small-scale end-users involved in collective self-consumption schemes or REC initiatives.

TPs have the technical and technological capabilities to best succeed in the new digital environment, thriving through the smart, real-time management of the overwhelming influx of energy-related data. Specifically, TPs can achieve that through the design and development of local energy market platforms, in connection with the necessary smart IoT infrastructure for data collection and monitoring, and interfacing with the existing residential and non-residential Energy Management Systems, that allows consumers, prosumers and aggregators to play their respective roles in local energy markets in a level playing field with other traditional market players, whilst still complying with physical and regulatory requirements (e.g., communications protocols, communications speed, data storage needs, and security) and responding in an aggregated way to upstream market requests.

The local energy market platform can be conceptualised to aggregate and manage distributed renewable energy generation and demand-side flexibility in real-time, resulting in an overall predictable, reliable and stable energy grid. Such platform works by operating as a proxy in upstream energy markets, allowing the monetisation of small-scale flexible loads from end-users and renewable generation surplus from RECs. As a result, it creates win-win scenario for all involved stakeholders, namely:

- Energy consumers and prosumers can optimise their energy usage via real-time monitoring and management of their energy consumption and production, which in turn decreases their energy bills and improve their Return of Investment (ROI); they can monetise their small-scale energy flexibility (e.g., flexible loads, storage systems, EVs, etc.) and renewable assets, creating new revenue streams that did not exist in traditional energy market structures; as REC members, they can share renewable production locally and benefit from reduced transmission fees; and, through gamification and embedded social engagement mechanisms, they can be rewarded based on their proactive participation in local energy markets;

- Aggregators can create new business models strategies based on: (i) the generation of revenue via time-shift; (ii) power demand; (iii) peak shavings; (iv) assets management related with storage systems, solar PV plants or wind turbines; (v) advice on reducing penalties. In this way, aggregators can enhance their energy assets and flexibility portfolio by offering real-time, accurate demand-side flexibility strategies and planning RES generation accurately, as well as manage in a seamless way a much larger number of distributed small-scale customers - hence improving their operational efficiency and the speed of dispatching. All in all, through the local energy market platform, aggregators can partake in balancing and ancillary services markets and demand-side response programmes; improve their retail margins; minimise imbalance settlements and optimise distributed energy flexibility. As an overall result, customers' competitive electricity prices will be obtained using participation in local energy markets and upstream markets with reduced deviation penalties and the improvement of market decisions.

In view of the abovementioned, the local energy market platform could play a fundamental role in the transition towards a more sustainable, dynamic, responsive, and democratised energy system by enabling the monitoring and control of distributed energy flows at every level in the energy network (Geelen et al. 2013) - from large scale generation and transmission to the low voltage distribution networks. These platforms can be conceptualised through a multifaceted approach as fully customised tools to suit and serve the purposes of different energy-related service provision models and energy community configurations that are yet not deregulated in Portugal, allowing it to be ameliorated and scaled up following the pace of the evolution of national frameworks in line with the EU Directives on that matter.

Finally, if coupled with proper social engagement and gamification mechanisms alongside utilizing novel Human-Machine Interfaces techniques and intuitive visualization, these tools can help TPs identify different customer personas that are taking shape and dynamically adjust segmentation strategies, reaching higher scalability and reliability of system performance.

2.3.3 UK

At present, the UK[3] is legally taken as one of the most progressive countries in Europe with regards to the promotion of collective self-consumption schemes and energy community initiatives, as seen in the significant efforts for the market integration of prosumers, and the openness for the competitiveness of innovative business models brought forth by the possibility of virtual net metering and different incentive schemes.

Campos et al. (2020) carried out a thorough comparison between existing regulatory frameworks of renewable energy prosumers in the EU, including the UK. These authors pointed out that, although the UK does not have specific legislation for self-consumption (Compos et al. 2020), it was a pioneer in the promotion of a legal framework with relevance to prosumers in 1989 (UK Public General Acts, 1989), predating other European countries. Furthermore, the UK early introduced important feed-in-tariff (FIT) regulations (UK Statutory Instruments, 2012) for the promotion of individual and collective self-consumption schemes under 5 MW (with subsidies for each kWh produced), including small-scale renewable generation schemes. Nonetheless, FIT schemes were gradually reduced until their extinction in 2019, which nevertheless followed the reduction of the overall costs of ICT systems.

According to the FIT regulations (UK Statutory Instruments, 2012), anyone other than licensed suppliers that supply their renewable generation is limited to a supply cap of 5MW. Up to half can be supplied to domestic end customers. This opens legal ways for collective self-consumption schemes and RECs to trade their surplus renewable generation. However, as Campos et al. (2020) pointed out, the connection of renewable generation systems to the distribution grid requires the compliance with grid codes and technical specifications to prevent any potential damages to the grid network.

Furthermore, the extinction of FIT schemes removed the obligation of suppliers to purchase the renewable generation from prosumers at a fixed price (Campos et al., 2020), opening pathways for aggregators to offer innovative tariffs for the purchase of surplus generation to be traded in upstream markets, as well as for the promotion of P2P energy sharing models for the trading of surplus generation in local energy markets.

As explicit in the British legislation, the participation of prosumers in energy markets is only possible through the national British Electricity Trading and Transmission Arrangement (BETTA) market (Ofgem, 2005), which demands burdensome overhead costs for members of RECs initiatives or collective self-consumption schemes. Nonetheless, they can overcome this limitation by selling their surplus renewable generation to any BETTA participant that acts as a proxy in the market (Campos et al., 2020). Additionally, aggregators (including prosumers and RECs) can participate in the wholesale market, provided that they are registered energy suppliers for the customers they are aggregating (Campos et al., 2020).

[3] In this section, the analysis of the feasible implementation of the innovative business models & market strategies in the UK only considers Great Britain, since Northern Ireland has its own regulator and electricity market

Campos et al. (2020) also pointed out that, although the UK does not have any specific legal framework for the promotion of RECs, the renewable portfolio standard scheme enforced might also represent an indirect incentive for their development, since it obliges utilities to have a fixed quota of their energy generation from renewable sources or financial penalties may ensue.

Furthermore, the promotion of CECs in the form of virtual energy communities might also be possible due to changes in the Grid Code (National Grid ESO 2020, apud Campos et al. 2020), and the Balancing Code & Settlement Code (Elexon 2020, apud Campos et al. 2020), alongside the right for prosumers to have direct access to the wholesale market.

Finally, the balancing market is also opening for independent aggregators (Campos et al., 2020), thus opening a pathway for collective self-consumption schemes or RECs to pool and trade their energy flexibility in this market.

As can be seen, the UK presents an essential factor for the emergence and prosperity of innovative business models connected to local energy markets, which is the flexibility of regulatory frameworks towards the implementation of innovative business models and market strategies focused on local energy markets. This allows TPs to design and enforce multiple new revenue streams that put them as proxy actors between upstream energy markets and proactive end-users engaged in collective self-consumption schemes and energy community initiatives.

Namely, TPs could become legally responsible entities that comply with grid codes and technical specifications for the connection of renewable generation units to the distribution grid in the name of collective self-consumption schemes or energy communities; TPs could design and offer innovative tariffs for both aggregators for the sale of aggregated flexibility in wholesale markets or balancing markets, and for end-users involved in peer-to-peer energy trading in local energy markets; interface the relationship between end-users and BETTA participants; connect REC members and energy utilities for the supply of renewable generation; create a virtual marketplace to enable CECs in the form of virtual energy communities; among others.

Competitiveness between TPs in the UK market is also beneficial, as it foments the continuous evolution of energy-related products and services, whilst pushing forward the makeover of legal frameworks at the same pace of technological developments. As an illustration of this scenario in the UK, Piclo (2021) created a peer-to-peer energy trading platform that allows direct trading between commercial consumers and renewable energy producers; Squeaky (2021) developed a peer-to-peer energy company that connects small businesses to generators of renewable energy via a digital platform; Upside Energy (2021) offers virtual energy storage as an example of a virtual power plant; Moixa (2021) provides a customisable cloud-based software platform that connects storage devices to the grid, to enable smart energy management; and Verv (2021) created a blockchain-based peer-to-peer renewable energy trading platform.

3 Alternative scenarios

This section will introduce three alternative scenarios for the DOMINOES vision on the local markets' role in the future. The scenarios are called isolated local markets, an extension of the existing market operator role and alternative ways to manage network access. Below is a short description of the business as usual and its possible challenges.

The share of renewable energy in the energy market will increase significantly. Electricity consumption is predicted to increase in the Nordic electricity market approximately 40 TWh by 2030 and 65 TWh by 2050. This consists of, for example, digitalization and electrification of traffic. Since electricity consumption increases and the share of renewable weather-dependent production increases can price volatility increase. For example, on a cold windless day in the Nordic countries, the price may rise high. (TEM, 2019)

The growing share of renewable production is also increasing network costs. Renewable production, such as wind and solar power, is uncertain, and the production varies according to weather. In addition, the geographical location of production may cause investment needs in the network. It is also difficult for individual customers to participate in the electricity market due to market restrictions such as size.

3.1 Isolated local markets

One possible scenario is isolated local markets. The idea is that energy can be traded between local market participants behind the connection point. Customers have then an opportunity to sell possible surplus energy to another customer who needs it. Customer who sells the energy gets a higher price than if the customer sells the energy back to the grid. At the same time, the customer who buys the energy gets the energy cheaper compared to grid price. This is possible since the distribution grid costs would be avoided or minimised. Trade can be made through bilateral agreements, for example, customer can share its solar panels with its neighbour. One option to implement this is to use a peer-to-peer trading platform.

Isolated local markets could also be implemented within retailers or energy community microgrids. Within the community can also be common production, which is distributed within the energy community. The idea is sharing the overproduction within the isolated local markets and try to optimise all production to use.

In this alternative scenario of isolated local markets, the local markets optimise their operation costs (energy costs usually) separately on their own and do not take into account overall system benefit and optimisation in their operations. When energy costs are optimised locally, in the large-scale scenario, it can increase socialised costs for those customers that are not connected to local markets and don't have the possibility to optimise distribution network costs.

In the energy markets where the price and distribution price is based on energy (kWh), the distribution costs might be unfairly distributed in the case of local markets are optimising costs for themselves (meaning lowering amount of energy distributed in distribution network but not in reality lowering the operating or investment costs from the DSO perspective) but the network operator needs to cover the costs anyway from all the customers. In that case, the local optimization can be harmful to those who do not participate in the isolated local market and it can lead to new and possibly unfair distributing of network and other costs. Partly this can be avoided by implementing new tariff structures for the distribution.

The model has vendor lock-in marketplace where it is traded. The marketplace can be changed, but then there is a new vendor lock-in marketplace. Compared to the DOMINOES project market model, the DOMINOES market model has no vendor lock-in the marketplace and thus it is easier for customers to trade in different marketplaces.

3.1.1 Driving forces

People are becoming more and more interested in producing energy which means that consumers are turning into prosumers. Thus, customers may have overproduction occasionally, and it is desired to get the biggest possible benefit of the energy produced. The isolated market is quite simple for the customer to understand, and thus this can be easy for the customer to start the electricity market's participation.

If an isolated market is implemented within retailers, the retailer could be willing to expand its own products. Retailers will be able to offer new products and thus be able to offer more services to their customers.

3.1.2 Market implications

In this scenario, resources are used only within the isolated local market since there is no coordination with other markets. This facilitates locally but does not take into account other markets and their needs. For this reason, for example, restrictions on distribution networks are not considered in the local trading and DSO doesn’t have other possibilities to handle the congested network situations than make investment as before.

When energy is traded in the isolated local market with each other, consumption curves may be more difficult to forecast. To the outside, it seems harder to predict compared with business-as-usual situation when electricity is traded behind the connection point. Consumption may behave illogically rather than expected, and therefore those in isolated markets may also find it more difficult to benefit from external markets. The external price may increase, but at the same time customer in the isolated local market will benefit more from self-sufficiency.

3.1.3 DSO perspective

The existence of isolated markets, from a DSO perspective, is on par with the existence of local energy communities that exist independently of the DSO grid. There have been tested projects whereas islanded system worked and can be connected and disconnected to the DSO grid. For example, the SENSIBLE H2020 project tested these kinds of features, using a MV storage that worked connected to the grid and islanded. The technical possibility was achieved, with all the necessary protections used to keep the frequency of both systems aligned and assured.

As we are talking about an independent microgrid system, the DSO will have to have an active role, facilitating the existence of this market and making sure the security of supply is not an issue. For that to happen, the DSO will also have to treat this new network node as a prosumer and will have to know in advance the local energy balance of this system, in order to have his own Optimal Power Flow calculated and make the necessary adjustments to the grid using flexibility from this market if needed in case of grid emergencies.

The DSO role will have three main parts:

- DSOs must act as neutral market facilitators, using their knowledge and information to help these markets. For instance, smart meter data can be shared with the local market to help the local energy balance.
- DSOs must act as a technical validator of the transactions that use the interconnection with the DSO grid, as the DSO is obliged to secure the supply and keep the quality of energy standards (EN 50160).
- DSOs will have the capability to request and buy flexibility in this type of market to solve problems detected in the forecasted algorithms, and to solve unplanned emergency constraints. For this to happen, there must be real-time communication between the local markets and the DSOs (as suggested in WP3).

The eventual proliferation of such markets, from the DSO point of view, will need to be coordinated. As an eventually isolated community that can fully work disconnected from the grid will not be a problem, the existence of several nodes with the capability of connecting and disconnecting to the DSO grid can have an impact in cases of high DER production and low DER production and the interconnections need to be activated,

For this, the DSO should also have a role and all the required information to coordinate these markets, adjusting their needs to the grid reality for instance, limiting excess production if needed.

It is also important to say that regulatory rules must be envisioned to help clear an existing gap in the islanded cases. One reason why islanding is avoided is liability in the case of islanded operation. In the case of damaged customer equipment, it is unclear which party is liable and it must be well defined.

Despite the existence of the local market, the DSO should enforce all the regulatory standards inside the microgrid and that will act as the distributor in outages problem solving and customer liability enforcement, as inside this microgrid should exist market costumers, but there can also exist regular customers.

3.2 Extension of existing market operator role

The other scenario is the extension of existing market operator role, which means that flexibility is traded at a greater extent within the current markets. In this case, the market operator would utilize smaller resources for flexibility trading, facilitating, for example, congestion management. This can lead to an increase in prize zones or nodal pricing. In the electricity market, prize zones are formed, and inside the price zone the price is the same. In situations when the transmission capacity is limited between the price zones, the price levels will differ between the price zones. If the network capacity becomes more and more limited, this might lead to new price zones.

In the extended operation, the market operator would also take care of the network restrictions and thus separate local markets are not necessarily needed. This is dependent on the level of the network, which will be considered in the markets. Perhaps not all the locational network issues in the distribution network in the low voltage level can be solved with extended market operator roles unless separate market places would be established. However, this may reduce competition of markets, since there are fewer competing marketplaces.

Market efficiency can become a challenge from a market and trading perspective as there are more small resources to consider.

A few parties have already implemented the extension of existing market operator role. For example, Epex spot has traded on flexibility platform enera (Epexspot, 2019). The idea is that epex spot acts between flexibility providers and system operators. The aim is to forecast network congestion and avoid it when possible. (Epexspot, 2019)

In addition, GOPACS operation are related to market-based mitigation of grid congestion. GOPACS facilitates solving congestions and provides a way for the parties to generate revenue with their flexibility available. Trading is implemented on the ETPA market platform (or other market platforms that hooks up to GOPACS. Three steps are calculated if congestion is possible: location data, is the congestion situation then resolved and not caused new congestion situations. (GOPACS, 2020)

With the DOMINOES model, small units could be aggregated into bigger ones and thus better utilized. When comparing the DOMINOES market model to this alternative scenario, more attention needs to be paid to aggregation. It should be thought how small resources can be aggregated and how trading with aggregated resources would be implemented.

3.2.1 Driving forces

From the market operator point of view, this alternative scenario provides good opportunities to expand their operations. In addition to electricity, market operators can also offer flexibility trading, which means that existing resources can be used more efficiently. From a customer perspective, this can also be easier since the flexibility and energy trading would be implemented with the same operator.

From the flexibility provider’s point of view, the advantage can also be that there are fewer providers. In addition, coordination between marketplaces and networks may be easier in a centralized solution.

3.2.2 Market implications

Expanding the market operator's role will take the development in the direction that the market is more centralized, and information is available in one place. In the long run trading methods might become similar and some of tradable products suitable for multiple purposes also in the flexibility perspective. Thus customers would have more products in one market interface.

Extension of existing market operator role could avoid congestion by using flexibility. On the other hand, it may not be possible to utilize all resources in the extended market operator model, since local resources could be stranded due to not fulfilling liquid participation requirements of the market operators. For example, the customer’s technical capabilities may be inadequate, or the size of flexibility could be deficient. In this perspective, local markets might be more suitable option for the smallest distributed flexibility resources. Also, fragmentation of wholesale asset pricing could lead to less liquidity and issues with price reference relevance.

3.2.3 DSO perspective

DSOs are a major driving force in developing innovative ways to allow the massive integration of distributed energy resources (DER), leading the way in the energy transition. Moreover, DER will mostly be connected to the side of the distribution grid and, as such, its massification will have a significant impact on how DSOs manage the network. A solution for these new challenges is the design and implementation of Local Markets, such as the one developed in the DOMINOES project that allows the trade of energy and flexibility more decentralized. Since DSOs are a neutral, agnostic and regulated business, they are the most prepared and placed to manage detailed data and ensure its privacy. Therefore, DSOs should become market facilitators for the energy/flexibility trading in Local Markets and have the duty of promoting and integrating them. The DSOs must follow some key principles in order to have this role, such as:

- DSOs must run their business in a way which reflects the reasonable expectations of network users and other stakeholders including new business models;
- DSOs must act as neutral market facilitators in undertaking their core functions;
- DSOs act in the public interest taking account of costs and benefits.

The improvement of consumer awareness to network-related issues has been directly linked to smart metering systems' penetration, where real-time analysis and communication between consumer and DSOs is becoming a reality. Once such communications are possible with the customers, the level of awareness of consumers and its impact on the grid support can shape and have a real impact on the network flows by exchanging some benefits in the tariff and establishing dynamic processes of alternative pricing.

There are several technical possibilities for energy trading in a local market environment, from the DSO perspective. In practice, when a consumer/prosumer is consuming below its contracted power, there is no restriction for the energy trade, but for this to happen it needs to have a smart meter that communicates with the DSO for technical validation purposes. In theory, there are other possibilities such as a consumer who can sometimes consume above its contracted power and pay up the exceeding cost per day for utilizing a higher contracted power. Another theoretical possibility is the implementation of virtual energy communities policies by the DOs, allowing a consumer to have ownership of the installed capacity from a PV system installed in a neighbour's roof..

An implementation of a Local Market can be very much beneficial for DSO activities in several ways:

- Assist the DSO in the system coordination and management;
- Help with congestion management problems;
- Deal with a mismatch between production and consumption;
- Allow for indirect observability and improve the “intelligence" of the network;
- Supply system services

On the other hand, Local Markets will bring new challenges regarding the installed capacity and integration capacity of DER. The DSOs should secure the supply, control the voltage, manage the grid and comply with resilience and quality of service standards in EN 50160. Any energy/flexibility trade using the distribution network from any asset in a Local Market needs at least to be communicated and pre-validated by the DSO according to the technical restriction and an access fee (subject to future regulation review) of the grid may be charged. In addition, in any extreme event, the BAU (business as usual) mode needs to be implemented. The assets connected to the distribution grid will be managed outside of the market by the DSO.

3.3 Alternative ways of managing network access

There are other ways to handle network access in congested network situations, and these possibilities will be discussed briefly in this section. The challenge in these solutions is that the flexibility value of the resources is not valued at all or valued only for the one system operator purposes. These approaches consider the electricity network as a copper plate and provide explicit implementation possibilities for the individual network limitations.

These approaches are already in use and partly business as usual and working well. It should be noted that in the future, the growing share of intermittent renewable generation, like solar and wind, will change the network operation and the predictability of the network situations will become increasingly difficult. Thus, new approaches might be needed as well.

Traffic light concept (CEDEC et al, 2019) can be used for signalling the grid congestion situation for the flexibility service providers and distribute the information about the congestion status of the network. If the traffic light is green, there is no congestion expected in the network and all markets operate as normal without system operators actively participating in the market. If the traffic light is orange, congested situations are expected, and system operators procure flexibility to move back to the green state. If this is not successful, the system will move into red traffic light which means an emergency state.

Network operator could bilaterally agree on the network access or the flexibility service provider's procurement in the congested network situations. One form of these bilateral agreeements are flexible network connections. The flexible network connection could mean e.g., that in return of cheaper network connection costs, the system operator is entitled to curtail the generation or consumption based on pre-defined rules and conditions or direct bi-later agreements about the purchase of flexibility between the system operator and flexibility service providers to reserve the flexibility for network use. Without this flexible connection agreement system operator would forbid the network access because of the congested network.

A more market-oriented approach to organising the agreements and increasing transparency are flexibility auctions, where flexibility service providers can provide bids on the flexible platform for the system operators' purposes and make flexibility contract based on these auctions. An example of such platform is Piclo Flex (Piclo, 2021) operating at the moment in the UK. With this approach, the flexibility resources are bound to the agreement and will be used only for that flexibility purpose. The agreement durations could range from weeks/months to multiple years.

Bilateral agreements lock the flexibility to one specific purpose, and a part of the flexibility value for the flexibility service provider and also for the whole energy system is lost. This lowers the possible revenues streams for the flexibility service provider. The bilateral reserve agreements might be promising from the system operator, and FSP individual perspective and they are improving the flexibility access to markets in the short term. In the big picture, they are helping only a part of the energy market. Thus, the system does not work most efficiently, and all flexibility investments are not in efficient use.

3.3.1 Driving forces

The distribution system operator defines network access at the local level. How the distribution system operates the network is regulated, and thus the regulation has a significant impact on the direction of the DSO role and how the congestions are solved.

Some of the issues related to network access in stranded situations might be handled by the ways mentioned above and traditional network investments. Still, while the share of the renewables will increase, and the network investment possibilities decrease, also market-based solutions are needed for network management.

3.3.2 DSO perspective

As described in previous sections and subsections DSO's play a major role as a neutral market enabler and facilitator by developing innovative ways to allow the massive integration of distributed energy resources (DER), leading the way in the energy transition.

As most of DER will be connected to the distribution grid it is essential that DSOs have a complete observability of all transactions that takes place at a local level and that validate the possibility of energy transactions to occur according to technical restrictions in order to maintain stability of the grid as a whole serving all stakeholders in a more cost-efficient way, despite of an access fee (subject to future regulation review) of the grid that may be charged. The DSO network will always have to ensure the quality of it's service, as well the security of supply in case there are problems with isolated nodes, which also reinforces the need of this complete observability.

4 Conclusions

Because of the growing amount of distributed energy resources and active energy customers, local markets are appearing all over Europe. They can operate in an isolated manner and optimize their own operations but also be an important asset to provide flexibility for the local and whole energy system benefit.

Regulation of the energy communities could advance the legal framework for establishing local markets. This is only the first step. Local market participants can benefit from connecting to the open markets and vice versa. While this is not regulated yet, it should be taken into account for an efficient implementation of LEM.

The system benefit comes from the possibilities of local markets to trade in multiple levels in the system. This requires price transparency so that the value possibilities can be identified and valued by all the market participants, including end-customers. Trading mechanisms should consider the possibility to trade in multiple market levels and remove possible barriers for that. At the local market level, the trading platform should consider possibilities for trading in other, cascading markets and open markets consider the aggregation possibilities from the local markets. Supporting structures, like flexibility register for information sharing, should be developed.

In order to enable the participation of smaller, distributed resources to be economically viable, more automation is needed. Even though the flexibility's value will probably increase in the future, the profit for the individual end-customer is rather small. Thus, scalable and highly automatized systems are needed to have the technical capabilities to trade flexibility as a distributed energy resource. Also, energy trading is transferring into more granular time units, and the real-time requirements become more important in all levels of the system.

DSO regulation plays a vital role for flexibility resources. Because the network management is based on the copper plate assumption and problems are usually handled via network investments, new ways of valuating flexibility are needed to support the utilization of distributed energy resources and local markets. Suppose the use of flexibility in network management is required and rewarded in the regulation model. In that case, it will increase the flexibility resources' system efficiency and increase possibilities for the DSO for network management. In order to promote the use of distributed energy and flexibility resources in overall system operation, the market rules should be written so that DSO has a possibility to purchase flexibility in the market environment.

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D2.1 Enabling technology for transparent local p2p energy markets

D2.3 Scalable local energy market architecture (second release)

D2.4 Information exchange processes and solutions to integrate local and centralized energy markets.

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