DOMINOES – DELIVERABLE

D4.5 Synthesis of the local market concept

This project has received funding from the European Union's Horizon 2020 research and innovation programme under **Grant Agreement No. 771066.**

Deliverable number:	D4.5
Due date:	30.6.2021
Nature[1]:	R
Dissemination Level1:	PU
Work Package:	4
Lead Beneficiary:	LUT
Contributing Beneficiaries:	Enerim, CNET, E-REDES, VPS, ISEP, UoL, USE
Reviewer(s):	ISEP

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1 **Nature:** R = Report, P = Prototype, D = Demonstrator, O = Other
Dissemination level PU = Public
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Secret UE = Classified with the mention of the classification level "Secret UE" according to Commission Decision 2001/844 and amendments

Version	Date	Description
v0.1	17.3.2020	First draft
v0.2	28.5.2021	Updated structure
v0.3	29.6.2021	Reviewed version
v1.0	30.6.2021	Submitted deliverable

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Executive Summary

DOMINOES project (2017–2021) aimed to enable the development of new demand response, aggregation, grid management and peer-to-peer trading services by designing, developing and validating a transparent and scalable local energy market solution. This deliverable summarizes the key aspects of the local market concept and necessary services to enable trading with distributed energy and flexibility resources. Details of the considered market architecture and developed solutions can be found in the previous deliverables.

DOMINOES project defined five use cases to refine the scope of the project and to identify implementation of the project results. Six business models related to the use cases were also developed. The use cases and business models consider the needs of various stakeholders (end-users, prosumers, communities, DSOs, TSOs, retailers, balance responsible parties).

The project has developed several services supporting the use of local energy and flexibility resources. These include, for example, load forecasting and customer segmentation tools, and an energy harvester enabling utilisation of local resources for multiple purposes. Furthermore, an ICT platform to enable local markets and trading with the distributed resources such as demand response has been designed and tested.

This deliverable also analyses the implementability, scalability, and replicability of the developed local market architecture. Furthermore, key performance indicators (KPIs) set for the project high-level objectives (progress related KPIs), the developed ICT platform, and key aspects (use cases, cyber security, energy harvester) considered in the project (operational and business related KPIs) have been analysed.

List of Acronyms

AF	Activated flexibility
AFM	Analysis and forecast module
aFRR	Automatic frequency restoration reserve
ARM	Alerts and reports module
BaU	Business as usual
BESS	Battery energy storage system
BM	Business model
BRP	Balance responsible party
C	Consumption
CBA	Cost benefit analysis
CV	Critical vulnerability
DA	Day ahead
DER	Distributed energy resources
DR	Demand response
DSO	Distribution system operator
DSOF	Requested flexibility validated by DSO
DSOFA	Accepted / allocated / activated flexibility
EA	Energy availability
EP	Price of transacted energy
FBFK	Flexibility benefit (€) with centralized optimization & full knowledge
FBMA	Flexibility benefit FBMA (€) using market with imperfect information
FCD	Forecasted curtailed DER
FCFK	Allocated flexibility cost with centralized optimization & full knowledge
FCM	Fuzzy clustering method
FCMA	Allocated flexibility cost (€) using market with imperfect information
FCR	Frequency containment reserve
FER	Restoration of flexible energy
FRBS	Fuzzy rule based systems
ID	Intraday
KPI	Key performance indicator
LEFM	Local energy and flexibility market
LEM	Local energy market
LEMH	Local energy market hub
LMM	Local market module

LV	Low voltage
mFRR	Manual frequency restoration reserves
MV	Medium voltage
NRA	National regulatory authority
P2P	Peer-to-peer
PV	Photovoltaic
R	Retailer price
RA	Reference architecture
RER	Local renewable energy
RES	Renewable energy source
RF	Requested flexibility
SO	System operator
SOM	Simulation and optimization module
SVM	Support vector machines
SWOT	Strengths, weaknesses, opportunities, threats
TCD	Total curtailed DER
TR	Transactions
TRA	Accepted transactions
TSO	Transmission system operator
UC	Use case
V	Vulnerability
VR	Validation request
VRA	Accepted validation requests
VTR	Voltage ride through
WMM	Wholesale market module
WSM	Wholesale market

1 Introduction

DOMINOES project (2017–2021) aimed to enable the development of new demand response, aggregation, grid management and peer-to-peer trading services by designing, developing, and validating a transparent and scalable local energy market solution. Local market architecture and several services facilitating the use of local resources have been defined in DOMINOES project deliverables. This deliverable summarizes the key features of the DOMINOES local market concept.

First, we briefly present the DOMINOES local market vision and how it is put into practice. Then, the use cases and business models considered in the DOMINOES project are summarized and the strengths, weaknesses, opportunities, and threats (SWOT) of the business models are analysed. Necessary services to enable use of distributed resources are summarized. Additional requirements caused by the local trading for the information exchange processes and regulatory framework are briefly discussed. Furthermore, techno-economic performance and scalability of the local market concept are assessed.

Finally, the different services developed in DOMINOES project and the local market concept itself were validated in pilot environments in Portugal and Finland. Key findings from the validation activities and key performance indicators (KPIs) are summarized.

2 Local market structure and processes

The goals of the DOMINOES local market concept are to

- enable local sharing
- create liquid flexibility for distribution grid management, enabling increased up-take of renewable power generation
- provide products which are compatible with wholesale and system services and settlement.

This section summarizes the key design features of the DOMINOES local market concept and discusses the regulatory framework related to local markets. First, section 2.1 addresses the DOMINOES market vision and how it is put into practice. Section 2.2 summarizes the use cases considered in the DOMINOES project. Section 2.3 reviews business models developed in the project and analyses their strengths, weaknesses opportunities and threats. Section 2.4 briefly discusses services needed to enable demand response (DR) use. Section 2.5 summarizes the key features of the DOMINOES local market platform developed in the project. Sections 2.6 and 2.7 (respectively) address the information exchange requirements and regulatory framework related to local markets.

2.1 DOMINOES local market vision

DOMINOES project has strived to design 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 (D5.4). To achieve this vision, goals related to compatibility, distribution grid management, accountability for flexibility, bottom-up flexibility, incentivization for customer engagement, active prosumer role, and changing market participant roles were set. Table 2.1 summarizes the specific goals and how they are addressed in the DOMINOES local market concept (mainly based on D2.3 and D5.4).

Table 2.1 DOMINOES market model vision and solutions enabling them

GOAL	DOMINOES SOLUTION
Compatibility	
For scalability	• Energy (and flexibility) is traded first within the local market and if not used can then be traded on existing open energy markets (local market is cleared before the gate closure in the open market) • Energy balances are allocated on the level of the end consumers and sold in a compatible process with existing wholesale markets
Market model compatibility	
Technological compatibility to meet market technical requirements or standards (i.e., information content)	

<table>
<tr><td></td><td>Local market products are compatible with the existing markets and include enough information so they can be transformed into compatible bids for higher level markets</td></tr>
<tr><th>Distribution grid management</th><th></th></tr>
<tr><td>DSO access to flexibility</td><td rowspan="4">DSO and other interested stakeholders (e.g., retailers, aggregators) are able to purchase (aggregated) flexibility from the local market
DSO validates the local market transactions and – in extraordinary emergency situations – invalidates the transactions and directly issues commands or constrains the network access of resources within the affected area
Bids include sufficient locational information for the DSO to manage the congestions</td></tr>
<tr><td>Availability of flexibility for its best use in case of no congestions</td></tr>
<tr><td>Role of DSO on transaction validation</td></tr>
<tr><td>Sharing of locational information of the resource</td></tr>
<tr><th>Accountability for flexibility</th><th></th></tr>
<tr><td>Settlement per metering point</td><td rowspan="4">Local balance responsibility is introduced as an extension of system level balances
Local balances support validation of flexibility activations, enable intracommunity trading and transparency of costs
Energy and flexibility are treated as separate products in order to provide the possibility to separately validate and take account of explicitly activated flexibility in an open market setting
Locational information enables valuation of flexibility for network related issues</td></tr>
<tr><td>Validation of flexibility</td></tr>
<tr><td>Local trading with locational information</td></tr>
<tr><td>Transparency of costs</td></tr>
<tr><th>Bottom-up flexibility</th><th></th></tr>
<tr><td>Local sharing of resources for communities and increased use of renewables</td><td rowspan="2">Opportunity to trade/share excess generation encourages larger generation investments
End-users/prosumers can offer their flexibility which can be aggregated and offered to system balancing purposes (e.g. TSO ancillary service markets). End-users/prosumers are remunerated for the flexibility they provide.</td></tr>
<tr><td>Incentives for use of flexibility for system benefit</td></tr>
<tr><th>Incentivization for customer engagement</th><th></th></tr>
<tr><td>The new role of end-customer in local markets</td><td rowspan="2">End-users transform from mere consumers to active service providers (energy and flexibility)</td></tr>
<tr><td>Energy community role promoted</td></tr>
</table>

Incentives for demand response Customer benefit and value for all stakeholders	• Business model and services to facilitate energy sharing proposed • Prosumers and end-users receive remuneration for the energy and flexibility they provide to others • Customers are able to set also other preferences than price (e.g. local or green energy)
Active prosumer role of the customer	
Easy access and participation, simple tools Transparent information on the prices at all levels available for the prosumer. Customers can make their own decisions	• Trading takes place in a platform where end-users and prosumers can save their preferences, thus increasing freedom of choice but reducing need for constant decision making • Customer has access to 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
Changing market participant roles	
Old participants providing new services New participants providing new services Interaction with the market and each other	• Energy community service provider (ECSP) role may be adopted by a retailer, and if regulatory framework enables, by a DSO • ECSP role may be adopted by new stakeholders • P2P trading enabled in parallel with traditional markets

2.2 DOMINOES use cases

Development of use cases (D1.3) enabled refinement of the scope of DOMINOES project and identification of implementation of the project results. D1.3 developed five use cases to be tested in validation sites in Portugal and Finland. Summary of the use cases (UCs) is presented in Table 2.2.

Table 2.2 Summary of DOMINOES use cases

UC ID	UC name	Scope
1	Local market flexibility and energy distributed resources for optimal grid management	This UC aims to clarify the definition and implementation of technical grid support services, in different timeframes, regarding voltage control and congestion management within the local Low Voltage (LV) grid, also taking into account that some of the constraints can have an origin in the Medium Voltage (MV) grid (MV constraints due to abnormal LV loads). The scope is concerned with the interaction between DSO, as flexibility procurer, and local users/resources that may provide the required flexibility. These interactions run through a Local Market-Hub, designed to provide adequate signals and market processes to regulate the use of flexibility for both grid and commercial applications.
2	Local Energy Market Data Hub Manager and Technical Validator of market transactions.	This UC focuses on the behaviour of the Data Manager (DM) role that will provide information to local trading market platform – "Local Energy Market Hub" (LEMH) as well as the role of Technical Validator (TV) that should assess technically all transactions intentions provided to the LEMH in a defined timeframe. DM is responsible for managing and metering and technical data collected from the smart metering infrastructure as well as other data from market participants (permissions, service subscription, …). DM should be also able to receive the requests for verified data from the LEMH. TV should technically assess all transactions intentions (market transaction program) provided by the LEMH in a defined timeframe. The TV runs a power flow tool with the given market transaction plan and validates / rejects the proposed plan if it respects / violates grid technical constraints.
3	Local community market with flexibility and energy asset management for energy community value	DOMINOES proposes a local market environment where prosumers and consumers are empowered, allowing their involvement in decision making and making it easier to get information in the current status of the electric system. The local market process inside a community is managed by a ECSP (Energy Community Service Provider). This use case is aimed at validating the activities of the retailer as an ECSP, whose goal is to manage the local market creating value for the all the relevant actors, especially for the community. The retailer runs forecast tools to get load diagrams and generation profiles for the day ahead. Based on the aggregated amount of flexibility, the retailer computes the value of the flexibility and sends the DR

		set points. Customers decide whether these orders are accepted or not and inform the retailer. Then, the retailer buys the electricity accordingly to maintain the local market running without constraints. In the intraday scenario, the retailer runs a tool continuously to verify the existence of deviations from the plan designed the day before and then initiates the process of collection of the available flexibility. Apart from participating in the DR schemes managed by the retailers, energy clients and prosumers could also establish P2P transactions with the actors inside the local market.
4	Local community flexibility and energy asset management for retailer value	This use case is aimed at validating the use of the local market flexibility by retailer as a service, whose goal is to optimise retailer's participation in the wholesale market and minimise the retailer deviations. In this use case, the retailer will not establish a contractual relation with the active participants of the local market, i.e., participant who can either provide flexibility or are electricity producers. Instead, retailer contacts the ECSP directly, who is managing the local market In the day ahead scenario, the retailer purchases local flexibility to" shift consumption from peak to off-peak times and to shift peak hour consumption to the following hour. In the intraday scenario, the retailer uses local flexibility to minimize deviations.
5	Local community flexibility and energy asset management for wholesale and energy system market value	The scope of the use case considers the allocation of the flexibility of the resources of the community for suitable timescales, to be used for wholesale and the overall energy system value. The flexibility is to be used to balancing services required for the balance of the whole system. The ECSP manages the services for the local community and offers the local market for utilization of the flexibility for wholesale and energy system market value. The flexibility offered by end-consumers and aggregators (e.g., as VPPs) can be used for balancing services from the local market. The balancing services can be acquired by the DSO, the TSO or alternatively an aggregator for sale to the TSO. In addition, retailers could use the available flexibility within the local market scope for managing their market positions.

A more detailed description of the use cases can be found in D1.3. Results of the validation activities in real life environments are discussed in D4.4 and in section 4 of this deliverable.

2.3 DOMINOES business models

2.3.1 Summary of business models

In parallel with the use cases, DOMINOES project developed six potential business models promoting utilization of local resources. Summary of the business models is presented in Table 2.3.

Table 2.3 Summary of DOMINOES BMs developed in D5.1

BM ID	Provider	Service	Client
1	Flexibility service provider (aggregator/ community manager)	Aggregated flexibility as a service. The flexibility service provider will provide the aggregated flexibility as a solution to grid operators and balance responsible parties.	DSO/ BRP/ TSO
2	Aggregator	Aggregators offer a new flexibility service to help the DSO solving congestion problems.	DSO
3	DSO	A transactive platform where end-users can make local energy transactions. End-customers receive signals from the DSO to promote local energy transactions. DSO provides incentives to end-users when local transactions contribute to the reduction of penalties caused by congestion situations.	Energy end-users
4	Community Manager	The Community Manager (CM) acts as an aggregator. Optimal scheduling and sharing of PV generation among the community are provided aiming at the reduction of bills and green self-consumption.	Energy end-users (i.e., public buildings equipped with PV generation and community members)
5	Local market operator (Flexibility comes from actors in the local market).	Use of the local market flexibility to be valued in the wholesale market or to optimise the retailers' portfolio	Retailer
6	Energy service provider (role can	ICT infrastructure to manage local market that can be used:	Energy communities

	be taken by multiple parties)	a. For energy community benefits in and energy community service provider (ECSP) role b. As an ICT tool by other stakeholders for multiple purposes In addition, the service provider may provide communities with assistance in choosing/sizing generation/storage/control systems in cooperation with technology providers.	

2.3.2 SWOT analysis of business models

The feasibility of the DOMINOES business models has been estimated in detail in cost benefit analysis (CBA) conducted in D5.3. Following Tables 2.4–2.9 present a summary of the strengths, weaknesses, opportunities, and threats of the business models.

Table 2.4 SWOT of BM1 (Aggregation of small-scale flexible loads as a universal virtual power plant)

Strengths	Weaknesses
• Virtual power plant could offer flexibility for various stakeholders (TSO, DSO, wholesale market, retailer...) • Enables small customers to participate in the market	• Lack of customer awareness of their potential and possibilities for revenues in providing flexibility • The technological solution must be scalable so that minimal customization is needed and the investment costs in the end-customer side remain at relatively low level • It is dependent on end-user' small-scale flexible loads or other resources (generation, storage) • Technologic readiness level of services • Level of market prices varies (significant impact on revenues)
Opportunities	**Threats**
• Future demand for flexibility services, especially for local flexibility services, is increasing • Small-scale flexibility resources are a big unused potential • Aggregation can be performed by the flexibility service provider (e.g., aggregator) or by the retailer or the community manager	• Competition with other flexibility service providers, private customers might change service provider quickly • If there is no purchaser for the flexibility service (for example, if DSO does a network investment) • Forecasting of the customer behavior and how to consider customer requirements for comfort and quality • Multiple technology integration requirements when considering many end-customer devices

Table 2.5 SWOT of BM2 (Aggregator flexibility provision to DSO for network management)

Strengths	Weaknesses
• Capacity to generate decentralised value for consumers/prosumers and communities with DER/RES. • Respond to systems operators and/or specific grid needs by using or leveraging decentralised resources that might be not used at full potential, e.g., not remunerated surplus of production of self-consumption facilities. • Use of new or existent flexibility services to tackle system needs especially in rural or less dense areas that can hardly sustain valuable CBAs for asset investment or grid reinforcement. • To develop complementary business models for DSO and TSO, and enhance the decentralisation of the flexibility market that can empower the creation of new energy and non-energy services for consumers or system operators	• Technologic readiness level of services, markets, and platforms to provide flexibility for DSO needs. • Lack of a clear economic regulation for DSOs to avoid asset-based investments and enable LEMs (Local Energy Market). • Lack of incentives for consumers to participate in a more complex system that is not addressing comfort and convenience in a purpose manner. • Business model defined over a need and DSO dependant.
Opportunities	**Threats**
• Addressing local level requirements of congested grids that directly or indirectly induce consumer participation and enable system value creation. • Capitalize new revenue sources for the investment of individual or collective consumers with the shared system benefits of deferring investment, e.g., investment deferral approved by NRA (National Regulatory Authorities) with the commitment of a given LEM to ensure DR mechanisms when needed. • To develop new energy services for systems and individual benefits, with the possibility to create new roles, functions, and business models	• Absence of a clear and standard, scalable and reference regulation for local markets and DSO flexibility provision. • Difficulty to assess the value, the needs, and the liquidity of a market tendentially dominated by incumbents such as retailers and SOs • To overcome asset-based regulated incentives for SOs to solve constrains and congestions.

Table 2.6 SWOT of BM3 (Using transactive energy for network congestion management)

Strengths	Weaknesses
• Respond to systems operators and/or specific grid needs by using or leveraging decentralised resources that might be not used at full potential, e.g., not remunerated surplus of production of self-consumption facilities. • To develop complementary business models for DSO and TSO, and enhance the decentralisation of the flexibility market that can empower the creation of new energy and non-energy services for consumers or system operators	• Technologic readiness level of P2P marketplace. • Lack of a clear technical and economic regulation for P2P and LEMs. • Lack of incentives for consumers to participate in a more complex system that is not addressing comfort and convenience in a purpose manner. • Need for a complex supervision of the DSO for any market transaction involving grid access.
Opportunities	**Threats**
• Addressing local level requirements of congestioned grids that directly or indirectly induce consumer participation and enable system value creation. • Capitalize new revenue sources for investment of individual or collective consumers with the shared system benefits of deferring investment, e.g., investment deferral approved by NRA with the commitment of a given LEM to ensure DR mechanisms when needed.	• Absence of a clear and standard, scalable and reference regulation for local markets and DSO flexibility provision. • Difficulty to assess the value, the needs and the liquidity of a market tendentially dominated by incumbents such as retailers and SOs • Complexity level of P2P when compares to BaU market and asset-based investment. • Quantification of systems gains associated to an extremely complex P2P environment.

Table 2.7 SWOT of BM4 (Sharing the exceeding PV generation in the scope of energy communities)

Strengths	Weaknesses
• Service is compatible with new European legislation concerning communities • Community manager can facilitate PV investments offering both technical installation and assistance in investment • Enabling use of local resources for consumers typically not active in energy investments (e.g., residents of apartment houses)	• Regulation related to energy communities pending in many countries • Can use of local resources be acknowledged in grid fees? (Depends on DSOs' willingness and/or regulatory framework) • Although European legislation acknowledges communities and their rights, some differences may prevail in national frameworks making scaling up of services difficult
Opportunities	**Threats**
• Distributed generation has grown significantly even without community services, the existing assets provide a good starting point • Assistance in generation investments/installations may make RES acquisition easier and increase the amount RES • Local ownership may promote the acceptance of new generation	• Regulated compensation /feed in tariffs for excess generation may reduce attractiveness of community solutions • Such services are not common now but after clarification of regulatory framework, competition is likely to arise and traditional energy market stakeholders, such as retailers, may benefit from established relationship with the customers and ability to offer wide service packages • Development of storage solutions and decrease in their prices may decrease the amount of generation that is available for sharing

Table 2.8 SWOT of BM5 (Retailer as user of the local market)

Strengths	Weaknesses
• Positive impacts on retailer's day-ahead and intraday portfolio management, either from optimising the participation in the wholesale market or from reducing the costs with imbalances settlement.	• Depending on the local markets scale and reach, engaging in several markets might be required. Moreover, if the entering barriers per marketplace are significant, when opposed to the tangible benefits achievable, this may hinder the retailers' engagement willingness. • Prices available at the local markets might present a more volatile nature, increasing uncertainty and the risk factor. • The competitiveness within the local marketplaces can also impact the retailer's activity, since energy providers are not the only stakeholders involved, and with different market players highly interested in accessing and activating local energy and flexibility the retailer may face some disadvantage, since all stakeholders are competing for the same resources but not necessarily with the same conditions, due to the different nature of their operational activity. Compared with the wholesale and retail market activity, in local markets retailers may face direct competition from system operators, energy communities and consumers, apart from other energy providers.
Opportunities	**Threats**
• Incoming and available smart grid solutions, based on ICTs, supporting demand response, DER integration, including self-consumption, home energy and flexibility management, and the privileged relationship between energy providers and end-users, consumers and prosumers, may open alternative business opportunities for retailers. Local markets managed by retailers and clustering their customers can be an alternative approach.	• The legislation and the regulatory framework surrounding the implementation of local markets are still under development in most countries, decreasing the short-term impact of the BM.

Table 2.9 SWOT of BM6 (Energy service provider in enabling / assistive role for local markets and providing ECSP capability for retailers, communities or other service providers)

Strengths	Weaknesses
• Services for multiple stakeholders (energy communities, end-users, prosumers, BRPs, DSOs and TSOs) • Regulation about energy communities is coming in Europe / already implemented in some countries	• Engagement of the customers is required, since consumers and prosumers are providers of flexibility/energy. Engagement should be as easy as possible • Information exchange requirements are different in different countries (scalability challenges) • Level of market prices vary • Many stakeholders and interfaces where to connect • Regulative environment to support local market is not fully in place
Opportunities	**Threats**
• Intermittent renewable generation will increase so there is need for flexibility management services • Many end-users are turning into prosumers and in end-customer customer market there is room for competition • Active end-customers/prosumers/energy communities are not energy-professional and do not have required skills and knowledge. Thus, they require services to enable market participation. Also, other companies (e.g., retailers, DSOs) may want to buy necessary platforms from service providers	• Competition from other service providers • Large retailers/DSOs may prefer to develop local market platforms in house • Profit sharing mechanisms might lead varying profits. Fixed prices might not be attractive from customer point-of-view • High investment costs and low operational costs -> risk for the investment

2.4 Services to support DR

Implementation of the use cases and business models may be facilitated via several new services and tools. Firstly, management of energy consumption requires information about the loads during upcoming time periods. Several different forecasting techniques may be applied and D3.1 presented load forecast models based on support vector machines (SVM) and fuzzy rule-based systems (FRBS) to predict the load consumption of a building. The ability of the forecasting methods to predict the peak hours of consumption and create a reliable load profile was demonstrated. To forecast the DR potential, SVM forecasting model was applied to predict the load of individual appliances (refrigerator, water heater, air conditioner). Furthermore, energy community managers and aggregators may utilise load profiling tools to better understand their customers' behaviour. For this purpose, use of fuzzy clustering method (FCM) may be utilised. Aggregators may also utilise consumer segmentation based on, for example, decision trees to classify new community members. More information about these methods and algorithms can be found in D3.1.

An energy harvester has also been designed as a validation tool for the local market. The harvester is a set of devices, mostly power converters, which work together to gather energy and store it in a collaborative way. The devices are connected to a common node in the electric system, and there are communication channels between the components through a central management system (D1.4). The harvester is controlled by E-Broker algorithm which may operate based on various goals, including optimization of the use of renewable power, minimization of prosumer costs, or offering flexibility to local stakeholders or ancillary service market. For more information, see D3.1 and D3.2.

2.5 DOMINOES ICT platform modules and services

Local market may be facilitated via a dedicated ICT platform. The reference architecture of DOMINOES local market platform was designed in D1.2 which grouped specific functionalities required in the DOMINOES use cases into five modules: Wholesale Market Module (WMM), Local Market Module (LMM), Simulation and Optimization Module (SOM), Analysis and Forecast Module (AFM), and Alerts and Reports Module (ARM).

WMM enables the connection of the local market to the wholesale market:

- Trading service provides functionalities for an aggregator or retailer in utilizing the local market for provision of services to e.g., the TSO or energy balancing of their own portfolios.
- Control service enables control of traded energy balancing and reserve activations during the operating day.
- Settlement & invoicing service provides functionalities for billing the customers based on the energy, grid access, and provided balancing costs and revenues, as well as local transactions.

LMM enables acquisition of local flexibility and energy trading within the local community:

- Energy and flexibility trading services enable the local trading and optimization of energy and flexibility of MV and LV resources within the scope of the local market.
- Validation service performs the necessary technical validation of market transactions or programs.
- Control service defines the services for the control of the end-user resources either directly or through a device operator or an aggregator.
- Clearance service implements services which clear the local market while considering the purchasing and selling bids as well as the constraints of the network.
- Settlement and invoicing service provides functionalities for billing the customers based on the market transactions taking in account the contract details

SOM encapsulates simulation and optimization techniques that can be used to decide and recommend alternative planning and energy management strategies to the stakeholders:

- RES service provides estimation of production profiles for a particular location and other indicators like self-consumption based on a consumption profile and ROI period if installation costs are available.
- Storage service provides estimation for storage capacity needed and usage based on particular generation/consumption profiles.
- Tariff service includes market tariff simulations based on generic or particular energy consumption profiles, including dynamic tariffs.

AFM is responsible for the implementation of various advanced analytics and forecast algorithms:

- Profiling service performs data aggregation, estimation, and clustering based on traditional and hybrid methodologies to generate data profiles based on different criteria for varied time intervals.
- Forecast service supplies generation and consumption (load) forecasts using appropriate algorithms and external data sources if necessary.

ARM provides services that support the other modules in managing alerts and creating reports:

- Alerts service is a generic alert management service with flexible condition definition, criticality based behaviour, and email notification

Reports service creates reports (documents and spreadsheets) based on predefined templates and stored data, on demand or on a set schedule.

2.6 Information exchange

Local markets create new needs for information exchange (more detailed information and information exchange with new stakeholders). The necessary information flows related to the DOMINOES use cases have been identified in D1.3 and D2.4.

Utilization of local energy and flexibility resources requires more detailed forecasts at the prosumer/end-user level, including consumption, generation and flexibility (flexible loads or other flexible resources such as storages) forecasts. Prosumers or aggregators bidding on their behalf, or retailers utilizing their customers' flexibility to optimize their participation in the wholesale may also need different types of market forecasts (e.g., wholesale market or ancillary service market prices). Forecasts may be provided, for example, by prosumers' home energy management system or external service providers.

If local resources are used, for example, in retailer portfolio optimization or offered to TSOs, the schedules and information needs in the existing higher-level markets need to be considered. Figures 2.1-2.2 demonstrate how the wholesale market (Nord Pool/OMIE) and ancillary service market (Fingrid/REN) impact the local resources and their information needs.

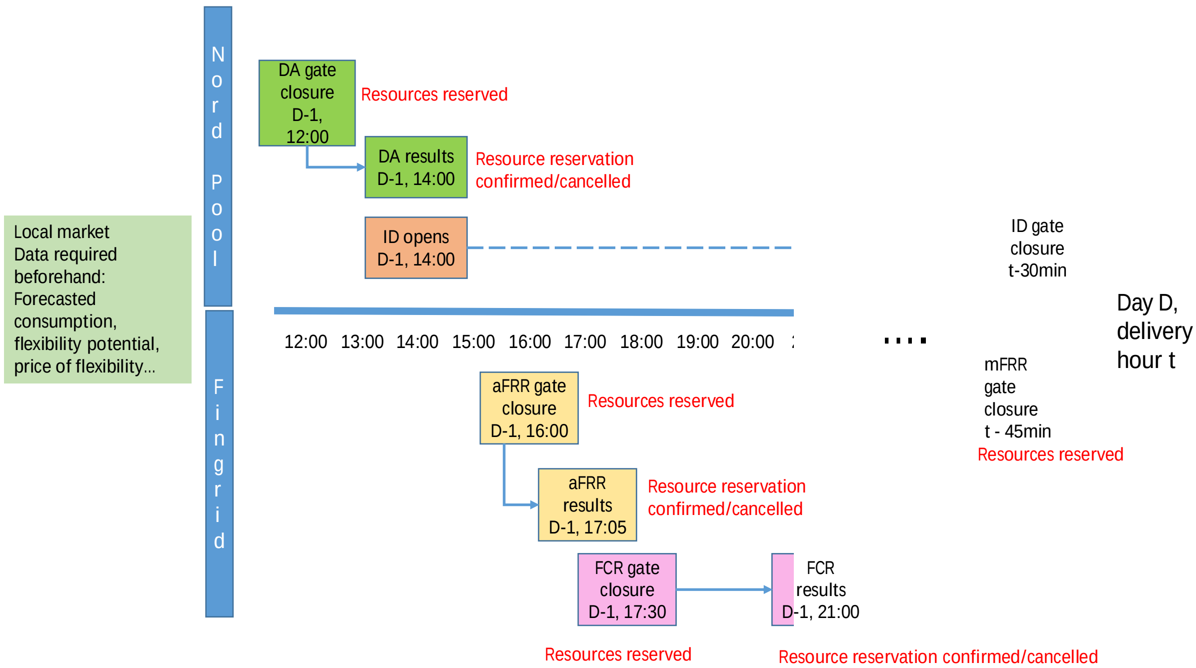

Figure 2.1 Market sequence in Finland and impact on local resources (D2.4)

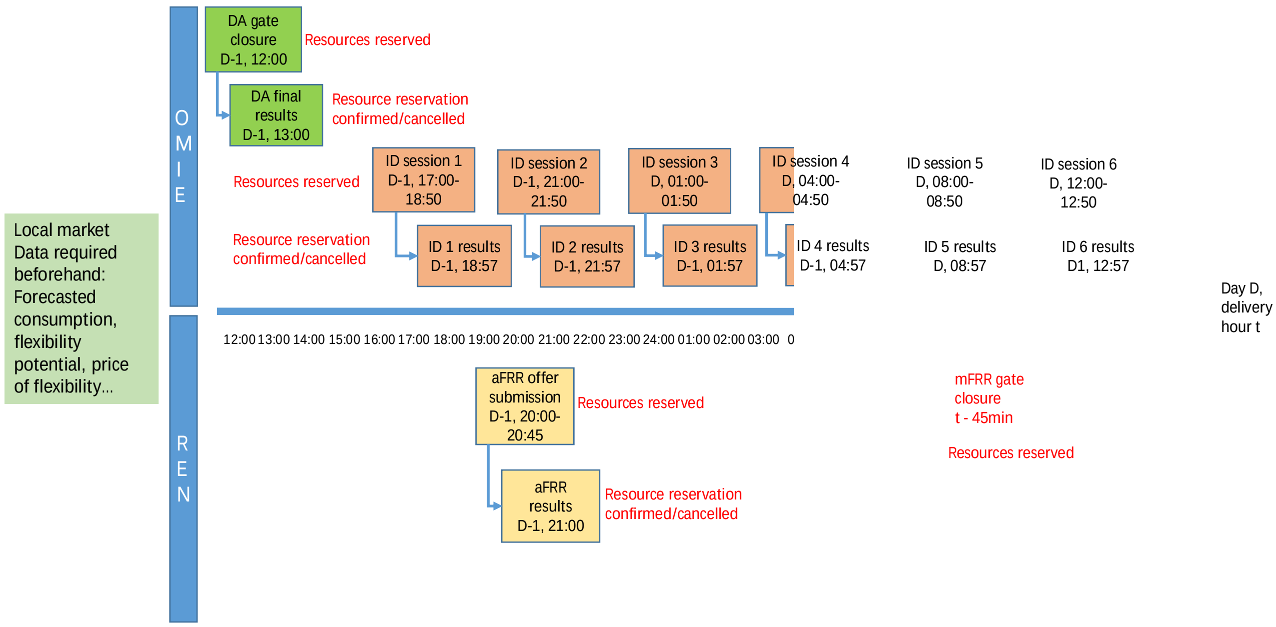

Figure 2.2 Market sequence in Portugal and impact on local resources (D2.4)

Figures 2.1 and 2.2 focused on utilisation of local resources in existing higher level markets. Local resources may also be utilised locally, for example by the DSO. DSO may also be impacted by local trading even if it would not actively take part in the local market. Thus, Figure 2.3 summarizes DSO's information exchange related to local trading.

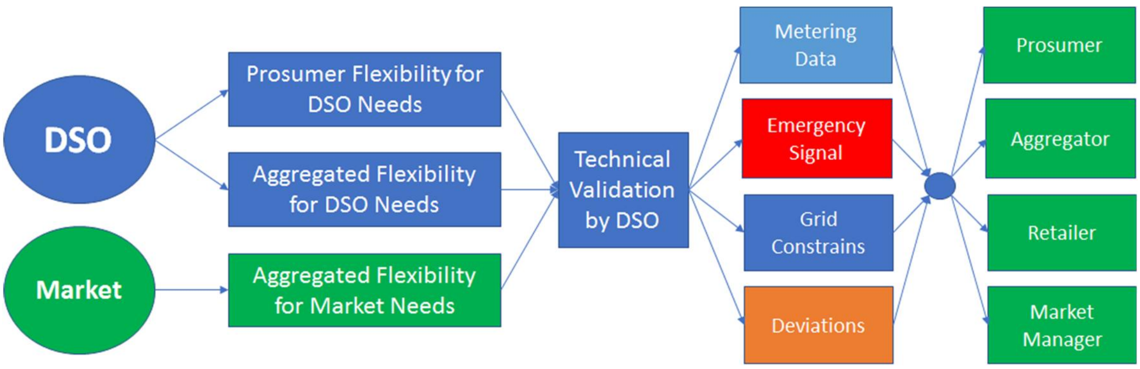

Figure 2.3 (D2.4) DSO information exchange related to flexibility trading (D2.4)

2.7 Regulatory framework

DOMINOES local market concept considers trading with local flexibility and energy resources locally (e.g., trading between prosumers, selling flexibility for DSO congestion management) and aggregating them to higher level markets for other stakeholders' needs. Thus, the minimum requirements for the regulatory framework are:

- Aggregated DR resources are eligible in ancillary service markets
- Network operators are remunerated for the use of flexibility services
- P2P trading is acknowledged in market rules

Local markets are a new concept and are not directly addressed in European energy legislation. However, the Clean Energy for all Europeans package (and the Recast Electricity Directive 2019/944[2] and Renewable Energy Directive 2018/2001[3] in particular) introduces two types of energy communities, definition of P2P trading, and rights of DR aggregators. Citizen energy communities (CECs, Directive 2019/944) and renewable energy communities (RECs, 2018/2001) are defined as legal entities based on open and voluntary participation. Their primary purpose is to provide environmental, economic or social community benefits to their members or shareholders or to the local areas where they operate rather than to generate financial profits. They must be able to share the electricity / renewable energy electricity that is produced by the production units owned by the community, and access all electricity / suitable energy markets directly or through aggregation in a non-discriminatory manner.

The recast Renewable Energy Directive (2018/2001) also introduces the following definition of P2P trading:

'peer-to-peer trading' of renewable energy means 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 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.'

However, apart from the definition, P2P trading is addressed only in Article 21 (Renewables self-consumers) which requires the Member States to ensure that renewables self-consumers are entitled to sell their excess production through P2P arrangements.

On the potential new service providers, aggregators are addressed in the Recast Electricity Directive 2019/944. According to Article 17 of the Directive, Member States shall ensure that TSOs and DSOs, when procuring ancillary services, treat demand response

[2] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU

[3] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

aggregators in a non-discriminatory manner alongside producers based on their technical capabilities.

Finally, transposition of Article 32 of Directive 2019/944 is especially relevant for many of the services developed in the DOMINOES project as it addresses DSOs' opportunities to utilize flexibility. This article requires the Member States to provide the necessary regulatory framework to allow and provide incentives to 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 to procure these services from providers of distributed generation, demand response and energy storage, and the procurement costs should be adequately recovered through network tariffs.

More detailed review of the regulatory framework including analysis of the development of in the project piloting countries Portugal and Finland can be found in D6.11. To enable uptake of local markets and utilization of services provided by them, D6.11 concluded that the following recommendations should be fulfilled:

- Requirements of the Clean Energy package should be transposed in Member States without delays
- Remuneration mechanisms for DSOs should take into account the use of flexibility for congestion management and for reliability and quality purposes
- When possible, Member States should strive for harmonized approaches to facilitate wide uptake and scaling up of the new services
- Piloting of novel solutions in cooperation with regulators should be promoted to identify best solutions and gaps in regulation and standardization.

3 Techno-economic performance and scalability

3.1 Technical and economic performance

Technical performance of the local market architecture has been validated in the three validation sites of the project and the validation results are discussed more in detail in DOMINOES deliverable 4.4 Distribution grid and microgrid validation activities report.

Technical performance can be evaluated by the key performance indicators described in D1.4. Technical performance related KPIs can be divided in three groups: operational KPIs related to validation sites and the validated use cases, cyber security and energy harvester KPIs. ICT platform related KPIs ICT1-7 analyse all the work related to the ICT architecture planning, development, and implementation in the DOMINOES project. KPIs OB6.1 and OB6.2 are related to cyber security performance of the project solutions and OB7.1-3 are related to Energy harvester. More detailed analysis of the KPIs can be found in section 4. In the DOMINOES ICT platform related KPIs most KPIs are fulfilled and thus technical performance is according to the reference architecture plans. However, not all KPI targets were achieved. There are some shortcomings in KPIs related to the data set classification (ICT2), secure protocols (ICT3), some support for the services is missing (ICT4), graphical interfaces are limited (ICT5) and not all deployment scenarios are described (ICT7). It can be concluded that technical performance of the local energy platform is close to real-world local energy market, but some improvements are needed.

From the technical performance of use case perspective KPIs are mostly according to the targets. From use case 2 technical validation KPIs were not fulfilled since the flexibility exchanged between the customers was inside the network limits.

Economic performance of the local market business models has been evaluated in the deliverable 5.3 Cost Benefit Analysis of the Business Models. Based on those evaluations all the business models were profitable. CBA with used assumptions and evaluations are described more in detail in the dedicated deliverable 5.3. Economic performance in the CBA was done for the business models so the different local market participant roles have been considered.

Some of the use case KPIs evaluate the economic performance as well. Almost all the economic performance related KPIs were successful except balancing capacity allocation in LVDC microgrid environment.

Solutions developed in the DOMINOES project are still in an early phase and not yet commercially feasible nor applicable from the regulation perspective. The electricity market price plays a significant role in the economic performance. Flexibility value from the local market level resources might not be yet recognised, but it is assumed that it will have an increasing value. At the same time, the potential to provide small-scale flexibility is quite high if scalable end-customer technical solutions are in place. The value and economic performance of the flexibility for the network management needs is very local and thus economic performance could be very location sensitive.

Future operating environment is considered in the deliverable 5.4 Roadmap to integrated energy market operation and management. Regulation plays a significant role in the development of local markets. The role of the energy communities and peer-to-peer trading impacts greatly the establishment of local markets. DOMINOES has also taken into account the role of distribution system operator as a technical validator in the local market and as a flexibility procurer. Both are of vital importance in utilizing all the benefits of the distributed energy resources in the energy transition and in the implementation of Clean Energy Package in member countries.

3.2 Implementability, scalability and replicability

This subsection focuses on analysing the implementability, scalability, and replicability of the developed local market architecture in the DOMINOES project based on the experience gained in different demonstration sites. Here, the implementability analysis defines the level of utilisation of the proposed architecture in different demonstration sites of the DOMINOES project, while the scalability and replicability analyses show the utilisation of the proposed architecture for wider and larger sites.

In other words, the implementability analysis aims to show what were the practical barriers and how successful was the proposed architecture in the demonstration sites. Scalability can be defined as the ability of the proposed architecture to accommodate the growth in the number of participants, range, and scope. Replicability is the ability of the proposed architecture to be duplicated in another location or time, while the energy regulation, technical specification of the existing energy systems, and the social condition of each country are different. The scalability and replicability analyses in the DOMINOES project are important to evaluate the potential of the proposed solution on a large scale for different EU countries.

To investigate the implementability, scalability, and replicability of the developed local market architecture in the DOMINOES project, a survey from partners involved in demonstrations has been developed. Annex A shows the questionaries used for this survey. For this purpose, first, factors affecting the implementability, scalability, and replicability analyses were identified and then, partners were asked to review each factor and write the potential barriers in each factor according to their experience in the demonstration site.

Table 3.1 shows the identified factors affecting implementability, scalability, and replicability of the developed local market architecture in the DOMINOES project. These factors can be divided into three main areas: technical, regulatory, and stakeholder areas. More detailed definitions of each factor are as follows:

Table 3.1. The proposed factors for implementability, scalability, and replicability

	Implementability	Scalability	Replicability
Technical	Existing infrastructure (1) External constraints (2)	Modularity (3) Technology evolution (4) Interface/ Software design (5) Existing infrastructure (1) External constraints (2)	Standardization (6) Interoperability (7)
Regulatory	Regulation and Incentive program (8)	Regulation and Incentive program (8)	Market Need (9) Regulation and Incentive program (8)
Stakeholder	Acceptance (10)	Acceptance (10)	Acceptance (10)

1. **Existing infrastructure:** this factor identifies to what extent the current infrastructure, including ICT system, monitoring and control devices, creates limits on the implementation of or scaling the solution.
2. **External constraints:** This factor refers to external elements, e.g. climate conditions, which are given and cannot be changed within the scope of the solution.
3. **Modularity:** This factor examines how easy will be to add new components to the proposed solution. It refers to whether a solution can be divided into interdependent components.
4. **Technology evolution:** This factor determines to what extent technological advances allow increases of the solution's size.
5. **Interface/ Software design:** This factor addresses the issues that the interface or software integration can be faced with when the size and complexity of the solution are increased. The architecture characteristic, such as centralised or distributed, storage capacity and the definition of registers to accept new pieces of information should be considered in the evaluation of this factor.
6. **Standardization:** It determines whether the solution can be implemented by different manufacturers. This item aims to facilitate procurement and construction process in replicability.
7. **Interoperability:** It evaluates the capacity of the solution to interact with existing systems without requiring tailored interfaces.

8. **Regulation and Incentive program:** This factor investigates whether the proposed solution is in line with the current regulation and the future vision or not. Besides, this factor investigates the level of changes needed in the current regulation to adopt better the proposed solution.
9. **Market Need:** This factor evaluates the need of forming a local market in the future energy system. It will answer the question that what will be the target need of the flexibility, local markets in provision of flexibility and related local market solutions
10. **Stakeholder acceptance:** This item evaluates the acceptance level of the proposed solution by all involved stakeholders.

Evaluation of the implementability, scalability and replicability were analysed with a survey send to the project partners. A summary of the survey results is presented in the following subsections.

3.2.1 Implementability

How to evaluate the implementability of the proposed solution according to the experience gained in the project is presented in Table 3.2:

Table 3.2 Evaluation of implementability

	100% Implementable	Implementable with minor modification	Implementable with major modification	Not Implementable
Technical • Existing infrastructure • External constraints		X		
Regulatory and Incentive program			X	
Stakeholder Acceptance			X	

The answers regarding implementability varied between implementable with minor or major modifications. The most popular option is presented in the table. In the UK, there were not any incentive programs now at all and thus regulatory and incentive programs were not implementable.

Table 3.3 Implementability, additional insights

Technical • Existing infrastructure • External constraints	*Some of the automation and control technology used in the project is already available in the field, but not yet widely spread.* *The maturity level of the market platform developed in the project is not yet high enough for providing forecasts and price matching.* *Further development of DSO operational and planning tools is needed to consider external provision of flexibility, this includes also information exchange.* *Market rules are required* *Some of the demonstration activities were performed in laboratory environment and laboratory infrastructure, transferring the forecast and optimitization algorithms might need some additional development*
Regulatory and Incentive program	*Lack of regulatory context affects the implementability and the developed concepts are not yet acceptable in some countries.* *From the DSO perspective, the recognition of flexibility provision as one mean to handle congestion management and grid investment deferral is very important for these local markets to appear.* *Demonstration activities were not performed in real market participation, e.g., bid sizes would have been too small and aggregation is needed.* *During the project, the market prices have been significantly lowered; if this continues, this market feasibility might be endangered.*
Stakeholder Acceptance	*Even though most trading and control processes should happen automatically, customer should have the possibility to interact and impact and this would require more intelligent solutions at the customer site with controllable features and remote communication and control* *Customer interface and their acceptance should be more studied and developed.* *Stakeholder acceptance of those actions performed in laboratory environment cannot be analysed.* *Stakeholder acceptance would be easier after the regulatory and incentive programs are in place*

3.2.2 Scalability

How to evaluate the scalability of the proposed solution according to the experience gained in the project and your country situations.

Table 3.4 Evaluation of scalability

	100% Scalable	Scalable with minor modification	Scalable with major modification	Not Scalable
Technical • Modularity • Technology evolution • Interface/ Software design • Existing infrastructure • External constraints		X		
Regulatory and Incentive program			X	
Stakeholder Acceptance		X		

The answers regarding implementability varied between scalable with minor or major modifications, the most popular option is presented in the table above. Stakeholder acceptance regarding scalability was considered unanimously scalable with minor modification. However, in the UK the regulatory and incentive program was considered not scalable at all.

Table 3.5 Scalability, additional insights

Technical • Modularity (3) • Technology evolution • Interface/ Software design • Existing infrastructure • External constraints	*There are some technical solutions in the field, but most small end-customers are not equipped with energy management system yet. Existing smart meters aren't suitable for dynamic demand response and thus technical solutions for assets and software solutions should be more widespread to enable cost-efficient flexibility trading* *Emerging data hubs might facilitate new services for energy communities and energy sharing.* *From market participant perspective better definitions of the information flow, data exchange and market process are needed before rolling into deeper implementation.* *Modular components are needed so that it can be chosen which modules are used if not all are needed. For example, the network data logging component can be split from the machine learning component. These two systems can work independently of each other. The barrier to this is making sure both of these systems*

	work efficiently together and when run apart, taking resources available into account.
Regulatory and Incentive program	*Main challenge regarding the scalability is related to the regulatory environments. Clear understanding about local energy and flexibility market potential, involvement of end-users in contributions to decentralisation and decarbonisation of the energy system is missing. The development of local markets requires a definition of the legal environment.* *Regulatory environment has not yet covered these new solutions in Portugal.* *In Finland, the legislative framework enables only local energy communities inside the same property. On the other hand, all Finnish TSO markets are open to demand response resources and some also to independent aggregators. Also, the current DSO regulatory framework does not encourage use of flexibility services but this is expected to change for the next regulatory period starting in 2024.*
Stakeholder Acceptance	*Customers, in general seem to accept external control of heating in Finland. Customer equipment is getting smarter and controllable and customers are realizing they role as part of the energy transitions. Development is needed for the customer access to their data and understanding their flexibility provision potential. Through regulatory and incentive programs the stakeholder acceptance should be easier.* *Finnish TSO has been progressive in allowing demand response resources in its markets so they are keen on looking new solutions. In Finland DSOs have not expressed big interest in demand response since they have not experience similar capacity issues as some of their European counterparts.* *Retailers may become more interested in flexibility also for their own use when the imbalance settlement period is shortened. Retailers and energy providers have a major role in the local markets' implementation in all the different customers levels. Stakeholder acceptance of the system scalability could be improved by allowing more or less machine-learning algorithms to be used.*

3.2.3 Replicability

How to evaluate the Replicablity of the proposed solution according to the experience gained in the project and your country situations.

Table 3.6 Evaluation of replicability

	100% Replicable	Replicable with minor modification	Replicable with major modification	Not Replicable
Technical • Standardization • Interoperability			*X*	
Regulatory and Incentive program			*X*	
Stakeholder Acceptance		*X*		

The answers regarding replicability varied between replicable with minor or major modifications, the most popular option is presented in the table above. Technical replicability was considered almost unanimously replicable with major modification. However, in the UK the regulatory and incentive program was considered not scalable at all. Stakeholder acceptance regarding replicability was considered almost unanimously scalable with minor modification.

Table 3.7 Replicability, additional insights

Technical • Standardization • Interoperability	*Standardization of the data exchange and information flow is a crucial point in creating replicability. Also, how to build an interoperable layer where all the stakeholders and devices could connect. In appliance level also standardization would be needed but now solutions are developed case by case.* *Controllable loads are different in different countries and might require adaptions. However, electric vehicles are likely to become more common in many European countries thus providing a potential controllable asset. Flexibility assets and energy use modelling would increase the suitability for end-customer needs and for local energy and flexibility market potential.* *Centralised datahubs, planned in Nordic countries, should promote the use of standardised information exchange.* *Modular architecture is good for interoperability if not all components are needed.* *The network data logging component can be spilt from the machine learning component. These two systems can work independently of each other. The barrier to this is making sure both of these systems work efficiently together and when run apart, taking resources available into account.*

Regulatory and Incentive program	*Local market regulatory environment is still developing in many countries and the situation between countries differ. Regulators have a key role in identifying regulatory guidelines and an open implementation of local markets to foster energy transition.* *Regulators also have a key role for achieving the standardization needed for building and interoperable system that can serve all the aspect touched by this project.* *Due to the requirements of the Recast Electricity Directive, energy sharing within communities, P2P trading, access of demand response resources to ancillary service markets, and flexibility incentives for DSOs should be enabled in all EU member countries. However, more detailed frameworks set at a national level will define how feasible the solutions will be. E.g., the current Finnish community legislation applies a tighter locational restriction than e.g. the Portuguese framework.* *In addition to the resource and stakeholder eligibility, also the product definitions (e.g. minimum biz size) in ancillary service markets affect the feasibility of the solutions.* *In UK, there is no regulatory or incentive program*
Stakeholder Acceptance	*In Portugal, these kind of local market concepts are not common practice. If the regulatory framework allows it, hopefully relevant stakeholders would be open to accommodate it.* *There is a need to further educate stakeholders on their role on the energy transition so they can understand how flexibility market could contribute to this objective. This way they could be willing to participate not also in pilot project but on the real ones.* *Outside Finland, DSOs may have more urgent needs for flexibility* *Stakeholder acceptance of the system scalability could be improved by allowing for more or less machine learning algorithms to be used. Any possible way to improve the collection and handling of network data would ease the stakeholder acceptance*

4 DOMINOES key performance indicators (KPIs)

Key Performance Indicators (KPI) measure the progress and success of a project. A set of progress related KPIs were defined in the DOMINOES proposal. A new set of KPIs were proposed when the use cases were designed in D1.3. The KPI list was finalized in D1.4 with additional KPIs related to the ICT infrastructure.

The following subsections consider first the progress related KPIs of the DOMINOES project, then the ICT platform KPIs, and finally the operational and business related KPIs (i.e., results of the validation of the use cases, cyber security issues and energy harvester).

4.1 Progress related KPIs

Table 4.3 presents the progress related KPIs and their achievement during the project.

Table 4.3 Progress related KPIs (D1.4)

KPI ID	Goal	Questions	Question weight	Metrics	Metric Weight	Achievement	Result
P1.1	Design and develop a local market concept that: • empowers prosumers to decide on the distribution of value of their energy resources • enables easy demand response service provision • creates relevant and liquid flexibility for innovative distribution management • enables easy wholesale market uptake of distributed resources • enables local sharing and optimisation of renewable resources in MV and LV grids • supports liberalized energy markets • is compatible with the ongoing policy development	1. Is the Reference architecture defined?	25%	Percentage of architecture defined	100%	Reference architecture has been defined (D2.3)	100%
P1.2		2. Is the Proof of concept developed?	25%	Percentage of concept developed	100%	The proof of concepts for necessary local market components and back-office were developed in WP2.	
P1.3		3. Is the Concept validated?	25%	Percentage of concept validated	100%	Local market concept was validated in demonstration sites in T4.2 and T4.3	
P1.4		4. Is the Roadmap to market defined?	25%	if yes, 100%, else 0%	100%	Roadmap to market was defined (D5.4)	
P2.1	Develop and demonstrate ICT components that will enable the local market concept, focusing on	1. Are components architecture defined?	25%	Percentage of components defined	100%	The key ICT components were de-scribed in D2.1. The interconnections and integration were described in the reference architecture (D1.2) and in D4.1.	100%

P2.2	• control technologies enabling transactive management of resources • interoperable and open interfaces between the stakeholders • monitoring and settlement functionalities provided by smart meters • energy storage system solutions providing services to the distribution grid and the consumer • market management tools for connecting the local markets with the traditional/centralized energy markets	2. Are components interfaces designed?	25%	Percentage of components designed	100%	The main platform components (modules and services) were described in some detail on D2.1.	
P2.3		3. Are components developed?	25%	Percentage of components developed	100%	All the modules and services necessary for validation (WP4) were developed.	
P2.4		4. Are components integrated?	25%	Percentage of components integrated	100%	All the modules and services necessary for validation (WP4) were integrated.	
P3.1	Develop and demonstrate balancing and demand response services that • forecast, profile, segment, and aggregate dynamic energy resources for the use of local optimisation • enable DSOs to manage grid congestions in cooperation with the end-customers • provide means to include virtual power plants and microgrids as active balancing assets • demonstrate interoperability between local and wholesale markets	1. Service requirements defined	25%	Percentage of service requirements defined	100%	Service requirements covering forecast, profile, segment, and aggregate dynamic energy resources for the use of local optimization and DSO to manage grid congestions using end/customers assets have been developed. Also, VPP and microgrids as balancing assets requirements and demonstration of interoperability service requirements have been addressed.	100%
P3.2		2. Service execution/architectures identified	25%	Percentage of service execution identified	100%	The service execution / architecture is related to the definition of DOMINOES architecture defined in WP1. The progress of this KPI has been completed and included in D3.1, D3.2 and D3.3.	
P3.3		3. Services developed	25%	Percentage of services developed	100%	Forecasting and Clustering (profiling, segmentation, aggregation) have been fully developed and made available. Forecast service of consumption implemented and validated with	

						pilot data from Portugal. Also, congestion management using DR models validated with pilot data.	
P3.4		4. Services validated in relevant environment	25%	Percentage of services validated in relevant environment	100%	Forecasting and Clustering (profiling, segmentation, aggregation) validated in relevant environments. D4.4 includes more details about these services.	
P4.1	Design and validate local market enabled business models that • enable transactions inside local communities and allow DSOs to participate in the market actions and thus create new means to manage increasing amounts of renewables • create a platform for innovative demand response schemes utilizing energy storage systems and other distributed energy resources to convert excess electricity, reduce/avoid curtailment and provide services to the grid • enable enhanced interconnections between Member States • contribute to ongoing policy development in the field of the design of the internal electricity market, of the retail market and ongoing discussions on self-consumption • comply and complement the current regulatory/legal framework especially from the DSOs perspective	1. Business models' key attributes defined	25%	if BMs' key attributes defined, then 100%, else 0%	100%	Business model's key attributes have been defined (D5.1)	100%
P4.2		2. Business environment analysed	25%	if Business environment analysed, then 100%, else 0%	100%	An analysis of regulatory environment has been delivered as part of D6.11, demand for new services has been analysed in D5.3	
P4.3		3. A SWOT analysis conducted	25%	IF SWOT done, 100%, else 0%	100%	SWOT analysis has been conducted (D4.5)	
P4.4		4. Developed business models validated	25%	Percentage of BM validated	100%	BMs were validated with a costs benefit analysis (D5.3)	
P5.1		1. Requirements for secure data	25%	if requirements defined, then 100%, else 0%	100%	Requirements for secure data handling have been defined in D2.6	100%

	Analyse and develop solutions for secure data handling related to local market enabled transactions with an emphasis being on • maintaining integrity of communication information between operators in the network • maintaining confidentiality of measurements, user's data and system parameters used in each operator	handling defined					
P5.2		2. Secure data handling procedures designed	25%	if procedures designed, then 100%, else 0%	100%	Secure data handling procedures were defined in D2.6	
P5.3		3. Procedures validated	25%	Percentage of procedures validated	100%	Secure data handling procedures have been validated and reported in D4.2	
P5.4		4. Procedures integrated in the overall concept	25%	Percentage of procedures integrated	100%	Secure data handling procedure has been implemented and reported in D4.4	

4.2 ICT platform KPIs

In D1.4, technical KPIs related with the development and implementation of the platform were defined. These KPIs can be used to assess the functional capabilities of the platform not only in terms of data processing and management but also in terms of security and privacy. Thus, these KPIs can offer an overall assessment of the readiness of the platform to be deployed and used.

Table 4.4 provides a qualitative assessment of the validation platform that was used in the project including the mobile app that was developed. This assessment shows that the platform can be used to create a real-world local energy market with minor improvements.

Table 4.4 ICT Platform KPIs (D1.4)

KPI	Goal	Questions	Evaluation	Notes
ICT 1	DOMINOES platform should provide access	1. Are the authentication mechanisms well defined?	100%	The platform supports a basic authentication mechanism (username/password) that can be integrated with Active Directory.

	control mechanisms to ensure against any unauthenticated or unauthorized access. Integration with a centralized user management system must be guaranteed (preferably AAA, or Active Directory), allowing privilege differentiation by user and user group.			It further supports a number of advanced features like two factor authentication.
		2. Is federated authentication possible?	100%	A single account can be used to access any number of metering points thus enabling a way to use a federated authentication.
		3. Are the authorization mechanisms well defined?	100%	Each user is associate with a profile with specific access rights.
		4. Is the authorization flexibility level appropriate?	100%	The profile can be defined in a very detailed level, including access to individual pages or API functions.
ICT 2	DOMINOES platform should handle personal data handling in compliance with the European General Data Protection Regulation in terms of security and privacy.	1. Are data sets classified?	50%	Not all data sets are not explicitly classified in a uniform way.
		2. Are the appropriate protection rights assured?	100%	The data access rights are well defined for each user and are also dependent on his/her profile.
		3. Are secure data handling algorithms selected for data exchange?	100%	Most of the data exchange use the API that is secure using HTTPS.
ICT 3	DOMINOES platform should provide the necessary integration mechanisms to exchange information with external data sources and, in particular, the pilot's operational management systems.	1. Are the integration protocols defined?	100%	The platform supports a number of standard protocols and integrations mechanisms.
		2. Are the integration requirements met?	100%	They were met for the validation scenario. Other scenarios should not be a problem due to the flexibility of the integration mechanisms.
		3. Are the implementation requirements and restrictions well defined?	100%	Since most of the protocols are standard, these requirements and restrictions are well defined.

	These mechanisms should use appropriate authentication and secure protocols.	4. Are the protocols secure?	50%	Not all due to legacy issues.
ICT 4	DOMINOES platform should provide generic data processing services (e.g., aggregation and tariff calculation) and data validation algorithms to guarantee that erroneous or unrealistic values are rejected.	1. Are these concepts well defined?	100%	The concepts are described on the RA with sufficient detail.
		2. Are the services supported as defined in the reference architecture?	75%	The great majority of the services defined on the RA are supported.
		3. Are data validation algorithms well defined?	100%	Data can be validated using a set of algorithms that detect invalid conditions (e.g., implausible meter readings, anomalous consumptions, and other impossible values)
		4. Are invalid data discarded?	100%	Invalid data is marked and not used in aggregation or other processing algorithms.
ICT 5	DOMINOES platform should provide clear, easy to read and interactive user interfaces, including mobile apps.	1. Is there a cross platform graphic identify concept?	50%	A novel graphic identity was only developed for the mobile app. The other user interfaces used were only customized.
		2. Are user interfaces main concepts well defined in terms of usability?	100%	Special care was taken to develop clear and intuitive user interfaces in particular for the mobile app that targets a more general audience.
ICT 6	DOMINOES platform should keep record of the major operations and transactions to enable fu-	1. Is the auditing concept defined in terms of format, storage and access?	100%	The platform supports an auditing feature that can be configured to keep record of different type of interactions and transactions.
		2. Are the required operations and transactions selected?	100%	The main operations and transactions can be tracked.

	ture examination of performance, accuracy, and accountability, and all security events. Dedicated auditing roles shall be established.	3. Are the implementation requirements and restriction well defined?	100%	The implementation is complete.
		4. Are security and privacy issues accounted for?	100%	Auditing data is only available to an administrator user on the back-office.
ICT 7	DOMINOES platform should be modular and easy to deploy in different scenarios and computational infrastructure.	1. Are deployment scenarios described?	50%	For the validation phase some scenarios were described and implemented but not all scenarios were described.
		2. Are deployment plans defined?	100%	The deployment plan is well established.

4.3 Operational and Business related KPIs

The operational and business related KPIs cover the five DOMINOES UCs, cyber security issues and the energy harvester addressed in the following subsections 4.3.1–4.3.7.

4.3.1 UC1

UC1 was validated using the distribution grid environment in Évora (Portugal). For this use case, validation activities used forecasted and metering data to identify possible distribution grid constrains situations for that specific grid. Details of the demonstration environment and activities can be found in D4.4.

The UC focused on the demonstration that the use of household level flexibility is a viable scenario to solve some local constrains that may happen. For the considered grid only three different constrains were identified using E-REDES power flow and network analysis tool (two of them correspond to undervoltage situations and the other one to an overvoltage situation). These situations were the only ones identified on that specific grid, but their occurrence was not unique, most of them happen throughout the year.

Table 4.5 KPIs related to UC1

ID	Use Case Name	Goal	Questions	Question weight	Metrics	Metric Weight
OB1.1	Local market flexibility and energy asset management for grid value	Validate the use of local market flexibility resources for DSO value	Q1. What is the number of successful activations of flexibility to solve technical constraints?	50.00%	Requested Flexibility (RF) - To solve a given constraint Activated Flexibility (AF) - To solve a given constraint 1. RF > AF - Failure (0%) 2. RF = AF - Success (100%) 3. RF < AF - Success (120%)	100.00%
OB1.2			Q2. What is the reduction of the amount of energy curtailed of DER due to technical constraints?	25.00%	"Forecasted Curtailed DER (FCD) - Due to predicted technical constraints Total Curtailed DER (TCD) 1. KPI Success = 100 - TCD/FCDx100 (%)"	100.00%
OB1.3			Q3. What is the reduction of the overall cost using new planning approaches?	25.00%	Grid Investment Cost (AP1) vs. Flexibility Market Usage Approach (AP2) For a given period: 1. AP1 < AP2 - Failure (0%) 2. AP2 < AP1 - Success (100%)	100.00%

After the validation tests for the KPI calculation some assumptions had to me made. The results and explanation can be found below. More detailed information about the calculations and values can be found on D4.4.

Table 4.6 Results of KPIs for UC1 at distribution grid demo site

ID	Value	Outcome
OB1.1	RF = 4,2kW AF = 4,25kW **RF < AF** – Success	100 %
OB1.2	FCD = 1,8 kW TCD = 0 kW **100 – 0/1,8x100 = 100%**	100 %
OB1.3	AP1 = 30 500 € AP2.x = Power x Price x Times Flexibility is Needed AP2.1 = 3,1x0,5x2x5x13x30 = 6 045 € AP2.2 = 0,8x0,5x2x5x13x30 = 1 560 € AP2.3 = 0,4x0,5x2x5x26x30 = 1 560 € AP2 = 9 165 € AP2 < AP1 – Success	100 %

OB1.1

- Results show that, for the 3 identified situations, households were able to provide a total amount of flexibility above requested;
- For each individual situation, clients were able to provide enough flexibility to solve the forecasted constrain. This was mainly possible as some of the households in these locations are equipped with PV and Energy Storage systems, these two types of systems enable a fine tuning of the household load profile;
- Without the existence of PV and Energy Storage systems on the targeted distribution network it would be difficult for the households to provide the given flexibility. More details can be found on D4.4.

OB1.2

- During the validation activities only one overvoltage situation was found that could lead to the need of DER curtailment. The results show that, using flexibility from another client positioned on a different phase, it was possible to solve the problem successfully without any curtailment.

- Results showed that resorting to flexibility a correct network analysis, there can be better options than DER curtailment or to request a large amount of load increase (more details can be found on D4.4).

OB1.3

- Regarding this KPI, several assumptions had to be made in order to calculate it. Although the results can be misleading, they give some insights on how useful flexibility might be in order to solve local constrains;
- To solve all the identified constrains situations definitively a total investment of 30,5 k€ has to be made on the network since the situation identified corresponded to 3 different LV feeders. This investment has a lot more benefits then only solving the identified situation (losses, increase grid overall capacity, etc.) but for simple comparison purposes we can considers this value;
- In order to compare the typical grid investment with the usage of local flexibility an average price of 0,5€/kW was considered that was multiplied with the needed flexibility (in kW);
- Then the values were multiplied by the number of times we assume we could need to activate this flexibility. Here for most of the situations a 2h period was considered as a worst-case scenario.
- As the congestions were only verified during week days it was considered that this flexibility could be needed at most 5 times a week during 3 moths per year (13 weeks) – winter time – and other situation 6 months a year (26 weeks) – spring/summer time – as a worst-case scenario.
- For grid investment we need to consider a 30-year period for the amortization, so we also need to multiply the value of the needed flexibly for 30 years to be able to compare it with the grind investment option (for the sake of simplicity we did not consider any update rate for the values);
- Although the cost of using flexibility seams a lot lower that the natural grid investment, we need to have in mind that the situations identified are not a matter of major concern (the values are still within the limits) and they can be solved with small amounts of flexibility;
- Other thing we should consider is that relying on flexibility to solve situations with a high level of occurrence (every day, week) shouldn't happen as flexibility is better suited to solve problems for a short period of time or in situation where grid investment is completely out of the table or before traditional grid investment solution are implemented;
- To summarize, these results tend to show that, if available, flexibility can have a lot of potential for solving some grid constrains (ones that do not happen to often) and can be used in a mix approach util traditional grid investment is made (periods up to one year) or even on long term situation where grid investment is not an option.

4.3.2 UC2

UC2 focused on the technical validation by the DSO of flexibility transactions. For this purpose, E-REDES power flow and network analysis was setup to enable the analysis of grid stability for any transaction that could have any impact on the grid.

As no transactions between customers surpassed the defined rules for energy transactions on the grid, no technical validation was done on the scope of the project. Analysis on grid stability using metering values was done and no violations were detected.

Table 4.7 KPIs related to UC2

ID	Use Case Name	Goal	Questions	Question weight	Metrics	Metric Weight
OB2.1	Local Market Data Hub Manager and technical validation and flexibility tool	Implementation of supporting tools for DSO to validate the transactions technically inside the local market	Q1. What is the number of successful validation requests in the LEMH?	33.33%	Validation requests (VR) Accepted validation requests (VRA) 1. VRA/VR %	100.00%
OB2.2			Q2. What is the number of successfully validated technical data sets for each request?	33.33%	Transactions (TR) Accepted transactions (TRA) 1. average TRA/TR %	100.00%
OB2.3			Q3. What is the number of successful market operation after technical validation by DSO?	33.33%	Requested flexibility validated by DSO (DSOF) Accepted / allocated / activated flexibility (DSOFA) 1. DSOFA/DSOF %	100.00%

As no transaction requested technical validation from the DSO the KPIs calculated are the following:

Table 4.8 Results of KPIs for UC2 at distribution grid demo site

ID	Value	Outcome
OB2.1	VR = 0 VRA = 0 **0/0 = NA**	NA
OB2.2	TR = 0 TRA = 0 **0/0 = NA**	NA
OB2.3	DSOF = 0 DSOFA = 0 **0/0 = NA**	NA

On the distribution demo site the level of flexibility exchanged between clients was not enough (higher than the defined limit) for any validation request to be sent to the DSO. This means both that there are few energy exchanges possible on the distribution demo site grid and that customers do not tend to change their consumptions patterns too much due to the existence of this possibility, they tend to only buy/sell excess production but maintained their typical load.

4.3.3 UC3

UC3 was validated in the distribution grid environment in Portugal, using data from a few dozens of end-users, prosumers and flexible consumers, from Valverde's local community, a village in the municipality of Évora. The selected end-users are connected to the same LV network and have residential photovoltaic systems, battery energy storage systems, smart metering, and home energy management solutions at their premises. Their metering data – distributed generation and consumption – and market profile preferences, a sellers and buyers at the local market were used to validate a local energy and flexibility market environment, where in the scope of use case 3 local energy management aggregated and made available by a local market operator entity aims to create value to the local community.

The detailed description of the rationale behind the mentioned validation can be found in D4.4.

The KPIs related to UC3 were previously defined and lately revised following the preliminary results emerging at the end of the implementation phase. The main metrics considered, and the objectives they are linked, are presented next.

Table 4.9 KPIs related to UC3

ID	Use Case Name	Goal	Questions	Question weight	Metrics	Metric Weight
OB3.1	Local community market with flexibility and energy asset management for energy community value	Validate the use of available energy within the Local Market to create economic value to the Community	Q1. What is the amount of energy/flexibility activated using the local market (day-ahead scenario) and what is its reference price?	50.00%	Energy availability (EA) compared to the total consumption (C): 1. EA >= 10% C (100%) 2. 5% C < EA < 10% C (50%) 3. EA <= 5% C (0%)	60.00%
					"Price of transacted energy (EP) compared to retailer price (R): 1. If EP>=0,8 R; then 100% 2. If 0,4 R<EP< 0,8 R, then 80% 3. else 0%	40.00%
OB3.2[4]			Q2. What is the amount of energy/flexibility activated using the local market (intraday scenario) and what is its reference price?	–	–	–
OB3.3			Q3. What is the number of P2P transactions?	50.00%	Number of transactions 1. If > 5 transactions per day, then 100% 2. else, then 0%	100.00%

[4] This objective was not addressed within the scope of the proposed local market synthesis due to some technical limitations imposed by the market platform – intraday scenario not implemented –, thus the associated KPIs were also not considered in the validation of the use case.

Following the use case validation, and after calculating the main metrics associated, the assessment over the key performance indicators considered was possible, and the results can be found in the following table. The KPIs were calculated based on the local market results for two months, April and May, and considering the sum of the PV excess sold at the local market and the total consumption, including self-consumption, for all the metering points connected and communicating. More details on the calculation methods can also be found in D4.4.

Table 4.10 Results of KPIs for UC3, validated at the distribution grid environment.

ID	Value	Metric Specific Outcome	Objective Specific Outcome	UC General Outcome
OB3.1	$\frac{1171{,}22\ (kWh)}{5644{,}05\ (kWh)} \times 100\% = 20.75\%$	100 %	60 %	80 %
	$\frac{0{,}0474\ (\frac{€}{kWh})}{0{,}2190\ (\frac{€}{kWh})} \times 100\% = 21.75\%$	0 %		
OB3.3	$\frac{712\ (\text{average n° per user, as buyer or seller})}{61\ (\text{n° of days in April and May})} = 12$	100 %	100 %	

The KPIs linked to OB3.1, addressing the volume and reference price of the energy transacted at the local market, studied the efficiency the local market reaches when valuing end-users excess distributed generation, leading to value creation for the community members. Particularly the second metric, is fully aligned with the prosumer's perspective, as local energy seller, since values higher local energy prices, closer to the retailer's reference selling price, thus increasing the prosumers gains when valuing and selling its generation surplus. Local buyer's perspective is neglected, since for these end-users the benefits are linked to the savings achieved when the local energy price is as small as possible, particularly when compared to the energy tariff contracted with their energy provider. The results from the KPIs assessment show evidence that support the hypothesis formulated and the overall validation of UC3.

4.3.4 UC4

UC4 was validated in the distribution grid environment in Portugal, using the same data used for use case 3, and using additional data provided by a virtual power plant environment, aggregating several commercial sites in Portugal, capable of providing demand response mainly based on load flexibility.

The KPIs related to UC4 were previously defined and lately revised, also following the preliminary results coming from the market platform and use case implementation phases.

For OB4.1 & OB4.2, the proposed deviations are:

- For OB4.1, the KPI_4.1 included in D1.3 suggested that, for the energy/flexibility allocated from the local market for energy sourcing optimisation, the focus should be on showing the amount of energy/flexibility allocated from the local market for energy sourcing optimisation of Retailer's portfolio considering volume (MWh) and price (€) as indicators;

  The change proposed is to instead address Q1, and use the suggested metric to assess the difference between the energy price at the LEFM, P1, and the energy price at the WSM, P2, for a day-ahead scenario, impacting the retailer energy sourcing optimisation at the wholesale level.

The main metrics considered, and the objectives they are linked, are presented in Table 4.11[5].

Table 4.11 KPIs related to UC4

ID	Use Case Name	Goal	Questions	Question weight	Metrics	Metric Weight
OB4.1	Local community flexibility and energy asset management for retailer value	Validate the use of available local community flexibility to create economic value to the Retailer	Q1. What is the difference between the costs with the energy activated at the LEFM and the energy price at	100.00%	WSM energy price day n (day ahead) P1 (€/MWh) LEFM energy activation price day n (day ahead) P2 (€/MWh) 1. If P1>P2, then 100% 2. if P1<=P2, then 0%	100.00%

[5] The validation activities focused in the day ahead scenario. Thus, question 2 is not addressed here.

			the WSM, in a day ahead scenario?			

As performed for use case 3, the validation of use ase 4 followed the calculation of the main metric associated, and the assessment over the key performance indicator considered. The results can be found in the follwing table. The KPI was calculated based on the local market results for the same two months, April and May, and considering the energy available locally, from the metering points PV excess offered to the market, and the needs imposed by the retailer's local portfolio. More details on the calculation methods can also be found in D4.4.

Table 4.12 Results of KPIs for UC3, validated at the distribution grid environment.

ID	Value	Metric Specific Outcome	Objective Specific Outcome	UC General Outcome
OB4.1	$0{,}0672\ (\frac{€}{\text{kWh}}) > 0{,}0284\ (\frac{€}{\text{kWh}}) = TRUE$	100 %	100 %	100 %

With a local energy price that is 42% of the wholesale price, the results from the assessment of the KPI linked to OB4.1, show that local community flexibility and energy asset management for retailer's value is plausible, once it leads to daily savings from reducing day-ahead energy buying costs to supply its local portfolio of customers, by accessing local market's lowest energy prices.

The assessed results corroborate the validity of UC4 and its linked business model – DOMINOES BM5, detailed in 5.1 and targeted by the project's cost benefit analysis in D5.3 –, showing evidence of the possible benefits an electricity retailer may access when engaging in local market energy trading and flexibility activation.

4.3.5 UC5

UC5 was validated in microgrid environments in Finland. In the considered scenario, prosumers (consumers with solar PV and battery energy storage system, BESS) in a grid-connected microgrid offer balancing services for other stakeholders' needs via an aggregator. The balancing service considered in this demonstration is the frequency containment reserve for normal operation (FCR-N) as this market is already open for aggregated resources and independent aggregators. The flexibility offer was formed based on a mixed-integer linear programming problem with the objective to minimize the microgrid electricity-related costs based on electricity purchase price, battery degradation costs, electricity sale price (excess generation), and the forecasted price for the provision of FCR-N service. Details of the demonstration environment and activities can be found in D4.4.

The KPIs related to UC5 were defined in D1.3 and D1.4. After consideration, the metric defined for question 2 has been revised. As stated in D1.4, the demonstration focused on FCR provision to the TSO which helps the system cope with the variability of renewable generation. The metric was changed to enable consideration of the impacts that services provided to the TSO have locally (i.e., at the DSO or connection point level), and thus the benefit of providing the service via a local market.

Table 4.13 KPIs related to UC5

ID	Use Case Name	Goal	Questions	Question weight	Metrics	Metric Weight
OB5.1	Local community flexibility and energy asset management for wholesale and energy system market value	Validate the use of flexibility for wholesale energy system market value	Q1. Is the balancing capacity allocation using the local market efficient?	33.33%	Allocated flexibility cost FCFK (€) and flexibility benefit FBFK (€) with centralized optimization & full knowledge (prices, demand) Allocated flexibility cost FCMA (€) & flexibility benefit FBMA (€) using market with imperfect information 1. if (FBMA/FCMA)/(FBFK/FCFK) > 80%, then 100% 2. else 0%	100.00%
OB5.2			Q2. Has the potential adoption of distributed (renewable) generation with the proposed balancing services Increased?	33.33%	Local renewable energy (RER) has been utilised for the restoration of flexible energy (FER) If RER/FER > 0, then 100% else 0%	100.00%
OB5.3			Q3. Have activated balancing services been settled fairly?	33.33%	1. if all participants are compensated more than costs are incurred, FBMA/FBCA>1, 100% 2. else 0%	100.00%

After the validation period, the KPIs were calculated separately for the two different microgrid environments used in the demonstration. The results can be found in the tables below, more detailed information about the calculation can be found in D4.4.

Table 4.14 Results of KPIs for UC5 at LVDC microgrid demo site

ID	Value	Outcome
OB5.1	$\frac{17.00/13.95}{14.68/9.59} 100\% = 79.56\%$	0 %
OB5.2	$\frac{20.96}{37.32} 100\% = 56.15\ \%$	100 %
OB5.3	$17.00 > 13.95$	100 %

Table 4.15 Results of KPIs for UC5 at LUT GC demo site

ID	Value	Outcome
OB5.1	$\frac{23.60/19.39}{19.55/12.88} 100\% = 80.2\ \%$	100 %
OB5.2	$\frac{33.97}{51.95} 100\% = 65.39\ \%$	100 %
OB5.3	$23.60 > 19.39$	100 %

The first KPI studied the efficiency of allocating flexibility using the local market when offers have to be sent with imperfect information. The predefined threshold for efficiency was met in one of the two demonstration areas. However, the differences were very small. This outcome means that the utilized forecast methods give a reasonable ratio estimation between flexibility benefits and costs despite the unpredictability of volatile BESS energy spikes caused by rapid grid frequency changes over particular settlement periods.

From 56 to 65% of restored BESS energy content matches the time of renewable generation depending on the demo site. Therefore, the proposed optimization method increases the utilization of energy from own renewable generation, and hence, outcome of OB5.2 supports the hypothesis of the increased potential of renewable generation adoption at both demo sites. Finally, the relative comparison of actual flexibility benefits and costs demonstrate that the remuneration from the provision of reserve service is larger than the corresponding costs at both demo sites. As a result, the hypothesis of OB5.3 is accepted in both validation environments.

4.3.6 Cyber security issues

As presented in Table 4.16, cyber security issues must be considered in all UCs and environments. Thus, cyber security framework for the DOMINOES ICT platform was introduced as a part of D2.6.

Table 4.16 KPIs related to cyber security issues

ID	Use Case Name	Goal	Questions	Question weight	Metrics	Metric Weight
OB6.1 OB6.2	All UC/ demos Cyber secure issues	Maintaining the integrity and confidentiality of measurements, user's data and systems communication between operators in the network	Q1. is the data transactions secure "up to 99% or above" inside the local market .	100.00%	"Number of Vulnerabilities (V) found 1. If > 5 , then V = 0% 2. If 3<= P =<5 , then V = 70% 3. else 100% "	15.00%
					Number of Critical Vulnerabilities (CV) found 1. If > = 1 , then CV = 0% 2. else 100%	25.00%
					Number of pages scanned/tested (S) 1. If none , then S = 0% 2. else S = 100%	20.00%
					Number of unsecure communication channels (UC) 1. If > = 1 , then UC = 0% 2. else UC = 100%	40.00%

After penetration testing and providing feedback and recommendations laid out in D2.6 to partners of any cyber security concerns, partners have addressed all cyber security concerns and all metrics are now at 100%. This means that all data transactions are secure above 99% inside the local market.

4.3.7 Energy harvester

Energy harvester has been validated in the laboratories of Escuela Superior de Ingenieros de Sevilla (University of Seville). In this context, the energy harvester is composed of renewable photovoltaic generation and storage, interacting with loads, represented by an aggregation of consumers, the grid and requests for ancillary services, such as flexibility. It is validated with two modes of operation, producer mode and consumer mode. In the producer mode, the operation of the harvester is optimised to maximise the profit from the sale of energy to consumers, grid and to satisfy a flexibility agreement. For the consumer mode, the operation is optimised to reduce the electricity bill by reducing dependence on the grid, but also by providing flexibility service to the grid. The details of this validation, as well as the results obtained, are included in deliverable D4.4.

The KPIs related to the energy harvester were initially defined in D1.4. After consideration, the metrics defined for question 3 have been revised. At the beginning of the project, it was defined that the energy harvester management system should be able to optimise operation based on price forecasts and consumption profiles, as well as offer ancillary services to the grid, being a multi-agent system to manage the devices. As the energy harvester control system is focused on local markets, being able to offer benefits to consumers, producers, provide ancillary services to the grid, as can be seen in the results shown in D4.4. It was decided to modify metric 3, initially defined as “Can the energy harvester endure Voltage ride through (VRT)?”, to an evaluation of the reduction of consumers' bills in the harvester's operating modes, evaluating its effectiveness and services in local markets. This is because it is also necessary to evaluate the local market performance of the energy harvester, and whether its control and optimisation of the operation that is implemented is correct and brings benefits. The provision of ancillary services was evaluated in metric 2.

Table 4.17 KPIs related to energy harvester

ID	Use Case Name	Goal	Questions	Question weight	Metrics	Metric Weight
OB7.1 **OB7.2** **OB7.3**	Energy harvester Validation (Évora demo)	Validate the performance of the developments related to the energy harvester and its control systems	Q1. Is the energy harvester capable of reducing the energy consumption from the grid?	33.33%	Reduction in the power imported from the grid compared with a situation without a harvester in % (R) 1. If R > = 7%, then 100% 2. If 4%<=R< 7% then 50% 3. Else 0%	100.00%
			Q2. Can the energy harvester provide ancillary services to the grid?	33.33%	Contribution to frequency regulation 1. If it can provide the service, then 100% 2. else 0%	100.00%
			Q3. Is the energy harvester able to reduce consumer bills in the local market?	33.33%	Reduction in the electricity consumer bill compared with a situation without a harvester in % (R) 1. If R > = 10% , then 100% 2. If 5%<=R< 10% then 50% 3. Else 0%	100.00%

Once the operation of the energy harvester has been validated and the defined objectives have been achieved, KPIs are evaluated.. Although the calculation of the results for assessing KPI is shown in more detail in D4.4, they are briefly described here.

Question 1 is validated, a reduction of more than 7% is achieved in both producer and generator mode. In the producer mode the reduction of energy supplied by the grid is 23.4% and in the consumer mode it is 23.75% (from 60.86 kWh per day to less than 47 kWh per day with the installation of the harvester in both modes).

Question 2 is also validated, as in all the tests carried out, the flexibility agreement was satisfied, with the harvester being managed in such a way that at a certain time and for a certain period of time, power was injected into the grid to provide this service. Battery operation was optimised and the battery was discharged during this period of time, validating in real time that the same discharge pattern was followed as in the simulation, with no significant differences or deviations.

Question 3 is validated for the most unfavourable mode of operation, the producer mode, where the energy harvester is installed to sell energy to the aggregation of consumers. Although the operation is optimised for maximum profit, a reduction of more than 10% of the bill of the aggregation of consumers is achieved. Without the energy harvester, the bill is 13.389 €/day, while when the energy harvester is installed with producer mode, the bill for the consumers is 11.559 €/day, a reduction of 13.67%.

5 Conclusions

DOMINOES project (2017–2021) aimed to enable the development of new demand response, aggregation, grid management and peer-to-peer trading services by designing, developing and validating a transparent and scalable local energy market solution. The high-level goals were refined through the development of five use cases and six related business models. Several forecasting and optimization services enabling the more efficient use of demand response and other distributed resources, and a local market platform enabling trading within the local market and connections to higher level markets were developed. The developed services, the local market platform, and feasibility of the use cases were validated in demonstration environments in Portugal (distribution grid, VPP) and in Finland (microgrid). This deliverable has summarized the key features of the local market concept and related services and results of the validation activities. More details can be found in the referred deliverables.

During the project preparation phase, the DOMINOES consortium defined KPIs related to development of the local market concept, ICT components, balancing and demand response services, local market enabled business models, and secure data handling related to local market enabled transactions. All of these progress related KPIs were achieved as explained in section 4.1. During the project, additional KPIs related to the ICT platform and DOMINOES use cases, cyber security issues and energy harvester were defined. The vast majority of these ICT platform and operational and business related KPIs were also met as discussed in sections 4.2 and 4.3. The feasibility of the use of local energy and flexibility for the benefit of the DSO, TSO, retailer and the local communities, and the functioning and security of the ICT platform were validated.

6 References

Internal references

D1.2 ICT platform and connected energy network reference architecture design

D1.3 Use cases and application scenarios requirements

D1.4 Implementation plan for the validation environment

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

D2.5 Tools for local energy market and end-user interaction

D2.6 Design and implementation of a data security framework

D3.1 DR enabling services

D3.2 Demand Response modes of use from the DSO and energy provider perspective

D3.3 Report on DR at TSO and local levels

D4.1 Overview of the validation framework

D4.2 Secure data handling platform validation activities report

D4.4 Distribution grid and microgrid validation activities report

D5.1 Formulation of alternative local market place enabled business models

D5.3 Cost Benefit Analysis of the Business Models

D5.4 Roadmap to integrated energy market operation and management

External references

Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU

Annex A: Questionnaire

Questionnaire about the implementability, scalability and replicability for the DOMINOES partners

DOMINOES' local market architecture

Implementability, Scalability and Replicability questionaries

General Information:

Participants Name:	
Type of the participants (Company/Research centre/University)	
Country	
Name of person	
Email	

Implementability

How to evaluate the implementability of the proposed solution according to the experience gained in the project.

	100% Implementable	*Implementable with minor modification*	*Implementable with major modification*	*Not Implementable*
Technical • Existing infrastructure • External constraints				
Regulatory and Incentive program				
Stakeholder Acceptance				

Describe with few sentences your understanding on the status of implementability. What were the main barriers in the implementation of the proposed solution in the demonstration sites?

Technical • Existing infrastructure • External constraints	
Regulatory and Incentive program	
Stakeholder Acceptance	

Scalability

How to evaluate the scalability of the proposed solution according to the experience gained in the project and your country situations.

	100% Scalable	*Scalable with minor modification*	*Scalable with major modification*	*Not Scalable*
Technical • Modularity • Technology evolution • Interface/ Software design • Existing infrastructure • External constraints				
Regulatory and Incentive program				
Stakeholder Acceptance				

Describe with few sentences your understanding on the status of scalability. What are the main barriers in the scalability of the proposed solution in your country?

Technical • Modularity (3) • Technology evolution • Interface/ Software design • Existing infrastructure • External constraints	
Regulatory and Incentive program	
Stakeholder Acceptance	

Replicability

How to evaluate the Replicablity of the proposed solution according to the experience gained in the project and your country situations.

	100% Replicable	*Replicable with minor modification*	*Replicable with major modification*	*Not Replicable*
Technical • Standardization • Interoperability				
Regulatory and Incentive program				
Stakeholder Acceptance				

Describe with few sentences your understanding on the status of replicability. What are the main barriers in the replicability of the proposed solution in your country?

Technical • Standardization • Interoperability	
Regulatory and Incentive program	
Stakeholder Acceptance	

Background information:

This sub-section focuses on analysing the implementability, scalability, and replicability of the developed local market architecture in the DOMINOES project based on the experience gained in different demonstration sites. Here, the implementability analysis defines the level of utilisation of the proposed architecture in different demonstration sites of the DOMINOES project, while the scalability and replicability analyses show the utilisation of the proposed architecture for wider and larger sites.

In other words, the implementability analysis aims to show what was the practical barriers and how successful was the proposed architecture in the demonstration sites. Scalability can be defined as the ability of the proposed architecture to accommodate the growth in the number of participants, range, and scope. Replicability is the ability of the proposed architecture to be duplicated in another location or time, while the energy regulation, technical specification of the existing energy systems, and the social condition of each country are different. The scalability and replicability analyses in the DOMINOES project are important to evaluate the potential of the proposed solution on a large scale for different EU countries.

In order to investigate the implementability, scalability, and replicability analyses of the developed local market architecture in the DOMINOES project, a survey from partners involved in demonstrations has been developed. Appendix 1 shows the questionaries that used for this survey. For this purpose, first, factors affecting the implementability, scalability, and replicability analyses are identified and then, partners ask to review each factor and write the potential barriers in each factor according to their experience in the demonstration site.

Table 1 shows the identified factors affecting implementability, scalability, and replicability of the developed local market architecture in the DOMINOES project. These factors can be divided into three main areas: Technical, Regulatory, and stakeholder. More detailed definition of each factor are as follows:

Table 1. The proposed factors for implementability, scalability, and replicability

	Implementability	***Scalability***	***Replicability***
Technical	Existing infrastructure (1) External constraints (2)	Modularity (3) Technology evolution (4) Interface/ Software design (5) Existing infrastructure (1) External constraints (2)	Standardization (6) Interoperability (7)
Regulatory	Regulation and Incentive program (8)	Regulation and Incentive program (8)	Market Need (9)

			Regulation and Incentive program (8)
Stake-holder	Acceptance (10)	Acceptance (10)	Acceptance (10)

(1) *Existing infrastructure:* this factor identifies to what extent the current infrastructure, including ICT system, monitoring and control devices, creates limits on the implementation of or scaling the solution.
(2) *External constraints:* This factor refers to external elements, e.g. climate conditions, which are given and cannot be changed within the scope of the solution.
(3) *Modularity:* This factor examines how easy will be to add new components to the proposed solution. It refers to whether a solution can be divided into interdependent components.
(4) *Technology evolution:* This factor determines to what extent technological advances allow increases of the solution's size.
(5) *Interface/ Software design:* This factor addresses the issues that the interface or software integration can be faced with when the size and complexity of the solution are increased. The architecture characteristic, such as centralised or distributed, storage capacity and the definition of registers to accept new pieces of information should be considered in the evaluation of this factor.
(6) *Standardization:* It determines whether the solution can be implemented by different manufacturers. This item aims to facilitate procurement and construction process in replicability.
(7) *Interoperability:* It evaluates the capacity of the solution to interact with existing systems without requiring tailored interfaces.
(8) *Regulation and Incentive program:* This factor investigate whether the proposed solution is in line with the current regulation and the future vision or not. Besides, this factor investigates the level of changes needed in the current regulation to adopt better the proposed solution.
(9) *Market Need:* This factor evaluated the need of forming a local market in the future energy system. It will answer the question that what will be the target need.
(10) *Stakeholder acceptance*: This item evaluates the acceptance level of the proposed solution by all involved stakeholders.