IFLEX

BEST PRACTICE REFERENCE BOOK

AND ROADMAPS FOR IFLEX MARKET REPLICATION

iFLEX has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957670

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Abbreviations and Acronyms

Abbreviation / Acronym	Description
AI	Artificial Intelligence
AFM	Automated Flexibility Management
API	Application Programming Interface
A&M	Aggregation and Market
BEMS	Building Energy Management System
BESS	Battery Energy Storage Systems
BEUC	Bureau Européen des Unions de Consommateurs, The European Consumer Organisation
BME	Business Model Evaluator
BRP	Balance Responsible Party
BSP	Balancing Service Provider
CR3	Concentration Ratio 3
DAM	Day Ahead Market
DPIA	Data Privacy Impact Assessment
DPO	Data Protection Officer
DR	Demand Response
DRMS	Demand Response Management System
DT	Digital Twin
DSO	Distribution System Operator
EMS	Energy Management System
EUI	End-User Interface
EV	Electric Vehicle
FCR	Frequency Containment Reserve (-D for disturbances, -N for normal operation)
FFR	Fast Frequency Reserve
FRR	Frequency Restoration Reserve (aFRR: automatic FRR, mFRR: manual FRR)
GDPR	General Data Protection Regulation
HEMS	Home Energy Management System
HHI	Herfindahl-Hirschman Index
HLUC	High-Level Use Case
HTTP	Hypertext Transfer Protocol
HV	High Voltage
ICT	Information and Communication Technology
ISP	Imbalance Settlement Period
iFA	iFLEX Assistant
KPI	Key Performance Indicator
LL	Lessons Learned
LIF	Loss Incentive Factor
LPWAN	Low-Power Wide-Area Network
LV	Low Voltage
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
MV	Middle Voltage

Abbreviation / Acronym	Description
NEMO	Nominated Electricity Market Operator
NRA	National Regulatory Authority
NRMSE	Normalized Root-Mean-Square Error
OCPP	Open Charge Point Protocol
PUC	Primary Use Case
RAI	Resource Abstraction Interface
RES	Renewable Energy Sources
REST	Representational State Transfer
SGAM	Smart Grid Architecture Model
SRA	Scalability and Replicability Analysis
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TSO	Transmission System Operator
V2G	Vehicle-to-Grid
VEN	Virtual End Agent
WWW	World Wide Web

1 Executive summary

The scope of this document is to present the final analysis conducted by the iFLEX project consortium towards deriving a roadmap based on a list of best practices, recommendations and guidelines allowing for the maximization of the potential benefits that could be yielded for various market stakeholders from the large-scale replicability of the iFLEX solutions.

First, the iFLEX innovative solutions that can be replicated at large-scale along with the inherent value brought by these technological solutions and which can be offered to various market stakeholders is identified in terms of the expected benefits for end-consumers, prosumers, energy communities, retailers, aggregators, other electricity market entities and market operators. It is concluded that the large-scale replication of iFLEX solutions essentially enables DR for a large number of users, thus creating a broad pool of controllable loads that can be employed in various time-scales. The wide activation of DR is expected to bring a new source of value for all stakeholders, whereas benefits will be directly applicable in most cases. Legal, regulatory and market structural modifications as well as proper education of the market stakeholders will need to take place and create new value chains that will further enable the energy transition as well as secure and amplify the profits of various market and power system participants.

Next, following the definition of the framework and the methodological approach for the Scalability and Replicability Analysis (SRA) that took place during the earlier stages of the project, in this document the SRA is carried out covering all five layers that are considered in the standard Smart Grid Architecture Model (SGAM) and are included in the SRA methodological guidelines published by the H2020 BRIDGE initiative, namely component, communication, information, function and business layers, along with explicit analysis and discussion of distinct dimensions within each SGAM layer. In this framework, the particular regulatory, business, technical and societal factors/metrics that may enable or hinder the large-scale implementation of the iFLEX solutions following the categorization of these factors in the five different layers of the SGAM framework are discussed. The evaluation of the aforementioned factors/metrics in the countries involved as pilot sites in iFLEX (Finland, Greece, Slovenia) is also presented, where applicable.

In addition, specific lessons learned from the actual implementation of the iFLEX solutions to the Finnish, Greek and Slovenian pilot sites during the entire project lifetime are presented and discussed. Indicatively, from the technical point of view, it was identified that the wide rollout of smart meters is crucial, as it will enable collecting higher quality data (e.g. eliminating downtime), which will also be validated by the Distribution System Operator (DSO), from a large number of end users. This can serve as a base for the development of improved accuracy models for tools such as Digital Twins. The installation of smart HEMS systems that are able to connect to already installed devices at the end-user premises via wireless network and without interference with concealed electrical installations is an extremely simple, fast and efficient procedure, as a number of measuring and control parameters can be obtained from the devices via already existing communication protocols. Heterogeneity of Building Automation System interfaces is a challenge as regards their interoperability with the main components of the iFLEX framework. It was also concluded that hybrid modelling is a good solution for the HVAC systems, since accurate and robust models can be created without a need to physically model all the details of the HVAC system. Security and privacy can be provided with a very light overhead and access to the iFA resources can be provided in a fine grain manner. Privacy requirements can be fulfilled even if the RAI backend systems are provided in the cloud. Regarding the potential of flexibility provision, heating systems constitute a fair source of flexibility both in terms of power and energy. Automation of the flexible assets, which is based on the end-users' preferences, greatly facilitates the provision of flexibility, as it does not require the physical presence of the end user at the premises to activate or deactivate manually a device. On top of that, automated operation enables avoiding end-users' fatigue, which is caused by multiple interactions with energy and flexibility management applications, such as iFA. From the user interface perspective, the agile approach that was followed for the design and implementation of the iFLEX app, which aimed at developing a user-friendly interface, was found to be efficient and produced high-quality end results.

Regarding the user engagement and acceptance dimension, easiness in recruiting potential end-users is very important to simplify recruitment procedure. A clear pilot user journey and early pilot user involvement in conjunction with a clear and prompt communication to pilot users is of utmost importance, since it provides a lot of benefits, including user satisfaction, early feedback, adaptability, and reduced risk of misalignment. Although potential pilot participants show very strong interest in the beginning in participating in such a research and innovation project, various technical and other restrictions may reduce significantly the number of eligible pilot users and/or their enthusiasm. Among others, the unavailability of flexible electrical loads, the unavailability or poor quality of telecommunication infrastructure or the fact that some electrical infrastructure does not fulfil minimum requirements for the installation of the necessary technical equipment may hinder the flawless installation as well as the testing and validation procedures. Moreover, web/mobile interfaces designed for residents and property managers are fundamental tools for the fulfilment of the project objectives. Feedback surveys was also found to be a good means to collect user experiences about the project and to detect changes in the end-consumers' awareness and consumption behavior. When involving users and personal data, being able to demonstrate data protection and privacy measures that comply with GDPR is of course a key requirement.

Regarding the evaluation of the applied incentive schemes, it was identified that monetary incentives are naturally in the interest of the building owners/end-consumers and they usually depend on the type of the end-consumer (households, businesses). However, it may be almost impossible to alter the billing systems of the electricity supply companies involved in the project to apply customized discounts or any special tariffs related to the incentive policies on end-consumers Exogenous rewards based on an agreed reward mechanism that is not linked to electricity usage or billing but is still designed to motivate users' enthusiastic participation in such innovative DR projects could be a viable alternative, whereas non-monetary incentives to end-consumers can also be successful. Heating systems are a great asset for demand-side flexibility and provide significant monetary benefits, which are naturally higher in case of spot price-based contracts for electricity consumption. Reselling by the provider of the harnessed flexibility in the market gives rise to a different value chain that offers new opportunities and indirectly associates the grid benefit to stronger user and provider incentives. With careful selection of parameters, i.e. incentives budget and flexibility unit resale price (if negotiable) can lead to "all-win" situations, i.e. beneficial for all players involved in the corresponding value chain.

Finally, a roadmap for iFLEX market replication is presented and discussed. The roadmap is based on a list of best practices, recommendations and guidelines that would enable the scalability and replicability of the iFLEX solutions. Some of these best practices, recommendations and guidelines may not refer to actions or improvements that need to be taken by private entities or independent research and development consortia like iFLEX, but they refer to fundamental legal, regulatory or institutional reforms that need to be addressed centrally by the EU Member States. In any case, the implementation of such best practices is deemed indispensable towards mitigating the barriers that hinder the large-scale deployment of demand response in versatile market environments.

For the sake of clarity, the derived set of best practices is separated in different groups and includes the following (summary information):

Legal, regulatory and institutional measures

- *Definition of proper national legal framework for all new entrants in line with European legislation in all EU countries.*
- *Eligibility of all energy resources to participate equally in all electricity market segments and system operation services.*
- *Definition of demand response baseline methodology and remuneration rules.*
- *Definition of legal and regulatory framework for the integration of energy storage systems and electric vehicles.*
- *Establishment of local flexibility mechanisms.*
- *Removal of restrictive requirements for participation in wholesale market segments and other mechanisms.*
- *Access to final customer data.*

Economic measures

- *Target competitive retail markets.*
- *Removal of price interventions.*
- *Formulation of clear, transparent and precise electricity bill.*
- *Availability of retail contracts with time-differentiation for electricity supply cost and network charges.*
- *Application of customized discounts or special retail tariffs to end-consumers participating in pilot projects.*
- *Promotion of exogenous rewards based on agreed reward mechanisms that are not linked to electricity usage or billing.*
- *Non-monetary/redeemable incentives to end-consumers can also be successful.*
- *Implementation of innovative trading schemes between market stakeholders.*

End-consumer recruitment and engagement actions

- *Broad communication campaigns through versatile channels (social media, websites, press).*
- *Clear and prompt communication to potential end-users.*
- *Easiness in recruiting potential end-users.*
- *Extensive surveys to identify technical and/or other restrictions in potential end users' premises*
- *Targeted communication campaigns through messages, emails and reminders to specific groups of consumers.*
- *Select and cluster end-users based on their responsiveness to incentives.*
- *Provide fully functional web/mobile interfaces designed for residents and property managers.*
- *Provide consumers with practical information about the power intensity of different devices supplemented by additional information on lower power substitutes and more energy efficient means of using devices.*
- *Targeted free (or more accessible) energy audits.*
- *Compliance with GDPR.*
- *Collaborative partnerships with stakeholders.*

Technical Aspects

- *Documentation of the system architecture.*
- *Compliance with common standards for system architecture.*
- *Compliance with trust, security and privacy standards.*
- *Wide roll-out of smart meters.*
- *Use of smart HEMS systems that are able to connect directly to already installed devices at the end-user premises.*
- *Ability to wrap diverse home and building energy management systems.*
- *Interoperability of the heterogeneous Building Automation System interfaces with the Resource Abstraction Interface module.*
- *Target heating systems.*
- *Automation of flexible assets.*
- *Use of HTTP Rest and MQTT protocols.*
- *Extend OpenADR for cloud-based communications or DR clients (VENs) managing multiple customers.*
- *Use of the agile approach.*

It is noted that the key points of this document and particularly the final best practices and replication roadmap that would allow for the iFLEX large-scale replicability are also available on the iFLEX website (https://www.iflex-project.eu/).

2 Introduction

2.1 Scope of the document

The purpose of this document is to present the final analysis conducted by the iFLEX project consortium in order to derive a set of best practices and guidelines allowing for the maximization of the potential benefits that could be yielded for various market stakeholders (technology providers, industrial and business partners, market operators, electricity market participants, end-consumers) from the large-scale replicability of the iFLEX solutions.

Since iFLEX project has now been completed, the number of tangible (and intangible) results has increased, mainly after the implementation of Phase 3 (Large-scale piloting) of the project. Specifically, the main goals of this document are as follows:

a) Provide a high-level description of the individual solutions that form the iFLEX framework and which have been developed and implemented in the various countries/pilot sites. The goal is to highlight the iFLEX innovative solutions that could be replicated at large-scale.

b) Provide an in-depth SRA on the particular regulatory, business, technical and societal factors/metrics that are expected to enable or hinder the large-scale implementation of the iFLEX solutions.

c) Present and analyse the lessons learned from the actual implementation of the iFLEX solutions to the Finnish, Greek and Slovenian pilot sites.

d) Provide a roadmap based on a complete set of best practices and recommendations that would allow for the large-scale replication and successful market uptake of the developed iFLEX solutions.

2.2 Structure of the document

The remainder of this document is as follows:

- Chapter 3 provides a high-level description of the individual technological solutions that form the iFLEX framework and which have been developed by the project consortium and implemented in the various countries/pilot sites. The goal is to present the iFLEX innovative solutions that could be replicated at large-scale. The inherent value brought by these technological solutions and which can be offered to various market stakeholders is also identified in terms of the expected benefits for end-consumers, prosumers, energy communities, retailers, aggregators, other electricity market entities and market operators that could be yielded from the large-scale implementation of iFLEX solutions.
- Chapter 4 provides an in-depth SRA on the particular regulatory, business, technical and societal factors/metrics that are expected to enable or hinder the large-scale implementation of the iFLEX solutions.
- Chapter 5 presents and analyses the lessons learned from the actual implementation of the iFLEX solutions to the Finnish, Greek and Slovenian pilot sites during the three pilot phases.
- Finally, in Chapter 6 a roadmap for iFLEX market replication is presented and discussed. The roadmap is based on a list of best practices and recommendations that would enable the large-scale replication and successful market uptake of the developed iFLEX solutions from different perspectives (legal/regulatory, economic, end-consumer, technical).

3 iFLEX Innovative Solutions

3.1 Description of innovative solutions

A high-level presentation of the innovative solutions that have been developed by the iFLEX consortium is illustrated graphically in Figure 1 and is further described below. In fact, these solutions constitute the core tangible developments that may be subject to large-scale replication. A more detailed description of these items can be found on the relevant deliverables of the technical Work Packages (WP) 2, 3 and 4.

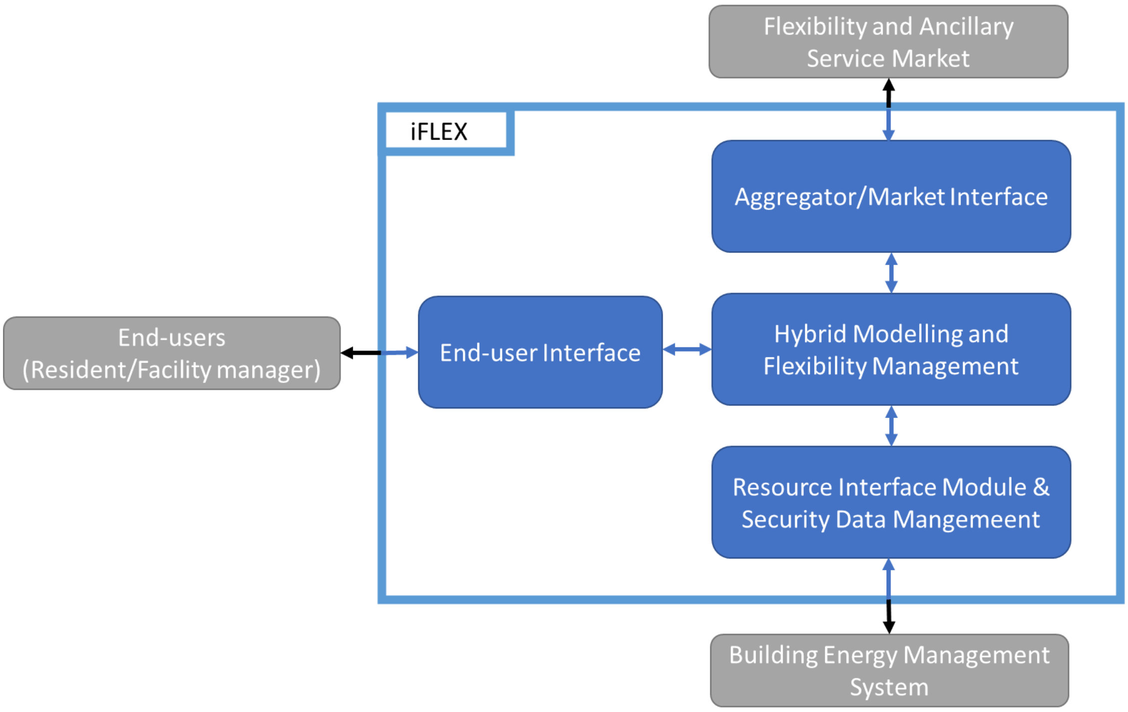

Figure 1: The main categories of tangible results of the iFLEX project

iFLEX Assistant (iFA) is an innovative software agent solution that facilitates consumer participation in demand response. The iFLEX Assistant can learn consumer behavior and the dynamics of their premises to provide optimal and personalized flexibility management for the consumer. Furthermore, the iFLEX Assistant provides consumers with natural and seamless ways for communicating their requirements and preferences to tailor the flexibility management according to their needs. It also enables the end-users to manage their household or building optimally, according to predefined goals and constraints. Goals can be defined in terms of costs, PV generation utilisation, environmental parameters, external incentives, DR signals, etc. Constraints reflect technical limitations and user comfort and social preferences.

Two types of end-users are supported, building and household end-users. The iFLEX Assistant supports the wrapping of a number of building and household energy management systems which enables accessing data details as well as control capabilities of managed devices. The iFLEX Assistant exports interfaces for control and management of end-user iFLEX Assistant instances as well as aggregator and market interfaces for participation in diverse DR programs. Primary goal of the iFLEX Assistant is to facilitate end-user self-management and participation in flexibility markets. Machine Learning (ML), Artificial Intelligence (AI) and advanced control techniques are used to help the end-user to effortlessly balance between his/her goals and constraints for his/her own benefit and for the benefit of the entire grid as well.

iFLEX Framework: The iFLEX Framework is a collection of libraries, tools and configuration scripts that provide means for the development and deployment of iFLEX Assistants into consumer/prosumer premises. The iFLEX Framework consists of the following individual components (modules):

a) Resource Abstraction Interface & Security Data Management,

b) Hybrid Modelling and Flexibility Management,

c) End-user Interface, and

d) Aggregator/Market Interface,

Each of these modules is briefly described as follows:

- **Resource Abstraction Interface & Security Data Management:** The Resource Abstraction Interface module (RAI) integrates external Building Management Systems (BEMS), Home Energy Management Systems (HEMS), and a variety of external data, including weather data and CO_2 emissions services. The RAI interfaces provide both access to the BEMS/HEMS data and mechanism to control flexible assets via HEMS/BEMS. The RAI provides access to available data and controls in a unified manner across all HEMS or BEMS systems through a RESTFul Application Programming Interface (API).

  The Security, Privacy and Trust module provides mechanisms to create system entities' identities, build trust relationships between them and provide security and privacy guarantees for the entities' data and control capabilities of their homes and devices. The module consists of a number of connected security modules providing secure communication, entities authentication and access control to entities and system resources.

  The analytical specifications and technical implementation of the Resource Abstraction Interface and Security Data Management modules are described in deliverables D4.3 and D4.8, respectively.

- **Hybrid Modelling and Flexibility Management:** The Hybrid Modelling and Flexibility Management solution comprises tools for consumer/building modelling and automated control of flexible assets. The models developed in the project create a digital twin of the consumer(s) and their premises and provide two main benefits:

  - The models allow to perform model-based control of the flexible assets and adjust the actions so that they are optimal with respect to consumer goals and preferences in the given market setting.
  - The models make it possible to forecast the baseline, flexibility and response to flexibility signals at the consumer level more accurately. This allows for the evaluation of the impact of individual consumers as well as the optimization of the flexibility management on a consumer level.

  Furthermore, the accurate forecast and capability to activate flexibility, in a more deterministic manner, enables aggregators and utilities to utilize demand-side flexibility for balancing the power grid.

  The analytical specifications and technical implementation of the Hybrid Modelling and Flexibility Management solutions are described in deliverables D3.3 and D3.9, respectively.

- **End-User Interface:** The End-User Interface (EUI) enables the interaction of the targeted end-users (individual home & apartment residents as well as facility managers) with the iFLEX Assistant. Web and mobile applications have been implemented. Key features of the end-user web and mobile applications include the following:

  - Capture user preferences and constraints concerning managing the energy and flexibility of the premises.

- Provide deeper insights into energy data, energy tariffs and participation in flexibility actions, as well as in the respective remuneration for their engagement in offering flexibility services.
- Control through parameterising the desired level of autonomy and customising the interaction with it.

The analytical specifications and technical implementation of the End-User Interface are described in deliverable D3.6.

- **Aggregator & Market Interface:** The Aggregator and Market (A&M) Interface module is able to communicate the flexibility potential of the iFA end-users, as provided by the Automated Flexibility Management (AFM) module, to the external DR system. As regards flexibility signals, also known as DR Events, the A&M Interface receives them, forwards them to other internal components, such as the EUI and AFM modules, and communicates the response to the external DR system. In case the iFA end-user participates in an explicit DR event, the A&M Interface receives flexibility validation data from the RAI and communicate these data to the external DR system. In parallel, the A&M module assesses the participation of the iFA end-user in an explicit DR event and exposes the outcome of the assessment to the external DR system. Thus, the iFA can provide a value-added service to Aggregators.

  Furthermore, the A&M Interface is able to receive a DR report from the external DR system in case of explicit DR and provide access to the information of this report to the iFA end-user. DR-related historic data are retained by the A&M Interface, so that iFA end users can track their actions and rewards at all times. As concerns tariff-related functionalities, the A&M Interface is equipped with the ability to receive the network, retail electricity and district heat tariffs from the relevant market APIs and provide access to these tariffs to both iFA end-users and the AFM module.

  The analytical specifications and technical implementation of the Aggregator & Market Interface are described in deliverable D4.6.

3.2 Offered value to market stakeholders

In general, the large-scale implementation of the aforementioned iFLEX solutions that form the entire iFLEX framework can have a positive impact both on the society as a whole and on individual market entities as well, as shown in Figure 2.

In general, an electricity system that operates with significant DR resources is expected to allow for higher shares of RES penetration and reduced electricity wholesale market prices. This combination shall translate to lower energy tariffs for all end-users. But most importantly, the continuous reduction of electricity production by coal-fired and other conventional thermal generating units (such as gas-fired units) will lead to notable environmental benefits, among which the reduction of CO_2 (and other) emissions can be identified. Besides these, other more specific value sources for the market stakeholders are analyzed below.

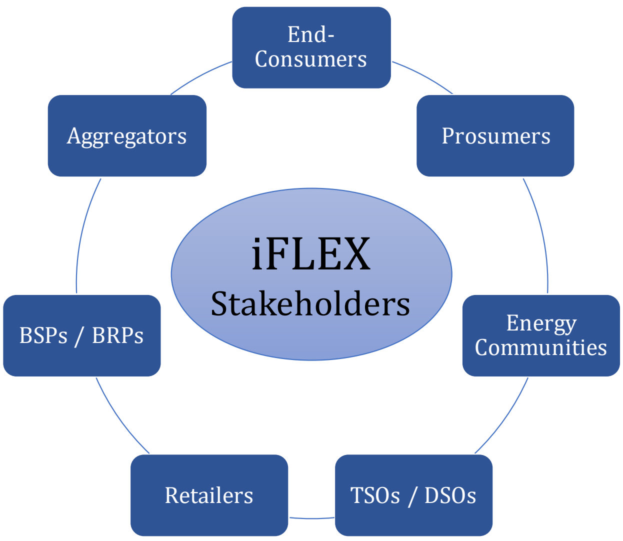

Figure 2: iFLEX Stakeholders

3.2.1 End-consumers

End-consumers can be roughly categorized according to the voltage level, namely High-Voltage (HV), Medium-Voltage (MV) and Low-Voltage (LV) users. HV customers are usually characterized by constant electricity consumption, while MV and LV users present a variety of consumption patterns according to their type, e.g. households, businesses, or their subcategories e.g. bakeries, super-markets, offices, etc. Value will be created mainly for MV and LV consumers according to their flexibility capabilities, which also vary according to their electricity consumption patterns.

The large-scale implementation of the iFLEX solutions is expected to be beneficial for the end-consumers in four ways, as follows:

- *First,* end-consumers will be provided with incentives to shift their electricity consumption schedules. These incentives may include a monetary part, which could be provided to convince them to alter their consumption profile towards meeting a specific goal (e.g. maximization of RES generation, minimization of CO_2 emissions, etc.).
- *Second*, the end-consumers' total energy consumption might be reduced, thus also affecting positively the electricity bill, although this is not the primary target of DR schemes. This could happen when the DR event aims at turning-off a specific device for a specific amount of time (load shifting). In this case of load shifting, it is assumed that the end-consumer will use this device once the DR load shifting event has ended. However, in some cases, the end-consumer may no longer need to use the device which will thereby lead to a reduction of the end-consumers' daily energy consumption (as compared to the case where a simple load shifting takes place).
- *Third*, the Retailer could employ multiple tariffs within the day, in the framework of Time-of-Use (ToU) or Real-Time Pricing (RTP) models. If part of the consumption is shifted, it would be reasonable to assume that it will be moved to other time periods of the day when electricity consumption is less costly, thus generating savings on the end-consumers' electricity bill.
- *Fourth,* besides the aforementioned direct benefits to end-consumers, in the future, network operators are expected to take advantage of smart metering infrastructure to introduce variable tariffs also for network operation. Therefore, it is highly probable that there will be time slots during the day during which the network charges will be lower or even zero. It is likely that, especially under specific occasions, these time slots will coincide with DR events. In these cases, not only will the end-consumers benefit by the direct incentives offered to participate in DR, but the regulated network charges' part in the electricity bill will also be reduced. An indicative example of this would be the event of having excess wind plants' generation during the night, when very low consumption is usually observed. In that case, if RES production becomes higher than electricity consumption, it would be more advantageous to schedule the activation of DR resources (e.g. activation of electric vehicles' charging or thermal accumulators) to increase consumption at night in order to make use of the low-cost renewable energy rather than resort to wind power generation curtailments. Moreover, increased electricity consumption during such an event would lead to decreased consumption during other time intervals, when unfavorable power system operating conditions may prevail (e.g. lower RES share, network congestion, etc.). In this example, the network benefits due to decreased network use during peak hours (e.g. noon) and increased network use during off-peak hours (e.g. night) coincides with the system benefit from the electricity generation cost perspective (i.e. taking advantage of the less costly and eco-friendly RES resources) and finally the end-consumer benefits from reduced costs.

To expand it further, the large-scale replicability of iFLEX will create a large pool of flexibility resources originating from the end-consumers that could be re-sold in the real-time balancing market. Apart from its usefulness as a controllable power source, this pool can also be considered as a significant amount of controllable energy. This may decrease the system load when demand reduction is requested or (more rarely) increase the system load when demand increase is requested (e.g. due to the presence of excess RES generation that would otherwise need to be curtailed). This amount of energy can be purchased or sold in the market either a day before its actual usage (day-ahead) or even during the day (intraday). In the first case, it could serve as a means of increasing RES penetration in the energy mix and in the latter as a means of preserving the power system stability. Therefore, end-consumers can create value in multiple levels under the large-scale iFLEX replicability. This multi-level usefulness will boost the gains of end-consumers due to all four factors mentioned in the previous paragraphs because part of the value generated is transferred to them.

The large-scale adoption of the iFLEX Assistant is also likely to create more (indirect) value for end-consumers, since it will allow for the permanent withdrawal of large conventional thermal generating units with high environmental footprint and/or electricity production cost that currently provide either electricity production or system services (e.g. provision of system reserves and/or balancing energy), since such system services will now be provided (in part) by the end-consumers. This is expected to significantly reduce the power system operation cost and, in turn, boost the earnings of market players (e.g. Retailers, Aggregators) and, eventually, the savings/earnings of end-consumers. The latter shall, therefore, play a leading role, and reap part of the profits in this case as well.

3.2.2 Prosumers

Prosumers are essentially consumers with additional production capabilities using mainly rooftop photovoltaic (PV) systems. Prosumers are differentiated from the end-consumers, since prosumers' goal is to balance the energy consumed with the energy produced locally by their own production facility. Successful minimization of the net energy balance (which is defined as "electricity withdrawal from the grid minus electricity injection to the grid") leads to the maximum monetary profit. In this context, DR can only bring value if it is incentivized, as in the consumers' case. However, another notable component of the electricity bill is the network fees, which are still applicable for those cases where PV production is not perfectly matched with the household electricity consumption. This is the case when household consumption exceeds the local RES production and the household must absorb the remaining amount of electricity from the grid. The iFLEX solutions could also assist towards facilitating the matching of production with consumption and, therefore, lead to a notable reduction of the associated network fees.

The wide penetration of the iFLEX Assistant in the electricity system could, however, create additional value for the prosumers when compared to the end-consumers. Consumers have the ability of increasing or decreasing their consumption, but prosumers are also able to produce power and inject it into the grid, if necessary. In this sense, prosumers are able to provide additional flexibility as compared to pure consumers. Prosumers could, as a result, increase their profit by absorbing more of the incentives provided to the user base, or new schemes could be established to compensate production in certain times of the day, thus further improving the current net metering scheme in their favor.

3.2.3 Energy Communities

Energy Communities mainly consist of producers, consumers or prosumers. By definition they provide environmental, economic or social community benefits for their shareholders, rather than pure financial profits. By adopting a holistic solution such as the iFLEX solution, various value topics can be foreseen. With the iFLEX Assistant, the community self-consumption can be optimized, and thus energy self-sufficiency will be promoted. Indeed, if the objective of the energy community is to provide energy autonomy to the participants, then this target will be easier to achieve by either putting less strain on already existing storage means (less maintenance costs) or by making less investments in RES or storage resources. The Energy Community will be more sustainable and shall better serve the goal of environmental protection, since the benefit of distributed RES will be harnessed to a higher extent when applying the iFLEX solution. Finally, in the point of connection with the grid, energy exchanges will be minimized, thus leading also to the reduction of network fees.

The large-scale replication of iFLEX is going to lead to a large number of users that will be equipped with an application (namely, the iFLEX Assistant), and, in turn, will be familiarized with the ability of using their energy consumption as a means of creating profit and/or environmental sustainability. In the first phases of user engagement, when the technology is new, a user would primarily be attracted if the incentives are considerable. However, once the population of users is familiarized with the concept and the user base already using iFLEX Assistant is expanded, part of the registered consumers could decide to use the application solely for environmental or social benefits without requiring economic benefits. Energy Communities could at this phase evolve and attract those users, even if they are geographically dispersed. Therefore, the energy communities' purposes would be more effectively served with large numbers of registered users that are characterized by enhanced flexibility capabilities.

3.2.4 Transmission System Operator (TSO) / Distribution System Operator (DSO)

The Transmission System Operator (TSO) and the Distribution System Operator (DSO) will be among the key players that will be mostly affected by the large-scale deployment of the iFLEX solutions. Both these entities suffer from the continuous fluctuations of the electricity flows in the transmission system or distribution network, respectively. Any new technology and solution facilitating steadier and, possibly, lower volumes of electricity flows in the network/system brings numerous benefits to both Operators. In principle, the network usage is expected to be minimized, and this has the following advantages/benefits:

- *Reduction of network losses*: The network losses are calculated proportionally to the square of the current that flows in the network lines. The wide implementation of DR schemes will eventually lead to peak load curtailments, and, therefore, bold energy savings (in terms of lower energy losses) are expected.
- *Reduction of network faults and maintenance costs:* The systematic operation of the network at steadier patterns (without intense fluctuations of electricity flows) will lead to fewer equipment breakdowns, thus the network maintenance costs are going to be mitigated.
- *Reduction of network expansion costs:* Network expansion is usually required when the current infrastructure cannot fully address the connection of new users, especially in terms of meeting their peak loads. Some of these investments, e.g. the construction of new HV/MV substations are particularly costly and their suspension (or cancelling) will be particularly beneficial.
- *Reduction of network congestion:* Among other functionalities, the iFLEX Assistant aims at promoting the match of local production and consumption. The large-scale implementation of iFLEX Assistant would reduce the need to transfer electricity through the distribution and/or transmission grids along long distances and, therefore, the remaining capacity could be used for energy trading. In the transmission system-level, high-capacity interconnections between national power systems will become more and more important in the future, given that it may be more economical to transfer excess domestic RES energy production to other territories. As far as the DSO is concerned, new types of energy-intensive loads (e.g. electric vehicles), if actively controlled through automatic DR schemes coordinated by the iFLEX Assistant, will pose a smaller threat to the stability and reliability of the network. Similarly to consumers' targeting for DR events, the iFLEX Assistant will allow for enabling

the provider (e.g. Aggregator) to distribute the electricity consumption of energy-intensive loads across time. In the case of EV charging, a typical EV would require 2-3 hours of charging that could take place anytime during the night. The iFLEX Assistant could populate nearby EVs and their charging could be initiated consecutively, thus reducing the stress of the local grid.

– *Reduction of generation schedule deviations and provision of system services:* At the transmission grid level, system load demand is forecasted so that the necessary generating resources are committed and dispatched. Inaccurate load demand forecasting along with the stochastic RES generation necessitate the activation of system services (e.g. activation of frequency containment and/or frequency restoration reserves), which, in fact, inject/withdraw additional energy to/from the grid in real-time to minimize the deviations between consumption and production. The iFLEX Assistant could employ its candidate resources to address load demand deviations on the system level, thus allowing for purchasing lower amounts of costly flexibility resources from conventional resources (e.g. large thermal or hydro units). In particular, manual Frequency Restoration Reserves (mFRR) and automatic Frequency Restoration Reserves (aFRR) shall be employed to a lower extent, which is translated to less resources and costs directed in this type of system service.

It should be noted that since TSOs and DSOs are regulated, any cost reduction in their business should be normally transferred also to the end-consumers' base. In other words, the TSO and DSO are not-for-profit companies, but rather organizations whose operation is funded by the end-consumers. The wide use of the iFLEX Assistant (which can be coordinated by a third-party, e.g. Aggregator) is expected to reduce their investment and operational costs and, subsequently, the associated costs transferred to the end-consumers' electricity bill (i.e. through the associated network charges) is expected to be reduced. All aforementioned benefits will become impactful only if the iFLEX Assistant is widely adopted by the end-consumers' base. Obviously, limited numbers of active users would create a marginal positive impact on the network and system operation.

3.2.5 Retailers

The core business of Retailers is to make a profit by selling energy to end-consumers that was purchased from various sources. In general, the sooner the Retailer buys energy, the lower its associated electricity procurement costs will be. On the contrary, if energy is purchased close (in time) to the time period of consumption, e.g. in the intra-day or real-time balancing market, its price is significantly higher. However, Retailers usually resort to last minute options to close/correct their market position, since they are unable to accurately predict the exact amount of load demand day-ahead, week-ahead or months-ahead.

Effective DR schemes, which can be implemented through the widespread adoption of the iFLEX Assistant, could minimize the real-time deviations, so that the Retailers don't resort to "last-minute" costly purchases. This would bring obvious monetary benefits to the Retailers and part of this could be shared with the consumers to incite them in DR schemes. Therefore, the large-scale replication of iFLEX is expected to also boost the value for the Retailers.

3.2.6 Balancing Service Providers (BSPs) and Balance Responsible Parties (BRPs)

The large-scale adoption of the iFLEX Assistant would allow for the engagement of a large number of active users along with the operation of an automated DR tool. Balancing Service Providers (BSPs) and Balance Responsible Parties (BRPs) would have a new source of flexibility that could be cheaper than the existing ones (e.g. activation/fluctuating operation of inflexible conventional resources, such as large conventional thermal units). For instance, instead of increasing production from such inflexible resources to meet an unexpected demand increase, controllable loads could be employed to contribute towards reducing total electricity consumption. Such an innovative demand resource could replace e.g. thermal generating units or battery energy storage units and provide equally effective results. Proper incentivization of users to lower their consumption could be significantly less costly than operating a thermal generating unit or investing in a large-scale battery energy storage system.

A possible future opportunity that could emerge both for the BSPs/BRPs and the end-consumers, without excluding other stakeholders such as the Aggregators, would be the introduction of joint investments on the consumer side. Flexible loads, such as heat pumps or EVs, could be jointly financed by both parties (i.e. BSPs and end-consumers), since the BSPs/BRPs would benefit by a smaller investment for the same service: Instead of building a large generating unit or a battery storage system, they could undertake part of the purchase cost of these flexible loads. On the other hand, the end-consumers would be equipped with devices that are cheaper to run at a lower price as well. Certain obligations could be established to make the investment more secure for both parties, such as an agreement to provide a specific amount of flexibility when requested (e.g. at least 2 hours of flexibility by a specific load every day). Since in this case the iFLEX Assistant would be already widespread, consumers that are the most active in DR could be preferred.

3.2.7 Aggregators

Aggregators are expected to be the entities that are going to benefit more by the large-scale implementation of the iFLEX solutions. Aggregating a DR portfolio is a service that can be resold to several other entities under different schemes. For instance, an Aggregator could alleviate the aforementioned imbalances of a Retailer at a cost. Similarly, it could provide flexibility services on behalf of BSPs or BRPs. It could even contribute to avoiding network congestion in favour of the TSO and the DSO. A controllable load that is evenly distributed throughout the electricity grid can create value in several more ways, such as provision of emergency services, power quality improvement, etc. The Aggregator is the most appropriate stakeholder to group such resources and the iFLEX Assistant is expected to considerably assist towards the collective, reliable and optimal management of all these controllable load resources. Obviously, this business would again create a meaningful value only if a notable number of units (i.e. flexible loads) is actively engaged.

3.2.8 Conclusions

The scale up of the iFLEX Assistant will essentially enable the implementation of DR for a large number of users, thus creating a broad pool of controllable loads that can be employed either in real-time or on a day-ahead / intra-day scheduling framework. The activation of DR will bring a new source of value for all stakeholders. Benefits will be directly applicable in most cases. Moreover, important changes will occur and create new value chains that shall further secure and amplify the profits of their participants. Most importantly, RES usage will be maximized, also mitigating the need for using fossil fuels for electricity generation. A good understanding of the wide range of possibilities of the new iFLEX Assistant technology will enable all those benefits to be fully exploited.

Modifications to the market structure will most likely be required and the players involved should be properly educated. But most importantly, it must be studied how all those different stakeholders and their capabilities can be combined in a way that is sustainable in the long-run without compromising the value that could be optimally generated.

4 Scalability and Replicability Analysis

4.1 General

The following definitions apply:

- ✓ **Scalability**: the capability of a system to increase in size, scope and/or meet a growth in demand
- ✓ **Replicability:** the capability of a system to be replicated in another location or time (context)

The factors that influence and condition a project's scalability and replicability are: a) technical factors, b) economic factors, c) legal/regulatory factors and d) stakeholder factors (stakeholder acceptance).

The former two are considered as "*technical scalability and replicability analysis*", whereas the latter two are considered as "*non-technical scalability and replicability analysis*" (i.e. non-technical factors).

Generally speaking, the analysis of technical factors is used to determine whether it is technically feasible to scale up and/or replicate the solution. The analysis of economic factors helps to determine if it is economically viable, and finally the analysis of the legal/regulatory and stakeholder factors is related to whether the regulatory and social environment is suitable (Sigrist et al., 2016).

In short, the Scalability and Replicability Analysis (SRA) helps to identify any barriers (and drivers) for scaling-up and replicating solutions as well as to formulate a roadmap based on the SRA and is, therefore, a useful and strategic tool.

The overall purpose of the SRA is precisely to identify the constraints, drivers and inhibitors for the iFLEX scalability and replicability. Based on these findings as well as on the lessons learned from the project and the pilot validation, a guideline strategy for the implementation of iFLEX in other contexts has been formulated and presented in Chapter 6. The guidelines are based on what is now considered the standard Smart Grid Architecture Model (SGAM) illustrated in Figure 3.

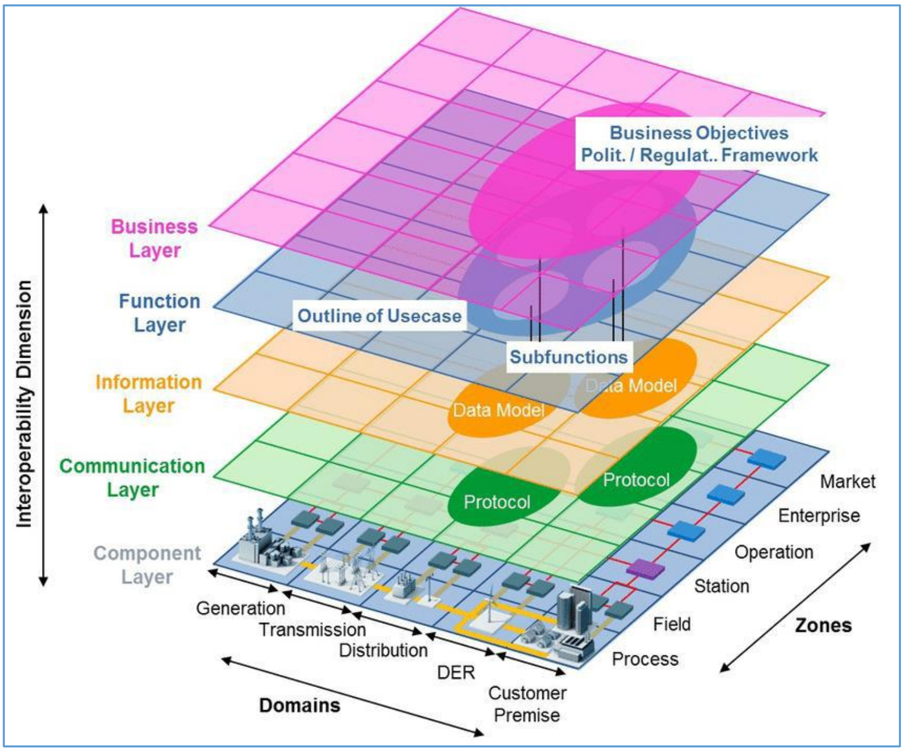

Figure 3: SGAM framework (CEN-CENELEC-ETSI, 2012)

The SGAM framework consists of five (5) interoperable layers, as follows (Bruinenberg et al., 2012):

- **Business Layer**

  The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Business capabilities and business processes can also be represented in this layer. In this way, it supports business executives in decision making related to (new) business models and specific business projects (business case) as well as regulators in defining new market models.

- **Function Layer**

  The function layer describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality, which is independent from actors.

- **Information Layer**

  The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.

- **Communication Layer**

  The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.

- **Component Layer**[1]

  The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes system actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.

4.2 SRA overview in iFLEX

The SRA layers and dimensions pictured in the SGAM (see Figure 3) that have been addressed in the framework of iFLEX are illustrated in Figure 4 and are further analyzed in the following paragraphs.

4.2.1 Business layer

The SRA of the business layer in iFLEX includes the following dimensions: a) Regulatory factors, b) Economic factors, including business models, and c) Stakeholder factors.

[1] BRIDGE found that the component layer is the least commonly addressed layer in the previous projects (and in most cases purely qualitatively).

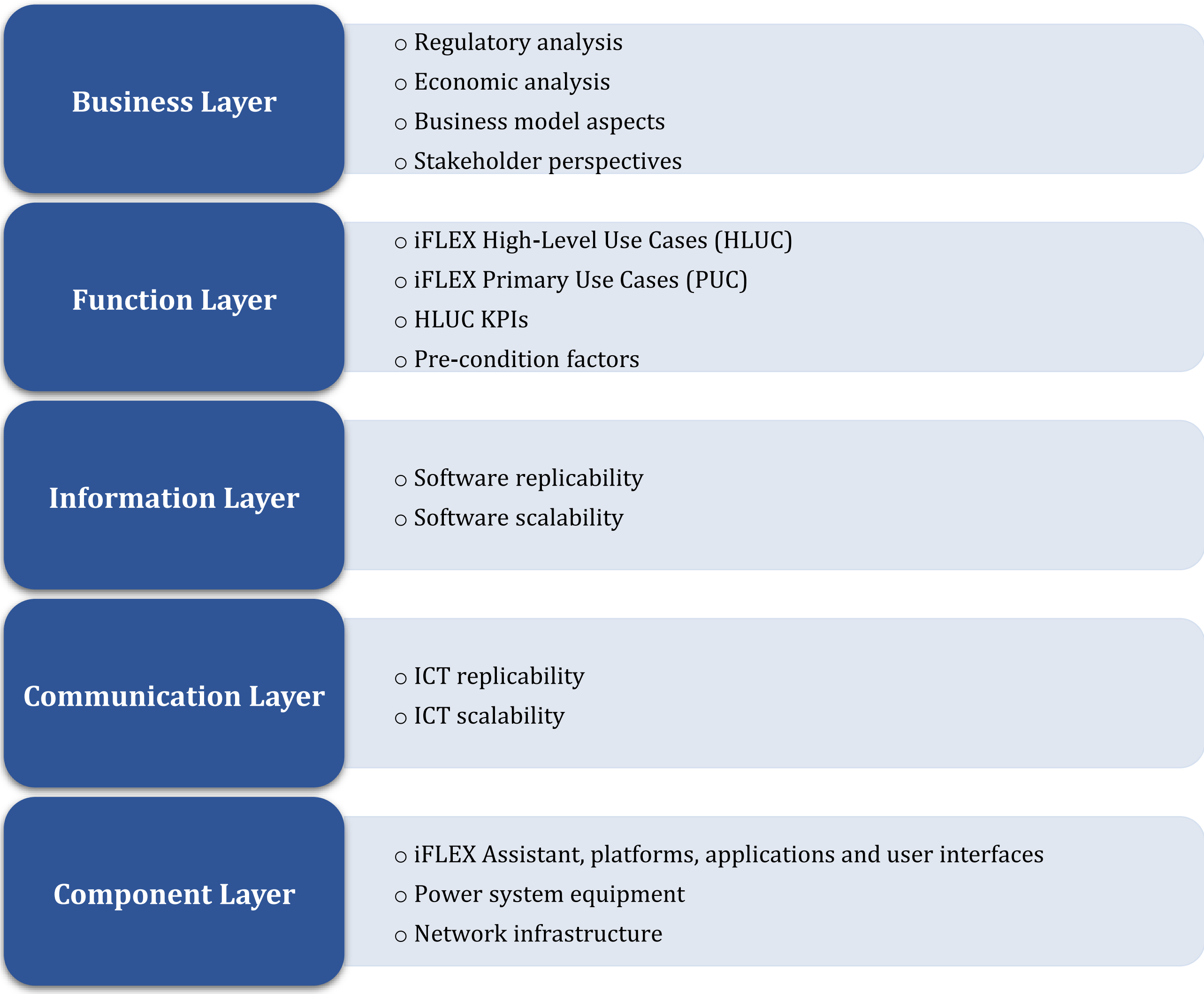

Figure 4: SGAM layers and dimensions addressed in iFLEX SRA

These dimensions/factors are interdependent, and their interaction has also been considered in the SRA. The SRA for the business layer has drawn on analysis and results from the WP5 “Consumer engagement, incentive mechanisms and economic sustainability”, particularly with respect to the analysis of economic factors and business models. A full analysis of European and national regulatory frameworks is out of scope for this project, instead the business analysis focus on some key regulatory drivers and barriers for the replication of iFLEX whether related to market structures, economic factors, or stakeholder acceptance. For each of the aforementioned dimensions of the business layer, the SRA analysis is presented below.

4.2.1.1 Regulatory analysis

- <u>Appropriate legal and regulatory framework for the active participation of DR in the wholesale market</u>:

  The Directive (EU) 2019/944 requires that Member States develop an appropriate regulatory framework for active customers, market participants engaged in aggregation, and citizen energy communities to effectively enable the active participation of demand response. The main roles and responsibilities of these new actors should have been transposed into national legislation by late 2020. However, their implementation is still work in progress in several Member States. It is noted that a full implementation of the main roles and responsibilities in the primary national legislation does not necessarily ensure an appropriate regulatory framework for these actors. A secondary legislation defining more detailed duties, rules, and procedures is also needed to ensure that these new actors can perform their activities in an efficient, non-discriminatory, and transparent manner.

The Member States must ensure non-discriminatory access to all market participants, individually or through aggregation, including demand response, in all wholesale electricity markets segments (i.e. day-ahead market, intra-day market and balancing market). When TSOs re-dispatch resources using a market-based mechanism or DSOs procure congestion management services in their areas, such procurement procedures must also be open to all market entities, including demand response, in accordance with a non-discriminatory procedure. To ensure non-discriminatory access, the national rules should legally allow all energy resources to become eligible parties, i.e., market participants. This legal eligibility does not refer to whether the resources meet the technical or financial requirements to participate in wholesale electricity markets and system operator services or whether they currently participate.

Most distributed energy resources are not expected to directly participate. They would rather offer their flexibility through market participants engaged in aggregation, hence the importance of allowing these new actors to become market participants. Even though some electricity markets and system operator services allow aggregation of resources, it is underlined that more than often this aggregation is only allowed under specific conditions, e.g., only some types of energy resources can be aggregated under the same group to provide balancing services. For instance, in some countries there are specific provisions for the participation of large (industrial) consumers (which are usually connected to HV and MV levels) in the wholesale market. However, there is still no appropriate regulatory framework for the involvement of small end-consumers (households and small businesses) in the wholesale market through an associated entity (e.g. Aggregator).

Therefore, the establishment and operation of a detailed legal and regulatory framework for the active participation of DR in the wholesale market lies among the most important drivers for the successful scalability and replicability of the iFLEX solutions. This is what will primarily unlock the huge potential for the operation of DR schemes to a wide consumers' base, through the large-scale implementation of the iFLEX solution.

In the above context, Greece has recently introduced specific regulatory provisions for the participation of DR as either an individual Dispatchable Load or through a DR Aggregator but only in the framework of the real-time balancing market. In addition, at this moment, only large consumers (e.g. industries or large commercial facilities) that are already equipped with 15-min telemetering infrastructure are able to participate in the balancing market through DR Aggregators. The wider participation of DR in other wholesale market segments (e.g. day-ahead market) as well as the participation of DR through aggregation of demand resources connected to the LV level (e.g. households and small businesses) is foreseen to be realized in the near future, provided that the wide implementation of smart metering infrastructure in LV consumers proceeds satisfactorily.

In Finland, there is already an operational regulatory framework for the participation of DR in the market, since there are eight (8) marketplaces for DR participation in Finnish markets, namely Day ahead market, Balancing energy market, Frequency Containment Reserve for Disturbances (FCR-D), Intraday market, Frequency Containment reserve for Normal Operation (FCR-N), Fast Frequency Reserve (FFR), Peak load reserve and Automatic Frequency Restoration Reserve, as illustrated in Figure 5.

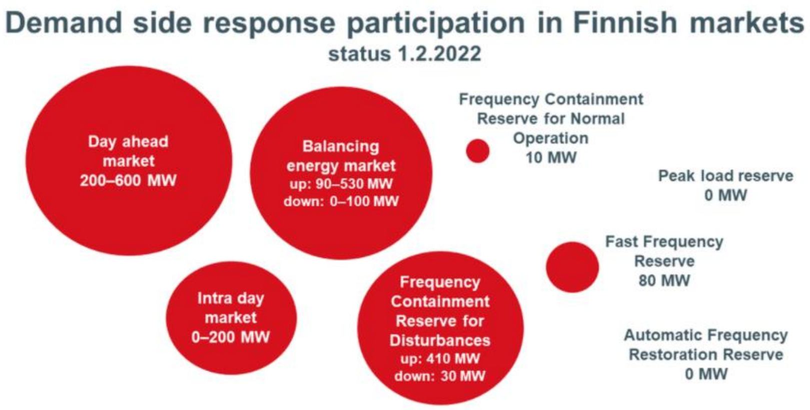

Figure 5: Marketplaces for DR in Finland (Fingrid, 2022)

In Slovenia, the Slovenian Market Operator Borzen introduced a formal independent aggregation model (IAM) already in 2019. This was created in order to regulate aggregated flexibility that was provided in terms of frequency restoration balancing services (mostly for secondary reserve: aFRR and tertiary reserve: mFRR) and had been present in the national framework even before the EU Clean Energy Package was transposed.

Small end-users in Slovenia can participate in all markets through aggregation. In case end-consumers wish to participate directly in the market (not through an aggregator), which is highly unlikely, then the user has to be part of a BRP scheme, which entails reserving substantial funds for financial coverage.

Aggregated residential end-consumers can access the wholesale market but in a limited scope of regulatory sandbox only. The participation of residential end-users is possible in the TSO balancing market. However, neither TSO nor DSO are allowed to play the role of an aggregator. The residential end-users can participate in balancing and ancillary electricity services through the TSO and DSO DR programs based on compensation and implicit flexibility mechanisms available through NRA's Research and Innovation sandbox. Within qualified pilot projects, the TSO and DSO can play the role of aggregators in order to test the potential of the aforementioned DR mechanisms.

The development of the demand side flexibility market is being supported in Slovenia, and the participation of the smallest customers (residential customers and small businesses) is encouraged. The rollout of smart meters was the most advanced at the distribution level and is planned to be completed by 2025. However, Slovenian suppliers request (jointly) that independent aggregators be charged the full cost of compensation to suppliers of curtailed consumers, thus breaching the spirit of the EU Directive by creating a barrier for DR aggregators.

- <u>Availability of DR baseline methodology and remuneration rules:</u> An important barrier for the actual implementation and settlement of DR programs is the absence of a specific baseline methodology regarding the participation of DR in the Balancing Energy Market that should balance integrity and accuracy. If a baseline methodology is not available, consumers cannot be remunerated for the flexibility they provide. This may entirely block the DR market, since consumers will not be actually remunerated for the services they deliver. On top of this, a lack of clear remuneration rules will act as a barrier for consumer participation. The implementation of sustainable remuneration schemes are important market and business aspects affecting all stakeholders. In addition, the calculation of the baseline should be transparent, since it may serve as the basis for (a) the activation of Balancing Energy Offers during the clearing process, and (b) the ex-post verification of activation of the Balancing Energy Offers submitted by the DR resources in the Balancing Market. In addition, the participants representing the DR resources should be able to submit balancing energy as well as reserve capacity offers on a voluntary basis and according to their technical capabilities. An obligatory participation of such units in the Balancing Energy Market as well as in the Ancillary Services Market based on their maximum availability (similar to the one applying for conventional Generating Units) is expected to prove a major entry barrier for DR resources in the above market segments. (see iFLEX D5.1, 2021).

In this context, Greek Independent Power Transmission Operator (IPTO) has already issued a detailed baseline load calculation methodology for the participation of DR in the Balancing Market. However, this is currently applicable only to HV and/or MV consumers, since the absence of the necessary infrastructure in the LV users (e.g. smart meters) to render electricity consumption measurements available in finest time resolution in real-time (e.g. every 15-min) does not still allow for the wide implementation of DR schemes in the massive LV end-consumers' base.

In Finland, there are several ways to validate the baselines in DR markets presented in 4.2.1.1. For instance, If the plant has an adjustable target value, the baseline power corresponds to this target value. In this case, the baseline power is determined by the target value and does not include any changes in the target value due to the activation of reserves. In FCR-D and FFR, reserves may be activated based on the power level immediately before the activation, assuming it represents the baseline at that moment. These reserves are activated during disturbance situations, and their activation duration is typically brief. Consequently, any changes in the baseline during activation can be overlooked. With this method, FCR-D downwards provision doesn't need to use available power. The verification process involves analyzing available power deviations and calculating the normalized root-mean-square error (NRMSE). The NRMSE should not exceed 5%, indicating the acceptable level of deviation from the normalization power. (Fingrid, 2024).

In Slovenia, the flexibility market for DSOs has not been established yet. However, in 2022 the distribution network operators commissioned a study on flexibility services in the power distribution network (EIMV, 2022), where the authors propose two scenarios of determining the baseline. Billing for the rendered service is performed monthly on the basis of 15-minute billing counters data. For billing purposes, counter measurements can be delivered the next day. Depending on the roles of the register of flexibility sources, the calculation of the baseline is performed by the register or the distribution operator.

In the first scenario, the flexibility resource register receives counter measurements and determines the quantity delivered energy. Flexibility register calculates the baseline and sends information about the amount of delivered energy to the distribution operator and to the flexibility provider who performed the service. In the event that both stakeholders agree to a certain amount of energy, the flexibility register provides the market operator with information about the amount delivered energy. Otherwise, the process of coordination and verification of measurements is initiated. Market operator evaluates the flexibility service and sends an invoice to the distribution operator for the service rendered.

The second scenario assumes that the flexibility register has no role in the calculation and gives the base load curve (baseline) and the amount of delivered energy is calculated by the distribution operator based on counter measurements. The algorithm for calculating the baseline must determine "acceptable authority' and must be accessible.

The market operator receives information about the quantity delivered from the distribution operator energy and requires confirmation from the flexibility service provider. When the service provider sends his consent, the market operator evaluates the rendered flexibility service and sends an invoice distribution operator. If the flexibility service provider does not agree with the calculated quantity energy, the coordination process begins.

- Availability of regulatory framework for the integration of battery energy storage systems and EVs: Battery energy storage systems (BESS) and EVs lie among the most prominent resources that are expected to provide large amounts of flexibility in the future power systems along with DR resources. Allowing BESS and EVs to inject/absorb power into/from the distribution/transmission system is a purely technical issue that should be regulated accordingly. Therefore, it would be rather beneficial to have an established regulatory framework for the integration of BESS and EVs in the power system, which can act complementarily with DR resources towards maximizing the efficient and economic operation of the grid.

  In this context, DSOs should act as neutral market facilitators and should not own, develop, manage or operate storage facilities nor EV charging facilities, unless they are used to ensure network security and reliability or unless no other market participant, including demand response, can ensure the provision of such services. A national derogation can only be granted if a market-based process did not identify any company willing to provide the same service. If granted, the NRA must revise the decision every few years to ensure that system operators do not hinder market competition from emerging market participants in the energy system. The same applies to TSOs with storage facilities.

  Although this is not directly relevant with the iFLEX pilot sites, since these primarily focus on the development and implementation of DR schemes by conventional loads, during the replicability of the iFLEX solutions it would be useful to include also other flexibility resources such as BESS and EVs. since they are expected to be very effective in providing flexibility.

  In Greece, there is currently no established framework to allow BESS and EVs to actively interact with the grid in the wholesale market framework. Similarly, in Finland and Slovenia there is still not any regulatory framework for BESS or EV integration.

- Local flexibility mechanisms: As already analyzed, considering the growing connection of distributed energy resources (DER) to the grid, distribution networks may face significant congestion or voltage problems. DSOs should take rapid steps for the integration of innovative solutions of grid planning and operation to address this challenge efficiently, as the use of flexibility mechanisms.

  Demand growth and the increase in intermittent renewable distributed generation make grid planning more challenging and uncertain. Relying only on traditional grid investments to cope with the challenge of network expansion could take too long to realize and result in under-utilized costly grid assets, not to mention the technical, social, and environmental obstacles it would face.

  Instead, DSOs could resort to flexibility mechanisms through which DER such as distributed generation, controllable demand, or storage, may support the expansion of the grid, reducing investment needs and DER connection times. Flexibility can be deployed either directly, by an external signal such as a power signal, or indirectly as a response to an economic incentive such as energy price or tariffs.

  Directive (EU) 2019/944 has already established that DSOs are able to procure flexibility services from providers of distributed generation, demand response or energy storage and shall promote the uptake of energy efficiency measures, where such services cost-effectively alleviate the need to upgrade or replace electricity capacity and support the efficient and secure operation of the distribution system. Moreover, flexibility procurement ought to happen, whenever possible, under market-based mechanisms and based on standard products. This demands DSOs and National Regulatory Authorities (NRAs) to address the use of flexibility in the short-term. Hence, the network development plans made by DSOs shall include the use of demand response, energy efficiency, energy storage, or other resources that may be used as an alternative to system expansion.

The implementation of flexibility mechanisms needs an innovative way of planning and operating the network that leads also to new organizational models and cost structure for the DSOs. NRAs still do not have complete evidence about how these innovations are going to impact the power system or the electricity market, and DSOs are not sure about the technical and economic strategy to follow.

Recently, some countries (e.g. United Kingdom, Germany, The Netherlands, Italy) began the creation of "safe spaces" or "sandboxes"; this is the selection of an "area" within a system or market in which a different regulation could apply for a certain period. This allows testing new services and products that are not yet stipulated or permitted under the existing regulation.

Regulatory sandboxes are used to promote entrepreneurship and innovation not only in power systems but within segments of the economy that may have restrictive regulation while keeping comprehensive consumer protection and regulatory oversight in place. The objective is to promote innovation, and so far, there is evidence of successful results. There are concerns as well to pay attention to, like when companies take riskier decisions or also when economic privileges are given to specific firms without extending those same privileges to others, that could ultimately harm consumers.

Market-based procurement of flexibility services requires flexibility providers on one side as sellers, and, on the other side, DSOs as buyers. To date, regulation considers DSOs as regulated neutral parties. Now, they may become a type of Market Operator. For this, regulation needs to establish procedures for flexibility providers to offer a generation capacity or controllable demand, and for DSOs to procure and use these flexibility services (Correa et al., 2021).

- <u>Bidding restrictions for participation in wholesale market:</u> A large minimum product size in the day-ahead and intraday markets and a low time granularity can hinder the effective participation of demand response in these markets. The Regulation (EU) 2019/943 sets that Nominated Electricity Market Operators (NEMOs) must provide products for trading in day-ahead and intraday markets sufficiently small, with minimum bid sizes of 0.5 MW or less so that demand response, energy storage and small-scale renewables, including direct participation by customers, can effectively participate. While Finland and Greece fulfil this criterion, Slovenia still has a minimum bid size higher than 0.5 MW in its day-ahead and intraday markets.

  In addition, market participants should also be able to trade energy as close as possible to real time on the day-ahead and intraday markets. The Regulation (EU) 2019/943 sets that NEMOs must provide market participants with the opportunity to trade in time intervals which are at least as short as the Imbalance Settlement Period (ISP) for both day-ahead and intraday markets. The ISP should be 15 minutes in all scheduling areas unless the NRA has granted a derogation or an exemption. Although in Greece and Slovenia the ISP is equal to 15 min, in Finland (as well as in almost half of EU Member States) is equal to 60 min. By the end of 2025, all Member States shall introduce day-ahead and intra-day market products that will allow market participants to trade in finer (shorter) time intervals which are at least equal to 15 min.

- Participation of demand response in interruptibility schemes and capacity mechanisms: Interruptibility schemes normally refer to national programmes dedicated to demand response, organised by TSOs for temporary load interruption or reduction. Interruptibility schemes aim to ensure a stable frequency in the electricity system or address short-term security of supply problems. These schemes have traditionally contributed to the development of a certain level of demand response at earlier stages. They typically pool only large industrial consumers from energy intensive industries with processes that can be suspended for a limited amount of time. As a result, some design features may hinder the participation of smaller demand-side capacity.

  On the other hand, Regulation 2019/943 sets out that capacity mechanisms:

  i. must be based on a transparent non-discriminatory, and competitive process,
  ii. must provide incentives for capacity providers to be available at times of expected system stress, and
  iii. must be open to the participation of all resources that can provide the required technical performance, including energy storage and demand-side management.

  In theory all capacity mechanisms are designed to be technology-neutral (i.e., all types of technologies are legally eligible to participate); however, some eligibility requirements exclude smaller units. For example, the German strategic reserve has a restriction regarding connection requirements: the units must be directly connected to the maximum voltage level of the transmission system and via not more than two voltage transformations. In practice, this condition restricts entry of distributed energy resources connected to lower voltage levels.

  The minimum eligible capacity for participation, the minimum bid size and restrictions to aggregation can also constitute barriers for the participation of demand response in capacity mechanisms. In principle, capacity contracts should be set with the same provisions for all types of capacity providers to ensure a level-playing field.

  The new Finnish strategic reserve introduced in 2022 is more inclusive of distributed energy resources than the former scheme with respect to the eligibility process: the new mechanism is open to energy storage, the minimum eligible capacity and the minimum bid size have been significantly lowered from 10 MW to 1 MW, and aggregation is now allowed for both generation and demand units.

  In Greece and Slovenia, there is currently no operational capacity mechanism or interruptibility scheme.

- Access to final customer data: The Directive (EU) 2019/944 sets that Member States must specify the rules on the access to data of the final customer by eligible parties. Such data should include metering and consumption data as well as data required for customer switching, demand response and other services (e.g., self-consumption or electromobility). Regardless of the data management model applied, Member States must ensure efficient and secure data access and exchange, data protection and data security as well as provide access to the data of the final customer to any eligible party. Member States must also ensure that the relevant procedures for obtaining access to data are publicly available and that no additional cost is allowed to be charged to final customers for access to their data or for a request to make their data available.

  In most Member States each supplier is only allowed to access data of the final customers with whom they have concluded an electricity supply contract. Accessing data of non-customers is fully restricted without their prior authorisation. However, having access to final customer data subject to its consent is a crucial enabler to allow new actors such as aggregators, offering their services to final customers and promoting explicit demand response or energy efficient measures. To ensure that all eligible parties have the requested data at their disposal in a non-discriminatory manner and simultaneously in line with the Directive (EU) 2019/944, all those eligible parties should be given access (i) to the same type and amount of data of non-customers, and (ii) through the same data platforms or tools to avoid creating undue administrative barriers between suppliers and new actors.

4.2.1.2 Economic analysis

The economic analysis includes a cost-benefit analysis, development and analysis of business models as well as an analysis of the incentive mechanisms. These activities have been carried out in WP5 and the results of the work are now included in the SRA. While the work in WP5 focuses on the three pilot countries (Finland, Greece and Slovenia), evaluating the sustainability of individual services has been performed in a single pilot country and then replicated to the remaining ones to identify economic challenges that may hinder the offering of those services as part of a reference business model.

In the above context, the market preparedness, market maturity, competition level, ease of doing business as well as the constellations of key actors in the energy market, such as the DSOs, TSOs, Retailers, Aggregators, Service Providers and new emerging actors, e.g. Virtual Energy Communities, prosumers etc., who will play key roles in the DR market have been analyzed. In addition, the design and evaluation of incentive mechanisms, both economic and non-economic, have been key to understanding how to encourage consumers to participate in DR as well as how to design mechanisms that can benefit all stakeholders.

One of the key barriers for consumers to offer flexibility through demand response in different electricity market segments is the lack of proper price signals reflecting the value/cost of electricity as a commodity or the respective transmission and distribution network cost in different time periods. Price signals may not be appropriate to all types of consumers and in all situations. In addition, consumers should be protected from being overexposed to price signals, especially during severe energy crises as experienced during the COVID-19 pandemic and the invasion of Russia in Ukraine. Therefore, consumers must always be informed about benefits and potential risks of price signals in their retail electricity contracts, must always be given the right to choose, and must be protected if they are in vulnerable situations.

Some economic aspects that may set barriers or reveal proper price signals that could hinder or enable, respectively, the large-scale replication of iFLEX solutions are as follows:

- Retail market competition: The ease with which a new entrant (e.g., an independent aggregator or a new market player with experience in other markets) can enter the electricity market is highly dependent on a well-functioning and effective competition in the retail market. With a low competitive pressure, incumbents may hold a dominant position that may limit new entrants' ability to compete on a level playing field and to offer innovative and flexibility products allowing end users to benefit from potential costs savings.

  Competitive pressure in some retail markets may be lower owing to a combination of factors, including:

  i. a relatively high market concentration,
  ii. a low entry-exit activity of suppliers and
  iii. a low correlation between the energy component of retail prices and wholesale prices, which may hinder market entry for new entrants.

The Herfindahl-Hirschman Index (HHI) is a commonly used indicator to measure the degree of market concentration. An HHI above 2,000 is a sign of a highly concentrated market. In general, a high number of suppliers and low market concentration are indicators of a competitive market structure. A higher HHI indicates a high entry barrier, and that more competition is possible in the market. HHI is usually complemented with other metrics to assess market concentration. Concentration ratio 3 (CR3) is a traditional structural measure of market concentration measuring the total market share of the three largest suppliers per Member State by volume in the retail market. Figure 6 illustrates the HHI in the household market and the CR3 (market share of the three largest suppliers) in the retail market per volume for all EU countries in 2022 (ACER, 2023). It is shown that the retail electricity market in Greece remains still highly concentrated, whereas in Finland and Slovenia HHI remains below the threshold of 2000, thus indicating that the ability of any market player to exploit market power to the detriment of energy consumers is reduced and consumers can benefit from competition and innovative services offered by some new entrants, such as explicit demand response.

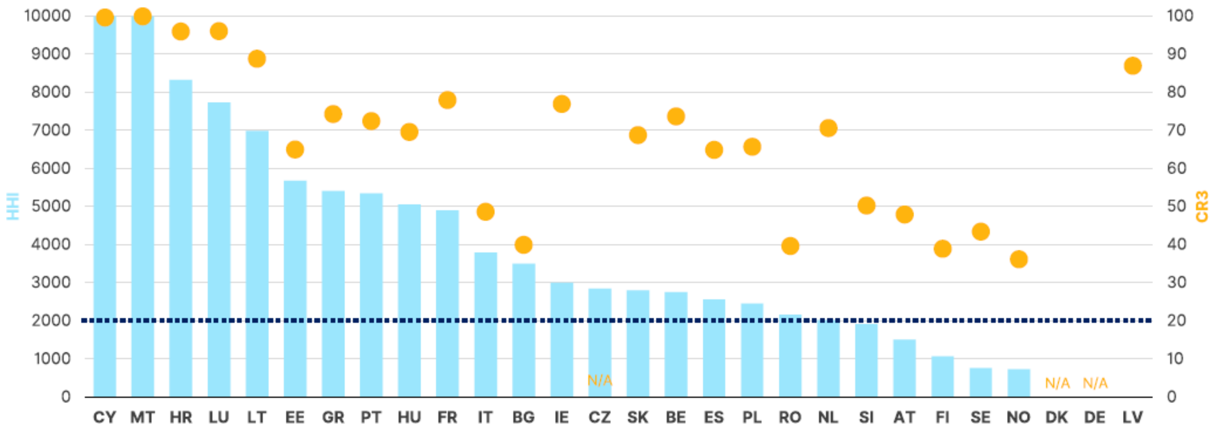

Figure 6: Market concentration metrics (HHI & CR3) for electricity retail market in EU countries (2022) (ACER, 2023)

- <u>Volatility of wholesale market prices:</u> In most electricity market jurisdictions in the EU, the unavoidable use of natural gas as "transitional fuel" towards obtaining the climate neutral energy system in 2050 along with the aggressively increasing penetration of renewable energy in the electricity system have recently caused wholesale electricity market prices to become highly volatile, as shown in Figure 7 (ACER, 2023). In addition, the number of hours in which electricity prices turned negative has increased sharply in most Member States in the first half of 2023 as compared to the same period in 2022, as shown in Figure 8 (ACER, 2023). Negative prices usually occur at times of very high generation from RES plants in combination with low system load demand. They indicate, among other aspects, that some generating resources are not sufficiently flexible to shut-down due to lacking incentives to respond, the demand side is not adequately price-responsive or there is not enough storage to conduct energy arbitrage and signal the high value of flexibility, which is currently not fully tapped into.

  An increase of price volatility and negative prices in the spot markets send clear signals of the need for introducing and operating flexible resources like demand response in the power system. However, end-users may not receive these price signals.

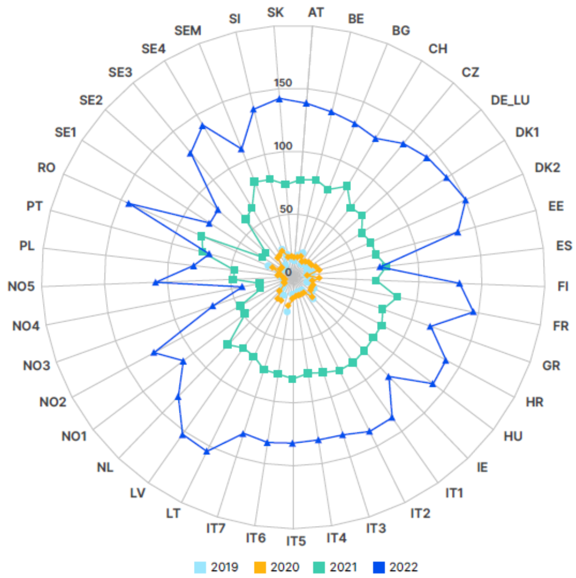

Figure 7: Annual volatility of day-ahead market prices in EU countries 2019-2022 (ACER, 2023)

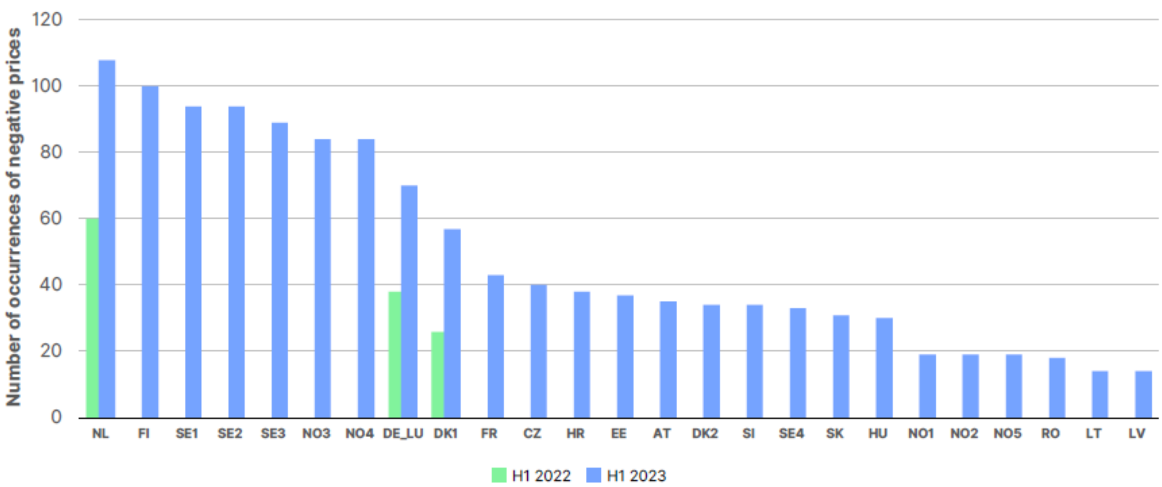

Figure 8: Number of occurrences of negative prices in EU countries (2023 H1 vs 2022 H1) (ACER, 2023)

Greece has heavily relied on the extensive use of natural gas as an intermediate step towards the anticipated full decarbonization of its electricity sector after 2030. In this context, the recent surge of natural gas prices in 2022-2023 in conjunction with the limited available capacity of interconnection lines with neighbouring power systems have led to very high and volatile electricity prices in the domestic wholesale electricity market, thus indicating that there is very high DR potential that could be exploited in the forthcoming period towards relieving end-consumers' electricity charges.

Slovenia uses a variety of primary sources to produce electricity. Nuclear energy accounts for the largest share (around 42%), followed by coal (26%), whereas RES share is 21% and electricity generation by hydro plants covers 11%. Total electricity consumption in 2021 was equal to 22,823 GWh, of which 14,435 GWh (63%) was produced by domestic power plants and 8,387 GWh (37%) was imported. As the price of electricity is traded on exchanges, the price of electricity has also surged in Slovenia, where a significant increase in electricity prices from 80 €/MWh to 125 €/MWh was realized for households. With increasing electricity prices, there will also be a great potential for participation in DR events.

Finland utilizes various energy sources and productions methods to produce electricity. Nuclear power, hydropower, wood fuels and wind power, in respective order, are the most important energy sources for electricity generation (Energiateollisuus, 2023). Finland's total electricity consumption (2022) was 81.7 TWh of which 85% was covered by domestic productions and the remaining 15% was imported (Statistics Finland, 2023). In 2023, the average price of electricity was 56.5 €/MWh. Although the price of electricity remained relatively low compared to other European countries, significant electricity price peaks occur occasionally in Finland as well. For instance, in the beginning of this year, the price of electricity surged to 228€/MWh (Energiateollisuus, 2024a). Electricity price in Finland is influenced by several factors. Large share of wind power is the biggest individual factor. Other factors also have considerable impact on the price such as temperature (cold winters), status of water reservoirs (hydropower), transmission connections and maintenance of power plants (Energiateollisuus, 2024b). Based on these factors, Finland presents also great potential for participating in DR events.

- <u>Price interventions in retail market</u>: Price interventions apply to a wide spread of consumers. In most EU Member States they are not targeted to vulnerable consumers; however, when targeted, they also apply to a huge segment of consumers who are not deemed vulnerable.

  In a context of unusual high energy prices, policymakers certainly face a tough dilemma: on the one hand, how to protect end-consumers from undesirable economic consequences while on the other hand, how to preserve the role and benefits of the price signals to promote demand response. Public interventions in retail prices may have significant downsides for demand response, energy efficiency and competition in retail markets. Public price interventions may create a legal framework that systematically eliminates price signals from the functioning of the market, thus discouraging the provision of explicit demand response and hindering competition in retail markets. This is particularly true when price interventions consisting of regulated prices are set below costs (i.e., without taking into consideration wholesale market prices and/or other supply costs). Nevertheless, artificially low regulated prices (even without ushing them below costs but with a very squeezed margin) also limit market entry and innovation, prompt consumers to disengage from the switching process or providing demand response and consequently hinder competition in retail markets. In addition, they may increase investor uncertainty and impact the long-term security of supply.

  The same happens when Member States subsidise certain technologies to trigger investments, before removing the barriers that were preventing such technologies from finding their way to the market in the first place. Such barriers should usefully be targeted ahead of any additional intervention, thus avoiding 'addressing symptoms before the cause'. Identifying and considering barriers to uptake of distributed energy resources is therefore crucial in national policymaking (see Figure 9, ACER 2023).

- <u>Structure of electricity bill</u>: A low share of the electricity supply cost component in the final electricity bill or a low correlation between the electricity consumption and the network charges does not provide end-consumers with clear price signals nor incentives to enhance their flexibility potential and it blurs the benefits of dynamic or time-differentiated retail electricity contracts.

  In Finland and Slovenia, the electricity supply cost component reaches around 50% of the final amount of the electricity bill, whereas in Greece it is even lower (25-30%), since many other charges that are fully irrelevant to the electricity consumption (e.g. municipal fee, municipal tax, property tax, state fee for the Hellenic Broadcasting Corporation etc.) are also co-collected by the electricity bills.

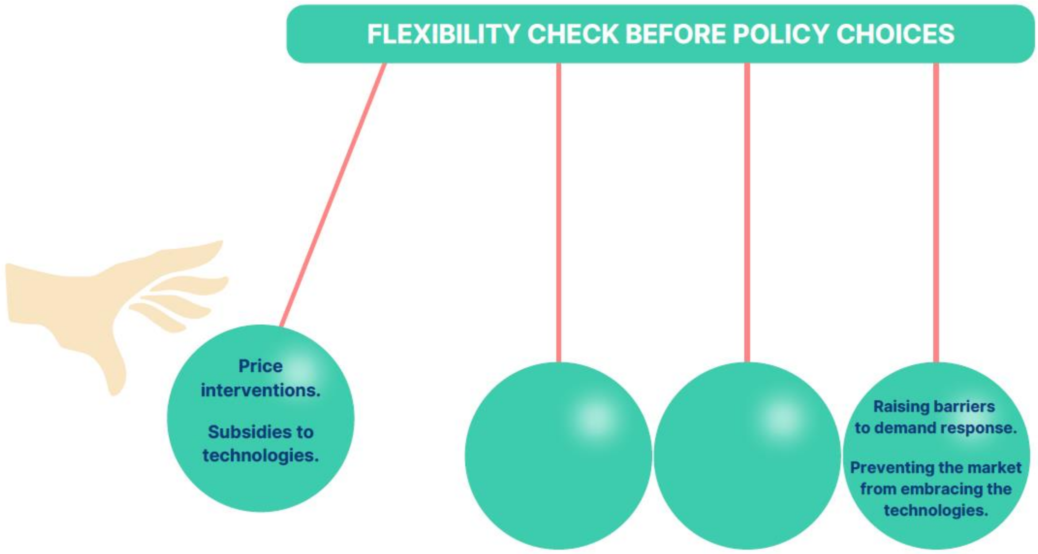

Figure 9: Price interventions raising barriers to demand response (ACER, 2023)

- Availability of dynamic pricing for electricity supply in retail contracts: Time-differentiated retail electricity contracts regarding electricity supply cost can provide adequate price signals to end-consumers as regards the cost of electricity production depending on the time of consumption. The effectiveness of those signals may depend on the share of the energy component in the bill and/or the price difference between the applied periods. However, at a certain point in time, the price signals coming from the energy price and from the network tariffs may strengthen each other or they may be conflicting with each other. In some national frameworks, suppliers may be allowed to offer fixed electricity price contracts to (some of) their customers, where both the energy component and the network tariff component is bundled into a fixed sum. In such cases, no time-of-use signals are provided to these customers, regardless of whether Time-of-Use network tariffs were set or not.

- Availability of variable network charges: Network Operators shall introduce variable tariffs for network operation, instead of static network charges that are currently implemented. In this way, end-users that actively participate in the energy management of their premises should also benefit themselves by exploiting reduced (or even zero) network charges when their energy behaviour contributes towards alleviating network burden. For instance, the activation of DR resources (e.g. electric vehicles' charging, thermal accumulators, etc.) to increase their electricity consumption towards counterbalancing the excess RES production during a specific period of the day (e.g. night) would lead to lower electricity consumption during other time intervals, when unfavourable power system operating conditions may prevail (e.g. higher loads, lower RES share, network congestion, etc.) that in turn, would require higher amounts of electricity transfer in the distribution grid. In this case, the network's relief (in part or as a whole) should be appropriately passed to the end-consumers through the consideration of reduced network charges for these periods.

  One relevant example of such a "win-win" strategy between the network usage and the network charges imposed to the end-consumers/prosumers is the net-metering scheme that is currently implemented for prosumers equipped with RES installations in Greece. In this scheme, there is no obligation to obtain zero net energy balance (which is defined as "electricity withdrawal from the grid minus electricity injection to the grid") constantly. On the contrary, the prosumer can inject and withdraw electricity to/from the distribution network during the day and network (as well as electricity supply) charges apply only to the amount of net electricity withdrawn from the network rather than the total electricity consumption of the end-consumer. In this way, the maximization of self-consumption (i.e. consuming energy mostly when locally produced by the associated local RES facility so that little (or zero) energy is absorbed by the network over an extended time period) allows for the minimization of the regulated (network) charges for the prosumer.

In Slovenia, for the purposes of promoting flexible use of the network, the distribution system operator can set dynamic tariff items for the network fee for the distribution system in various closed geographical areas of the distribution system, so that the user of the system is encouraged to provide net benefits in the use of the network through adapted network usage.

The local dynamic tariff is intended to reduce the consumption of system users at the time of critical peak load of the local network, or to increase the consumption of system users at the time of critical net production of the local network, with the aim of ensuring the greatest possible relief of the distribution system, reducing electricity losses, or ensuring adequate voltage quality in the local network. The onset of dynamic network charge tariff items for the distribution system can be predicted in advance or in real time. At least one hour must be guaranteed between the onset of individual periods of validity of dynamic tariff items. The period of validity and the amount of dynamic tariff items is determined by the distribution operator based on forecasting the operating state, considering environmental factors or the availability of energy from local distributed energy sources.

When determining the local dynamic tariff, the distribution system operator follows specific general principles and objectives of the network fee calculation methodology, as follows:

- The non-transactional postage stamp method is used. This is derived from a system of uniform tariff items, which are charged separately for each pick-up-handover point by the competent electricity operator to the users of the system.
- Network fee tariff items for the transmission and distribution system are calculated on the basis of the network fee determined in accordance with the methodology for determining the regulatory framework.

The market regulator follows the following principles when determining the methodology for charging the network fee:

- the principle of economic efficiency, where the goals of cost reflection, symmetry, predictability, technological neutrality, and minimization of cross-subsidization are pursued;
- the principle of justice, where the goals of fair allocation of costs, fair distribution of costs and gradual introduction are pursued;
- the principle of transparency and
- the principle of simplicity.

The methodology for calculating the network fee in connection with the methodology for determining the regulatory framework ensures the distribution of the eligible costs, which are covered by the network fee for transmission, the network fee for distribution, the network fee for excessive absorbed reactive energy and the network fee for connection power.

The dynamic tariff items of the network fee for the distribution system for working energy shall be determined in such a way that a system user in a specific billing interval is rewarded for reducing or increasing consumption in accordance with the price signal of the dynamic tariff item.

The calculation of the dynamic tariff items of the network fee for each completed geographical area is voluntary for the system user and is carried out exclusively on the basis of a contract with the distribution system operator. The user of the system who concludes a contract with the distribution system operator for billing according to the local dynamic tariff is responsible for ensuring the technical conditions for ensuring adequate adjustment of the demand and assumes the cost risks if they are not provided in accordance with the contractual relationship with the distribution system operator.

- Availability of incentives for the reduction of energy losses: An appropriate mechanism for the provision of incentives aiming at reducing the energy losses in the distribution network would enable the large-scale implementation of the iFLEX solution. At a first level, such a mechanism would allow the DSO to incentivize end-users to shift their electricity consumption in order to minimize peak load consumption that requires higher network utilization in terms of electricity transfer and, in turn, higher energy losses. At a second level, a centralized incentive-based mechanism that targets the DSO needs to be also established: the DSO internalises, to a degree and through this mechanism, the costs that the distribution network energy losses involve for the market. The Operator may obtain additional revenue by reducing energy losses, whilst an increase in energy losses entails a reduction in the revenue that the Operator is entitled to recover through the Network Required Revenue. Thus, the DSO has, in principle, an incentive to take into consideration the cost of energy losses in his network and make efforts to reduce them, to the extent this is economically justifiable e.g. by appropriately incentivizing the end-consumers in this action.

  The correlation of the DSO revenue with the level of network energy losses is based on the introduction of the Loss Incentive Factor (LIF) in the calculation of the Required Revenue. The value of this factor for any given year is established on the basis of energy losses in previous years in relation to predetermined reference levels for these years and the financial penalty (incentive rate for losses) which reflects the cost of network losses for the market (RAE, 2020).

4.2.1.3 Business model aspects analysis

In this section, a targeted analysis of the enablers/barriers that may facilitate/hinder the large-scale replication of iFLEX solutions regarding business model aspects is presented. Most of them are related to organizational and business development aspects of the new market entities (e.g. DSOs, TSOs) and are summarized as follows:

- Consumer support: Electricity markets are rapidly changing, and consumers cannot keep the pace with new forms of electricity bill components or new compensation mechanisms for prosumers (e.g., net billing instead of net metering). One of the findings of D5.6 was that the Energy Services Company business model providing support and/or automated control of some energy hungry appliances could be replicated in all three pilot countries to facilitate consumer engagement.
- Squeezed margins for demand-side flexibility: Increased accuracy of load and/or (RES) generation forecasting (e.g., AI-based solutions) can lead to lower imbalance penalties and, therefore, lower costs that would need to be mitigated via demand-side flexibility. At the same time, increased cost for smart equipment that can facilitate massive-scale demand response campaigns (i.e. those targeting LV customers) in some countries can lead to the need for higher monetary incentives. Indeed, in D5.6 it was found that using demand-side flexibility for mitigating the risks of imbalances in Finland and Slovenia was unattractive for an Independent Aggregator.
- Adaptation of DSOs to new business environment: Adaptation of DSOs to new concepts, technologies and procedures that shall be unavoidably introduced in order to implement DR schemes in a large-scale can be time-consuming, especially in those countries where DSOs employ thousands of people.

Integrating DR support in DSO's responsibilities shall bring many changes and new entries regarding the operating procedures. These two factors, namely changes in procedures and big organization size, create a mix full of challenges, which undoubtedly can lead to severe delays towards the large-scale implementation of DR schemes.

The Greek DSO (Hellenic Electricity Distribution Network Operator - HEDNO) - one of the biggest in Europe – currently has approximately 6,000 employees and is broken down to numerous sectors and departments, which, in principle, makes it rather difficult to effectively run such ambitious projects.

- <u>Recruitment of skilled and experienced personnel:</u> The smooth operation of a telemetering system with DR capabilities will require even more skilled personnel (e.g. electrical engineers, IT specialists, etc.) with combined knowledge and experience on programming, databases, network operation and data analysis. Attracting such skilled personnel may turn to be a challenging procedure for a DSO.

- <u>Challenges in operating local/autonomous grids:</u> Due to their size and complexity, interconnected power systems and network grids usually present increased resilience and flexibility in handling differentiated electricity consumption profiles and, therefore, they generally pose limited constraints on the large-scale integration of DR schemes. However, this is not the case for autonomous power systems (e.g. non-interconnected islands), which present totally different needs and limitations than the main interconnected networks. In such isolated systems the generation mix usually involves low-efficiency and polluting diesel-fueled generating units with limited RES penetration shares. These systems are much more expensive to operate than the interconnected power systems, they have stricter operation limits mainly owing to their inability to rely on cross-border flows to relieve power imbalances in real-time and are more susceptible to faults. The latter two factors are more significant when the island is fully autonomous, i.e. it is not connected with others insular systems to form a larger, yet still autonomous, network. In such cases, DR schemes should be implemented with careful consideration of the local technical and operating limitations and, most importantly, with regard to the specificities that the local production and demand curves present (e.g. irregular load demand patterns as compared to interconnected power systems due to seasonal peaks and off-peaks).

  Such challenging operation of local grids is very common in Greece, which currently comprises over 25 non-interconnected insular power systems. However, there are currently huge investment projects for the interconnection of all insular power systems (Crete, West Cyclades, Dodecanese and North Aegean islands) during the course of the current decade. These projects are expected to reduce operating costs, increase security, eliminate most current operating limitations and allow for the maximum utilization of the high RES potential in Greek islands. The latter is expected to allow for higher and more successful implementation of DR schemes.

4.2.1.4 Analysis/evaluation of the incentive mechanisms

The analysis and evaluation of the incentive mechanisms that were proposed within iFLEX fuelled significant findings regarding the various aspects of the incentive mechanisms that may serve as enablers or barriers, respectively, for the large-scale replication of the iFLEX solution. More specifically:

➢ *<u>Enablers</u>*

- The incentives optimization framework that has been developed in iFLEX is capable of maximizing either the total flexibility to be harnessed or minimizing the expenditure of the provider/aggregator or both. It therefore provides a strong motivation for the provider/aggregator to utilize this scheme in practice.

- Guidelines have also been put in place that mandate the provision of incentives to the users that are at least higher than their minimum acceptable ones. In this way, feasible optimization solutions always ensure profitability for the users as well. Providing value to all stakeholders is crucial for the wider adoption of this framework.
- It has been shown that reselling of the flexibility in the wholesale market creates a new value chain and, effectively, more room for profit for both the end-consumers and the provider/aggregator. Moreover, an indirect coupling of the grid benefit to stronger user and provider incentives is achieved. The market itself provides ample opportunities for revenue and, in turn, allow for the scalability of these operations.
- Regarding the user incentivization schemes, it was indicated that the bilateral trading scheme allows all three stakeholders (end-consumers, DR and RES aggregators) to achieve significant profits if they are properly coordinated. All of them can thus benefit from a deviation, paving the road for a wider adoption of this scheme.
- Under the same scheme, the RES aggregator can follow a "riskier" policy in the Day Ahead Market (DAM) if he is aware that the DR resources are ample. It is a strategic advantage of the RES aggregator to be able to identify this point in advance and act accordingly in the DAM.
- A capable algorithm for the accurate modelling of the user was introduced and found to require a small set of DR event data to converge to the parameters that define the user attitude towards the provision of incentives. This algorithm can be employed in large numbers of users, thus providing high accuracy in the provision of incentives from the provider or aggregator. High precision in the incentives' calculation creates the maximum profit both for the provider and the aggregator.

➢ *Barriers*

- Modelling of the actual user, although it was made easy with the proposed parameter learning algorithm, could possibly prove a challenging case if users change their habits often due to different factors, such as time of day/week/year, weather, special events and others. This would lead to their parameters fluctuating regularly, thus reducing the accuracy of targeting of the provider/aggregator.
- Users that are unresponsive towards incentives are difficult (or, in other words, costly) to engage in DR. If most of the users belong in this category, then a large number of them will be required to achieve the total flexibility target. If the user base is restricted, this could bring an obstacle to replicability.
- This also applies to the case of the bilateral trading scheme. If users are few or unresponsive to incentives, then neutralizing a large deviation can be very costly or onerous. Moreover, in this case, it is critical for the DR aggregator to negotiate high bilateral trading prices to realize the DR program and ensure his profit.

4.2.1.5 Stakeholders perspectives

Consumers are crucial and integral stakeholders of iFLEX project as well as of possible post-project implementations and further development. It is crucial that all stakeholders, especially business stakeholders, understand the following enablers and disablers for large-scale implementation that were derived from public survey, workshops and focus group survey.

- Trust and security: From the project point of view, we estimate the feedback from consumers as positive and a good potential for further development. But on the other hand we can also see certain lack of trust. We estimate that consumers have trust issues regarding their energy providers.

Approximately half of respondents in the iFLEX public survey (2021) are neutral or would not allow their energy provider to regulate specific energy demanding devices in their house (see Figure 10). They would rather allow this automation to be done by digital assistant than energy provider. Reasonably there are still some trust issues related also to digital assistant, but not as much as we would expect, since the technology is new, unknown to most of consumers.

Another trust issue is related to personal data, data privacy, data sharing and control. The issue was raised during the iFLEX focus group survey in Slovenia (2023, see Figure 11) and even prior on workshops with consumers. The end user validation results in the Greek pilot (see section 5 in iFLEX D7.7) also indicated that some users are a little hesitant when it comes to trusting that their personal data is handled securely. Consumers do not fully trust how their personal data (e.g. household data, consumption data and patterns) would be treated, who will be able to see and manage data, who is in control of personal data, etc. Thus addressing privacy and security is one of the most important aspects when going for the large-scale replication of iFLEX or similar solutions. As per focus group survey (2023) results: "*We should strongly emphasise data security and privacy; give users control over the information shared*".

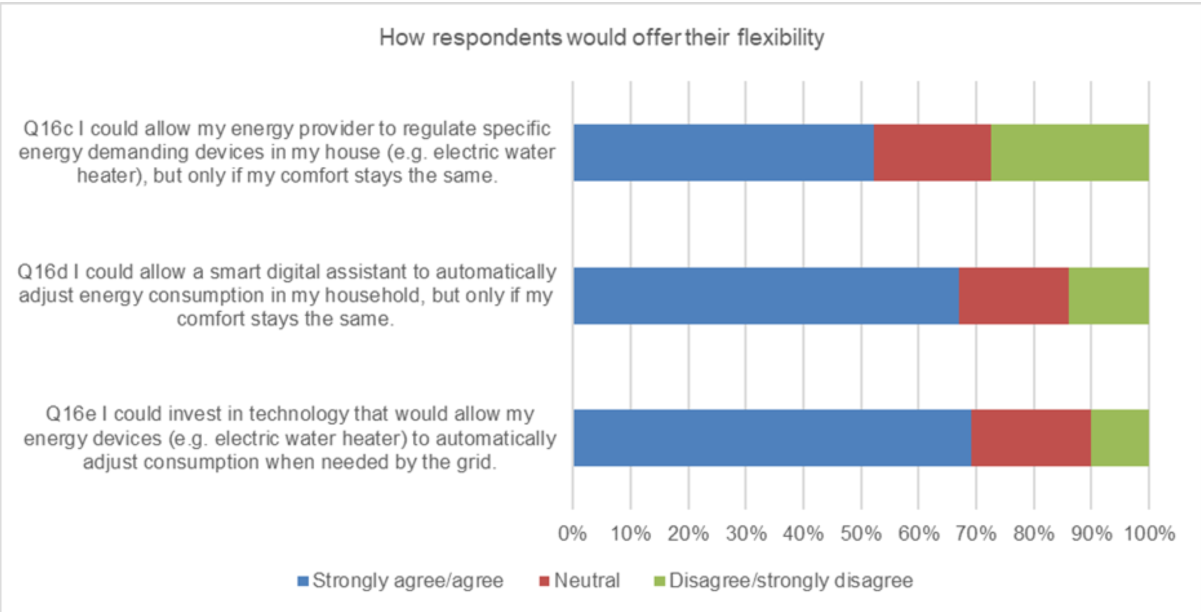

Figure 10: How all respondents would offer their flexibility (Slovenia)

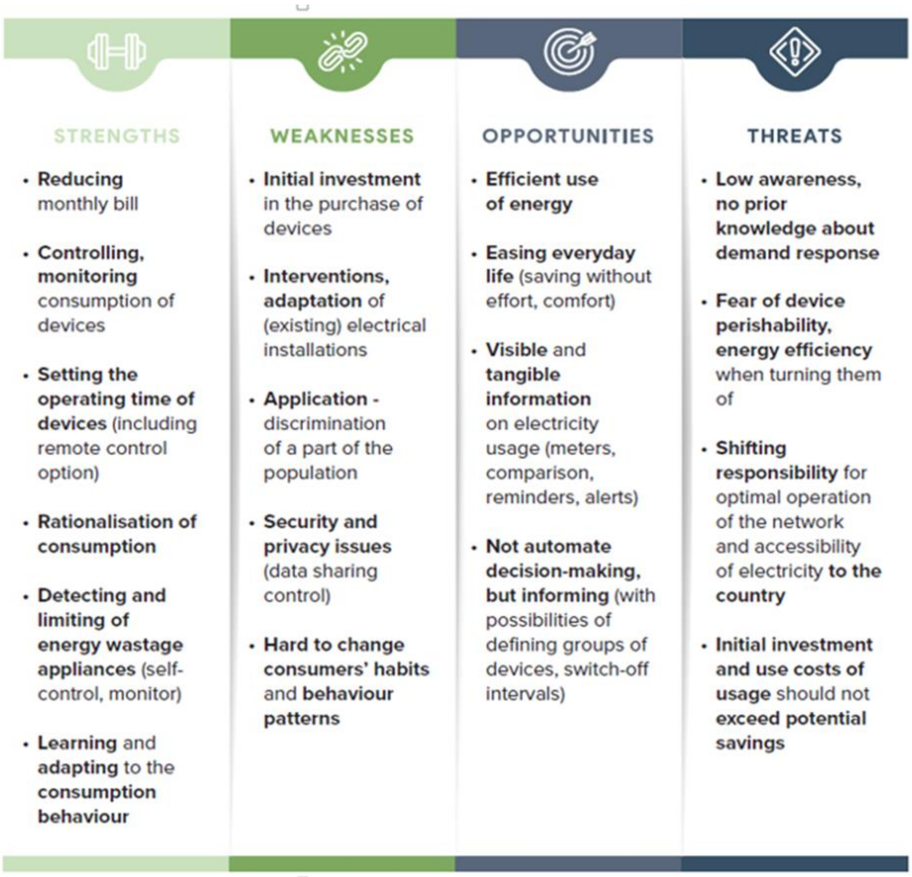

Figure 11: SWOT analysis of iFLEX solution in SLO focus group survey (2023)

- Lack of knowledge: Another issue that could hinder the large-scale replication of iFLEX solution is the lack of knowledge. The focus group survey shows that consumers are not familiar with modern concepts, terms and business models related to providing flexibility energy services, respectively demand response services. The main outcomes of the focus groups survey when discussing flexibility and demand response terms with consumers are the following:
  - Both concepts (flexibility and demand response) are mostly associated with saving electricity, reducing the cost of bills, and buying energy-saving appliances.
  - Very passive and disengaged, thinking of the subject only in terms of the cost of their monthly bills.
  - Why should I adjust my energy consumption to the times of day when more renewable energy is available?
  - No experience of grid congestion or insufficient power quality. They do not recognise these two reasons as an argument for adjusting consumption. It is essential for further development to raise consumers' awareness of both concepts.

  Another issue related to lack of knowledge is also a digital literacy or digital divide in general. Not all consumers are capable to accept new digital solutions without having prior general knowledge and understanding of possible implications. Thus, further activities to build digital literacy and close the digital divide gap is crucial to have consumers on-board and increase trust.

- Trade-off between investment and benefits: The most common barrier pointed out almost in every survey or analysis is the trade-off between the initial investment and the potential benefits. Consumers are sceptical that the initial investment to technology would be high, and the benefits, where monetary benefits are the crucial ones, could be very low, compared to the investment and, therefore, it is concluded that the return of investment period would be very high. The main drivers for consumers to participate in demand response services and flexible energy services are: money awards and cost savings. This was pointed out during almost every iFLEX survey or workshop done with consumers or pilot users, as shown in Figure 12 from the iFLEX public survey report accomplished in 2021. The results are similar for all groups involved and show that nearly all respondents are primarily driven by the idea of to "Save money" followed closely by to "Save the world".

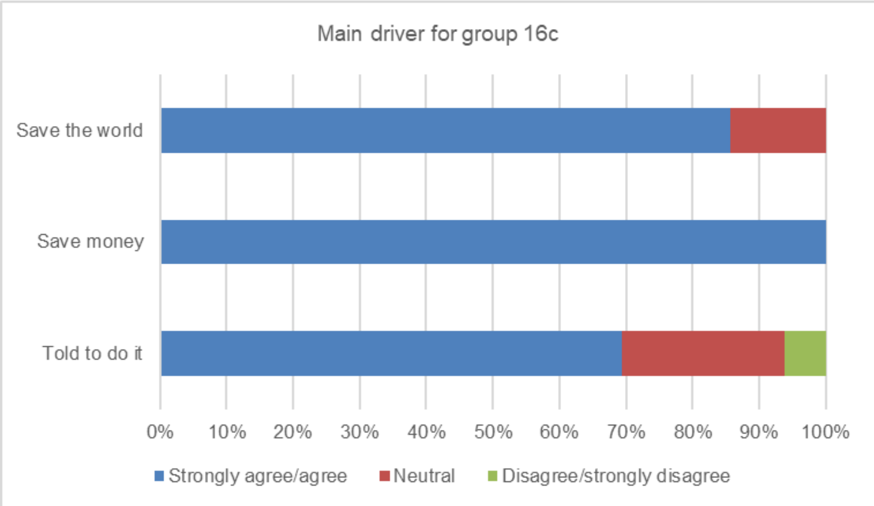

Figure 12: Main drivers for consumers to participate in demand response (Slovenia, 2021)

- <u>Clear communication on the economic incentives</u>: If we can further prove and deliver the most important value to the consumers, in terms of saving money and/or reducing costs, the probability to be successful in large-scale deployment would rise significantly. Through the project we see this potential high enough to encourage further development, but the awareness of this aspect must be an integral part of further developments for all stakeholders in the chain of delivering a service. If only one stakeholder in a chain (e.g. aggregator) underestimates the importance of this aspect, the large-scale deployment is endangered.

  Among the main conclusions of the iFLEX focus group survey (2023) are the following:

  - Participants will only test iFLEX Assistant if they know in advance what savings they will make on their bill and when the full cost of their investment will be recovered.
  - The savings with iFLEX assistant should be clearly communicated.

- <u>Difficulty in changing electricity consumption behaviour and/or reduction of comfort at home:</u> The successful implementation of DR schemes will certainly cause a fundamental change in the traditional electricity consumption pattern (profile). End-users have become accustomed to consuming electricity whenever they need to, often without even considering the low-tariff periods (if applicable). Even if adequately incentivized, it is likely that they may still deny reducing their own comfort. This may not be the case with a few pilot users that may be innovators and technology enthusiasts, but the general population has a variety of behavioral characteristics, and some of them could be challenging for the large-scale implementation of flexibility schemes. The crucial importance that personal comfort and convenience at home have for the iFLEX users is illustrated in Figure 13, which summarizes the responses from public survey analysis accomplished in 2021 regarding personal preferences.

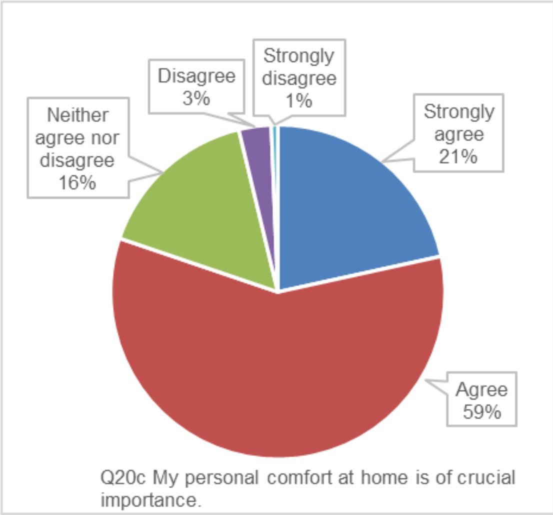

Figure 13: Importance of comfort at home for end-consumers (iFLEX public survey analysis, 2021)

- Environmental awareness: Besides saving money or reducing costs, the use of renewable resources, saving the planet, saving energy, reducing carbon footprint were often found on the second place of motivators or drivers for consumers to join demand response services. With the right communication to consumers and proving that iFLEX solution actually contribute to reducing carbon footprint or energy efficiency, there is a potential of faster implementation on a large-scale. The communication could be driven and proven through the mobile application itself, since participating in demand response events could be easily transformed into numbers of carbon footprint or energy saving.

In a more generalized framework, other factors related to stakeholders that may enable or hinder the large-scale replication of the iFLEX solutions include the following:

- General public awareness on demand response: Final customers may not be aware or receive enough incentives to provide demand response despite having a smart metering system and a retail electricity contract with proper price signals. Therefore, communication is key to raise awareness in demand response. Even though implementing a higher number or more diverse measures does not necessarily lead to more awareness, the lack of national measures to inform consumers on how they could participate in all forms of demand response could be seen as a barrier for market entry and active participation of demand response in the market.

- Classification of end-consumers: Classification of end-consumers to businesses and households is critical, since these two groups exhibit totally different consumption patterns. The former varies considerably according to the business type as well (industry, commercial buildings, etc.). The electricity consumption pattern of households may also vary according to demographic factors and related criteria, such as income, age, location and educational level. For instance, elderly people present totally different electricity consumption patterns than young couples that spent most of their time outside their homes or families with young children. In addition, younger people are expected to be more likely to participate actively in the implementation of DR programs, whereas poorer users could possibly require less incentives to participate than richer people. Such classifications can improve the effectiveness of DR targeting and operation.

4.2.1.6 Understanding consumer engagement dynamics in the context of the iFLEX project (and beyond)

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In the landscape of today's energy transition, consumers find themselves amidst a whirlwind of change. Shifting energy market conditions, economic uncertainties, and global crises like the COVID-19 pandemic have fundamentally altered the way consumers perceive and interact with the energy market(s). Within this dynamic environment, the iFLEX project sought to engage consumers in energy flexibility services, offering them an opportunity to adapt their energy consumption patterns to meet the needs of a renewable energy system. However, consumer responses to this initiative vary significantly, influenced by a multitude of factors.

One of the primary drivers shaping consumer behavior in the wake of these transformations is the altered financial landscape. The aftermath of the COVID-19 pandemic, coupled with financial crises and changing energy market conditions, has left consumers grappling with economic uncertainties. As a result, consumers predominantly view participation in programs of energy flexibility like iFLEX through a financial lens. Direct cash rewards, bill reductions, and other monetary incentives hold greater sway in their decision-making process. With financial stability becoming a top priority, other incentives, such as environmental benefits or energy sustainability, often take a backseat.

Furthermore, consumers perceive a strong shift from being empowered to their disempowerment in the energy market(s). Rising energy prices, coupled with a reduction in choices and state regulations have left consumers feeling increasingly powerless. In this scenario, the burden of navigating the complexities of the energy transition falls heavily on their shoulders. As people see, they have less say in energy choices, worries about fairness get stronger. They feel less in control, which affects how they see projects like iFLEX. They are afraid they will suffer from the change without getting enough benefits.

These changing dynamics have profound implications for the iFLEX project too, particularly concerning consumer participation and engagement. Pilot users, who are at the forefront of testing and implementing iFLEX solutions, are not immune to these influences. Their willingness to participate and become proactive users is intricately linked to their perceptions of the energy market and their own role within it. As things change, it's crucial to grasp the subtle changes in how consumers behave. This is really important for initiatives that want to get consumers involved.

It becomes evident that further engagement efforts are necessary to re-empower consumers and to bring them back to the path of the green transition and energy market engagement. As economic and financial uncertainties continue to loom large in the geopolitical sphere, consumers require reassurance and support to navigate the evolving energy landscape effectively.

Re-empowering consumers involves more than just offering financial incentives or rewards (however, they are the basis). It requires a holistic approach that acknowledges the multifaceted nature of their concerns and aspirations. Initiatives like the iFLEX project must pivot towards addressing these broader needs, ensuring that consumers feel empowered and valued participants in the energy transition.

One crucial aspect of re-empowering consumers is providing them with greater control and autonomy over their energy choices. This could involve enhancing transparency in energy pricing, providing access to real-time data on energy consumption, and offering personalized energy management tools. By equipping consumers with the knowledge and tools they need to make informed decisions, the continuation of the iFLEX project can empower them to take charge of their energy usage and contribute meaningfully to demand response efforts.

Despite all the progress and digitalization in the household energy sector, it's important to acknowledge that there will still be users who may not be digitally literate (enough) to get them fully on board. The recommendations of BEUC (European Consumer Association) clearly emphasize the principle of "nobody left behind," meaning that despite technological advancement, ensuring the inclusion of all users is essential. Consumer advocates, like ZPS, often emphasize that the energy transition and adaptation should not become a "full-time job" for consumers, implying that solutions should be user-friendly and not overly burdensome. It's crucial to design energy management systems, even within projects and solutions like iFLEX with user diversity in mind, accommodating varying levels of digital literacy. Striking a balance between technological sophistication and user accessibility is paramount to ensure that all consumers can benefit from innovative energy solutions without feeling overwhelmed.

Moreover, re-empowering consumers requires addressing the systemic inequalities and disparities that exacerbate their sense of disempowerment. Initiatives aimed at promoting energy equity and inclusivity are essential for ensuring that all consumers, regardless of their socio-economic background, have equal opportunities to participate in the energy transition. This could involve targeted outreach programs, financial assistance schemes for vulnerable populations, and policy interventions aimed at levelling the playing field.

Ultimately, re-empowering consumers in the post-COVID era requires a concerted effort from all stakeholders involved in the energy transition. By listening to consumer concerns, addressing their needs, and providing them with the tools and support they need to participate actively, initiatives like the iFLEX project can help build a more sustainable and resilient energy future.

In conclusion, while the COVID, post-COVID and the current era of major geopolitical turmoil present significant challenges for consumer engagement in the energy transition, they also offer an opportunity to reimagine and redefine the relationship between consumers and energy systems. By re-empowering consumers and fostering greater inclusivity and resilience, the iFLEX project can contribute to a more equitable, sustainable, and consumer-centric energy transition.

4.2.2 Function layer methodology

The SRA of the function layer is built on the basis of the project's systemic use cases (i.e. Primary Use Cases, PUCs), which enable the realization of the different conceptual use cases of the project (i.e. High-Level Use Cases, HLUCs), which include the following:

- HLUC-1: Manage energy of the premises in an optimal way
- HLUC-2: Manage flexibility requests or price signals at individual premise level
- HLUC-3: Manage flexibility requests or price signals at building level

One dimension that the analysis focuses on is the challenges of realization of each use case, based on the satisfaction of the pre-conditions/assumptions. Another dimension that is investigated is the ability of some computationally intensive functions (e.g. sophisticated algorithms for the optimal targeting of users) to satisfy a larger set of users.

In this section, the challenges stemming from satisfying assumptions and preconditions of all three HLUCs of the iFLEX project are presented collectively for the readers' convenience, instead of dividing them per HLUC, as there are multiple assumptions and pre-conditions that are valid for more than one HLUCs. It is noted, however, that the complete documentation of HLUCs and PUCs for the iFLEX project, including the relevant assumptions and preconditions per UC, can be found in (iFLEX D2.1, 2021).

- Interoperability with Energy Management Systems (EMSes): Interoperability with EMSes is crucial for the replicability of iFLEX Assistant (iFA), as there is no unique standard adopted by all EMS manufacturers for the interfaces of such systems. Hence, customization is needed to effectively interact with EMSes provided by different manufacturers or even with various models of the same manufacturer. Furthermore, in order for the iFA to be appropriate for premises at the level of both individual household and apartment building, it should be able to communicate with Home as well as with Building Energy Management Systems (HEMSes and BEMSes).

  Subsequently, the EMS should be able to access energy meters and sensors, as well as to provide the status of local assets and to relay the control commands of controllable ones, so that the relevant functionalities of the iFA can indeed be exploited. Naturally, as highlighted also in the relevant section on the Component layer, the existence of such equipment (e.g., smart meter, sub-meters, sensors, control relays) at the premises of iFA end users can be an additional challenge, as it cannot be taken for granted yet in many European countries, especially in case of aging building stock.

  These aspects impose additional work for the iFA development team, if it pursues to achieve its wider adoption by the market.

- Integration with Meter Data Access Interfaces: iFA should communicate with Meter Data Access Interface(s). Such interfaces belong to Meter Data Administrators (e.g., a Retailer could assume this role), whose systems receive smart meter data from various external systems (e.g., Distribution Management System) and provide access to these data to iFA. Interoperability of iFA with different Meter Data Access Interfaces is a prerequisite for its adoption by end-consumers living in various countries and having contracts with different Retailers, who typically act as Meter Data Administrators.

- Integration with Weather Services: Weather data are needed as inputs by the models of iFA's Digital Twin. Because of this, integration of iFA with an external Weather Service is necessary. Furthermore, the external Weather Service(s) should support different countries and regions, in which the iFA could be deployed.

- Consent of users for personalised services: Certain functions of iFA, which concern personalised services to its users, cannot be demonstrated unless the users provide their consent to sharing certain energy metrics and/or preferences. Examples of personalised services are provision of tailored energy advice, as well as alerts specific to various energy goals set by the users. This prerequisite can be considered as a problem for end users that may be sceptical or even unwilling to share such sensitive data with the iFA developers, as they are not accustomed to this concept based on the so-far practices in the energy domain, especially for residential end users.

- Integration with Market Interfaces: iFA should be able to communicate with external Market Interfaces. Such interfaces provide iFA with information on energy market data, such as retail and network electricity tariffs. Furthermore, interoperability with such interfaces is a prerequisite for flexibility-related communications between iFA and relevant external systems, such as Aggregation Platforms. To fully exploit the potential of iFA, integration with Market Interfaces of different providers, accounting for features related to both energy and flexibility markets.

- Registration of end users for Demand Response (DR) programs: Apart from the aspect of integration with different external flexibility-related systems, the demonstration of flexibility-related functionalities of iFA can be realised only under the assumption that iFA end users have registered for at least one DR program. Furthermore, as part of the enrolment in a DR program, the end users should provide their consent on sharing baseline load and flexibility information with the Flexibility Procurer and sign an agreement detailing power and compensation aspects. This process can be perceived as a potential barrier for wide market adoption, as the majority of end users – especially residential ones – are not even familiar with the concept of DR, while DR-related legislation considering certain categories of end users, such as residential, may not even exist yet in many European countries.

- Scalability of optimization algorithms: The algorithms employed currently for the optimal targeting have been tested with only a small number of users, since this is the case for the pilot sites. The complexity of the algorithms, however, is small and should be appropriate for a possible significant scaling-up of the iFLEX solution. Moreover, the problem can be divided to smaller pieces so that execution can run on parallel threads. For instance, learning of the parameters of the users is a separate problem for each user. However, we should not rule out the possibility of scalability difficulties emerging owing to the inherent problem complexity.

- Weather conditions variation: Weather conditions may vary across different regions of a country, since they often depend on the morphology of the terrain. As a result, RES production may also vary across the country. The variation in weather conditions across a country may have a negative effect on the effectiveness of the DR schemes implemented: DR schemes in LV customers have a bolder local effectiveness, since the system presents transmission/distribution losses and transmission bottlenecks, which finally affect negatively the harvested flexibility. Therefore, DR schemes should consider local production/demand needs rather than consider the entire power system as a whole in order to maximize effectiveness.

  Such a situation may occur in Greece, where there is a rich terrain (mountains, mountain ranges, islands, long coastline) with notably differentiated weather conditions across the country. For instance, a cloudy weather in Macedonia (in northern Greece) may dictate increased flexibility demand to account for the loss of local PV generation. If this flexibility is requested and finally provided from Peloponnese (in southern Greece), which may be characterized by sunny weather, rather than locally from Macedonia, then the DR effectiveness will be lower. The latter may be even poorer if cloudy weather is also accompanied by lower temperatures in a winter day, given that network losses increase exponentially as power flow in transmission and distribution network rises.

  Similarly, weather dissimilarities also affect the DR effectiveness in the demand side. When the outside temperature is close to the inside temperature, the heat transfer through the building insulation is low and the building optimal living conditions are deregulated slowly. Thus, locations with mild temperatures can serve as better candidates for flexibility procurement than areas with extreme temperatures. For instance, in Greece, during a hot summer day it will be more difficult to request flexibility from Athens that usually suffers from very high temperatures during summer, than from a windy remote region, since the residents of Athens will be highly reluctant to reduce electricity consumption related to A/C operation.

  Because of the local weather particularities in a specific country, there may be permanent differences in the weather conditions or trends, that should also translate to different DR potential across the country and in certain seasons of the year. For instance, a mountainous town may have increased flexibility capacity in the winter and less in the summer as compared to a town by the sea, which may have the opposite behavior.

In Finland as well, the weather conditions are varying depending on the season and the exact location within the country. However, the seasonal weather variation in Finland is remarkably more intense mainly due to its geographical position.

The climate in Slovenia is determined by many factors, the most important being its geographical location, varied relief, orientation of mountain ridges and proximity to the sea. Consequence the intertwining of many factors is a very diverse climate. Thus, Slovenia has three dominant types of climates, and in individual areas their influences are intertwined: in the east Slovenia has a temperate continental climate, in central Slovenia a subalpine climate (in alpine mountain world) and sub-Mediterranean west of the Dinaric-Alpine barrier climate. Slovenia's climate diversity is reflected in differences between values climate change and their daily, seasonal and multiannual variability. Despite the fact that Slovenia is a small country, it is extremely diverse in the field. Thus, Slovenia has changing weather conditions, which depend on the time of year and the location within the country.

Figure 14 to Figure 16 provide a graphical representation of the function layer for the three different HLUCs addressed within the iFLEX project (each applicable to one or more pilot sites, as indicated), following the SGAM framework illustrated in Figure 3.

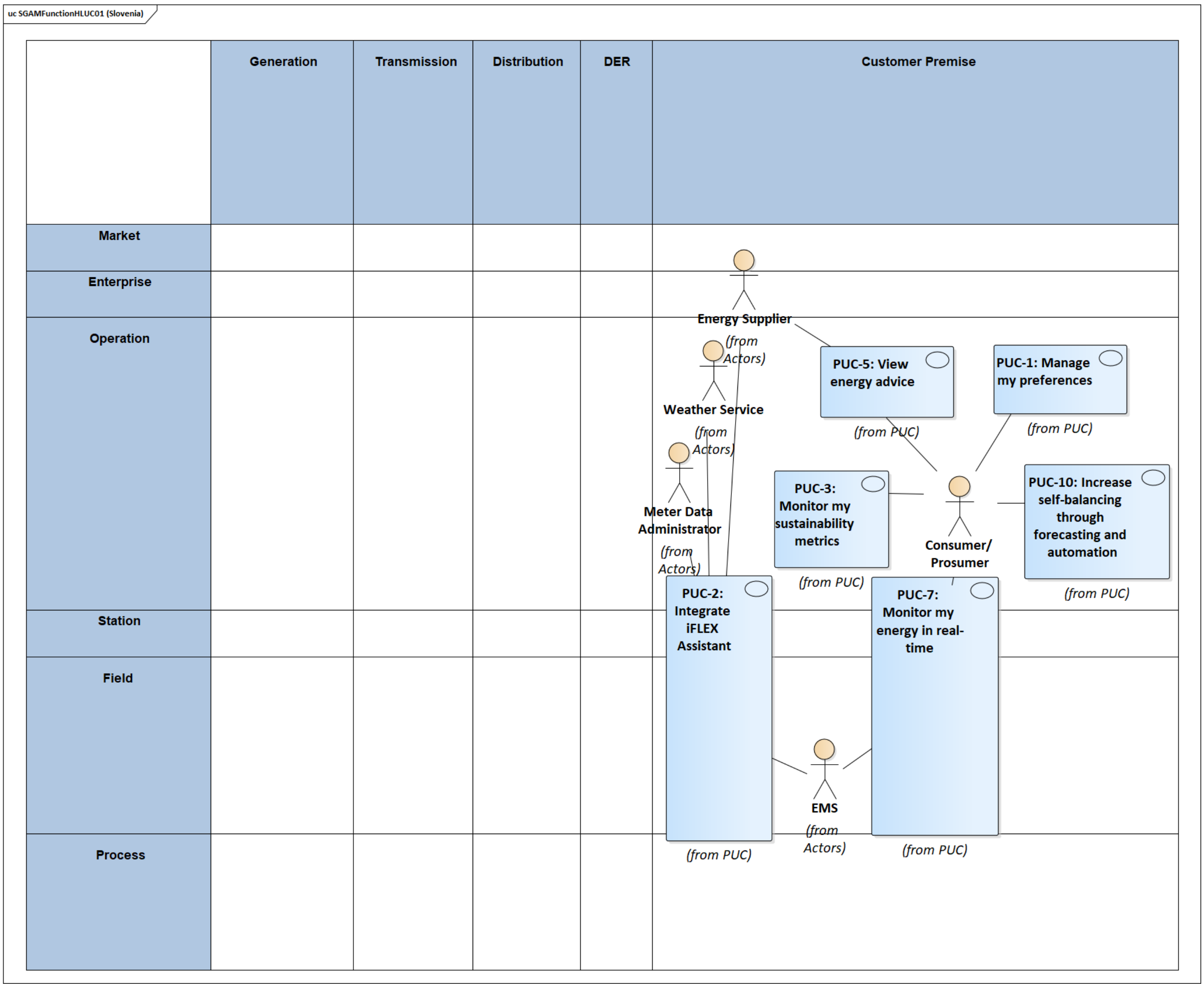

Figure 14: Representation of Function layer for HLUC-1 “Manage energy of the premises in an optimal way” (applicable in Slovenian pilot)

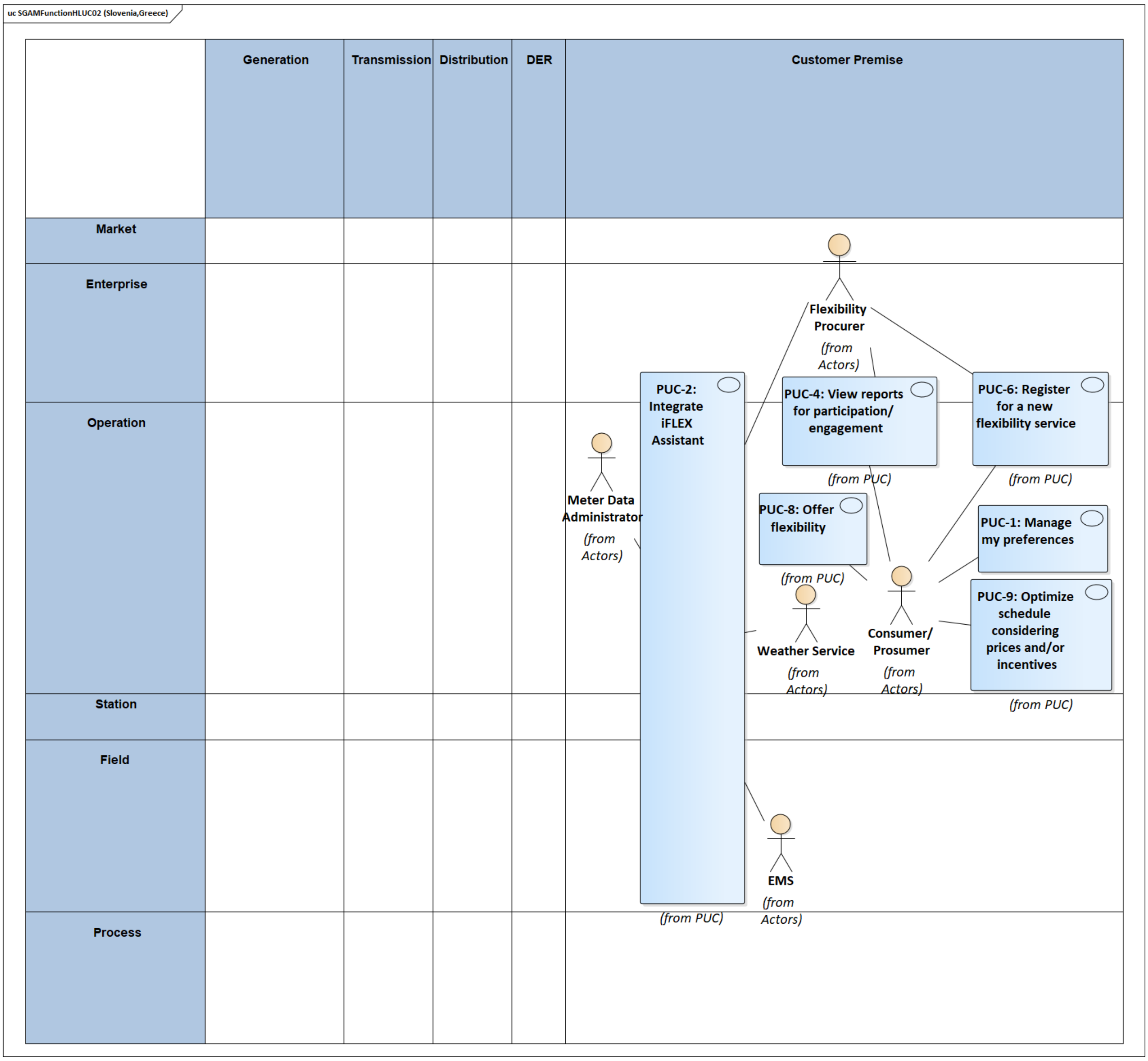

Figure 15: Representation of Function layer for HLUC-2 "Manage flexibility requests or price signals at individual premise level" (applicable in Greek and Slovenian pilots)

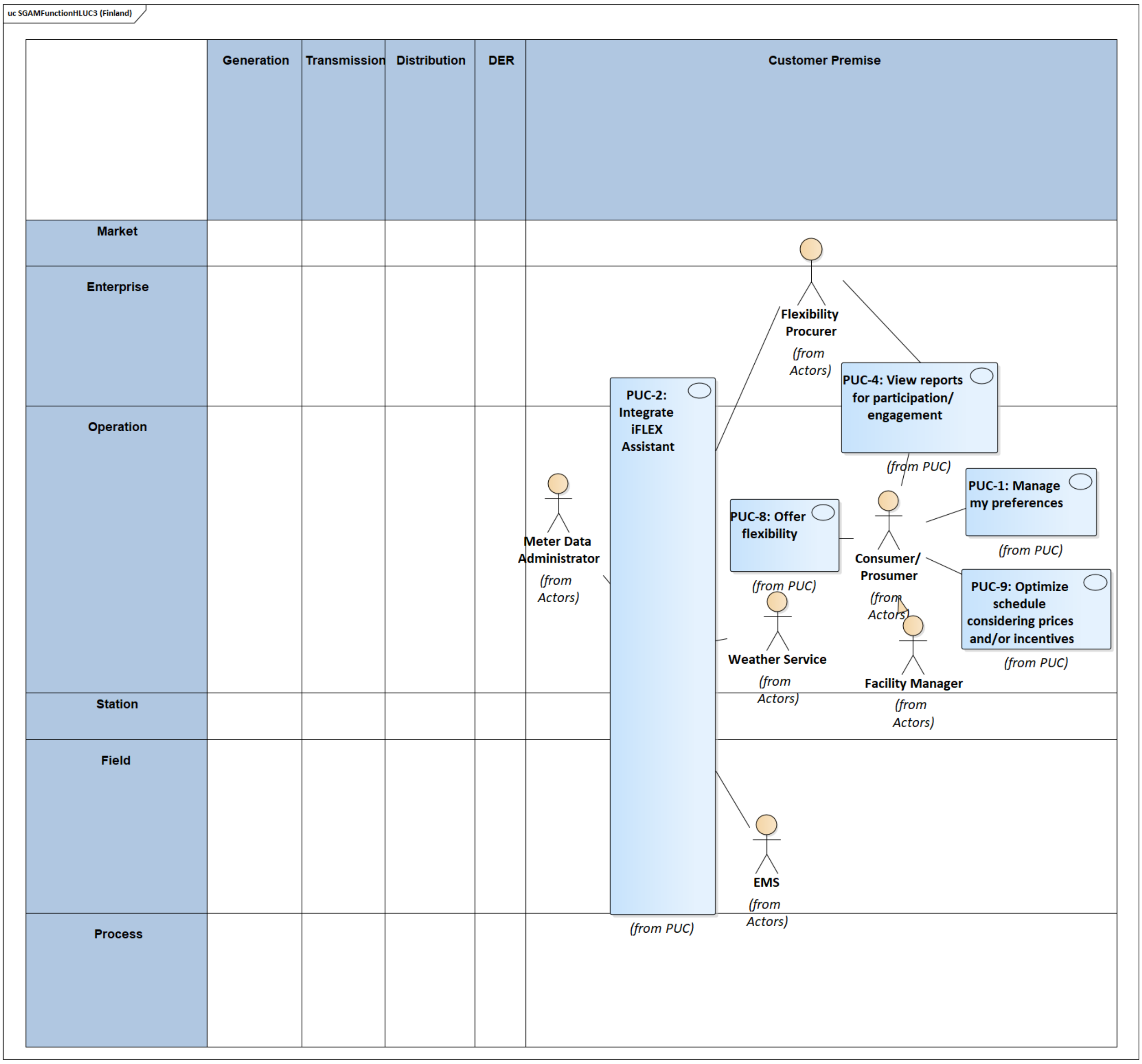

Figure 16: Representation of Function layer for HLUC-3 “Manage flexibility requests or price signals at building level” (applicable in Finnish pilot)

4.2.3 Information and Communication layer

Regarding the Information and Communication layers, the qualitative approach has been followed for analysing the replicability and scalability potential of the iFLEX Framework from the Information and Communication Technology (ICT) dimension point of view.

We focused on the iFLEX Framework system architecture, since it provides the backbone for both the replicability and scalability of the iFLEX Assistants. The following items have been analysed as part of the methodology for the ICT dimension:

- **Replicability of the system architecture**: The replicability of the software architecture refers to the following items that are analysed as part of the methodology.
    - Documentation of the system architecture: The first question for the analysis is: "*Does the documentation of the iFLEX system architecture enable parties outside of the project to replicate the solutions in a way that their solutions are also interoperable with the original iFLEX Assistants developed in the project?*". This measures to which extent parties outside of the project can replicate adequately the iFLEX solutions in their own business.

      The iFLEX system architecture has been thoroughly documented in the relevant deliverables (see WP 2 deliverables), thus allowing for an unobstructed replication of the proposed solutions.

    - Compliance with common standards: The second question for the analysis is: "*To what extent the architecture complies both with standard system architectures for smart grid premises, and the standard protocols at information and communication layers?*". This measures how easy it is to integrate the iFLEX Assistants with demand-side flexibility management solutions developed outside the project.

      Compliance with standard system architectures for smart grid premises, and the standard protocols at the information and communication layers have been guaranteed to allow for the integration of the iFLEX Assistants with demand-side flexibility management solutions developed outside the project.

    - Ability to wrap diverse home and building energy management systems: Replication requires an ability to wrap diverse energy management systems (EMS) with an intent to collect data from the EMSs and to control the devices through EMS. On the one hand, since the iFLEX Assistant needs to support broad integration, compliance with common standards is a good indicator of wrapping ability. On the other hand, iFLEX has little control on what is available from the EMSs that the project would like to wrap. Often there is little or no information how EMS systems could be accessed or controlled.

    - Trust, Security and Privacy: iFLEX Assistant trust, security and privacy procedures, mechanisms and services are fully compliant with common standards and relevant regulation and legislation. In general, compliance with the General Data Protection Regulation (GDPR) is addressed and fulfilled. Planned use cases have been carefully studied and assessed from privacy and information security point of view. The iFLEX Assistant solution uses broadly used security standards for security services provisioning, like X.509 (ITU-T, 2019) and TLS (IETF, 2018) with standard communication protocols like TCP (IETF, 2022) and MQTT (OASIS, 2019). The security provisioning is fine-grain and can control access to the data and households' controls to a level of a sensor, a single piece of information or a device actuator.

The said compliance assures that the iFLEX Assistant and framework can be replicated in diverse environments and ecosystems and the compliance with regulation and legislation is not a barrier for replication in target countries.

However, data security and data privacy concerns could be raised along with the expansion of iFLEX applications to a wider population, due to the fine-grained electricity consumption and/or sensor data that are normally collected. The consumption pattern, if hacked, can provide valuable information to the wrong hands, and this threat may be of elevated importance to the wider public that is not familiarized with new technologies. On the other hand, the iFLEX Assistant enables control of household or building devices which needs to be carefully checked and allowed only to authorized persons.

- **Scalability of the system architecture:** The scalability of the software architecture specifies how well the architecture supports the increasing number of customers (i.e., consumers/prosumers). Regarding the Communication layer, the focus is on the communication technologies and their scalability. At the Communication layer the iFLEX system architecture is based on highly scalable HTTP REST and MQTT protocols. The scalability of HTTP is evident in the WWW. Depending on the quality of service a single MQTT broker can serve up to 40.000 messages/second when run on a typical computer (Mishra et al., 2021). A single broker is therefore enough to serve more than 100.000 customers in typical iFLEX use cases. The system can be easily scaled to larger group of iFAs by adding new MQTT brokers and configuring the routing between iFAs and aggregation platforms accordingly.

4.2.4 Component layer methodology

In the Component, layer, the SRA dimensions include:

- iFLEX Assistant, platforms, applications and user interfaces
- Power system equipment (e.g. end-user electrical devices, smart metering infrastructure)
- Network infrastructure (e.g. wired / wireless communication connections, routers, switches, servers, data storage and data processing infrastructure)

The SRA of the component layer has been built on the basis of the project's assumptions on the existence of physical actors. The dimension that the analysis focus is on the validity of relevant assumptions on the existence of such devices in actual environment. In the above context, a joint analysis with the Function layer has been pursued.

Figure 17 to Figure 19 provide a graphical representation of the Component layer for the three different pilot sites, following the SGAM framework illustrated in Figure 3.

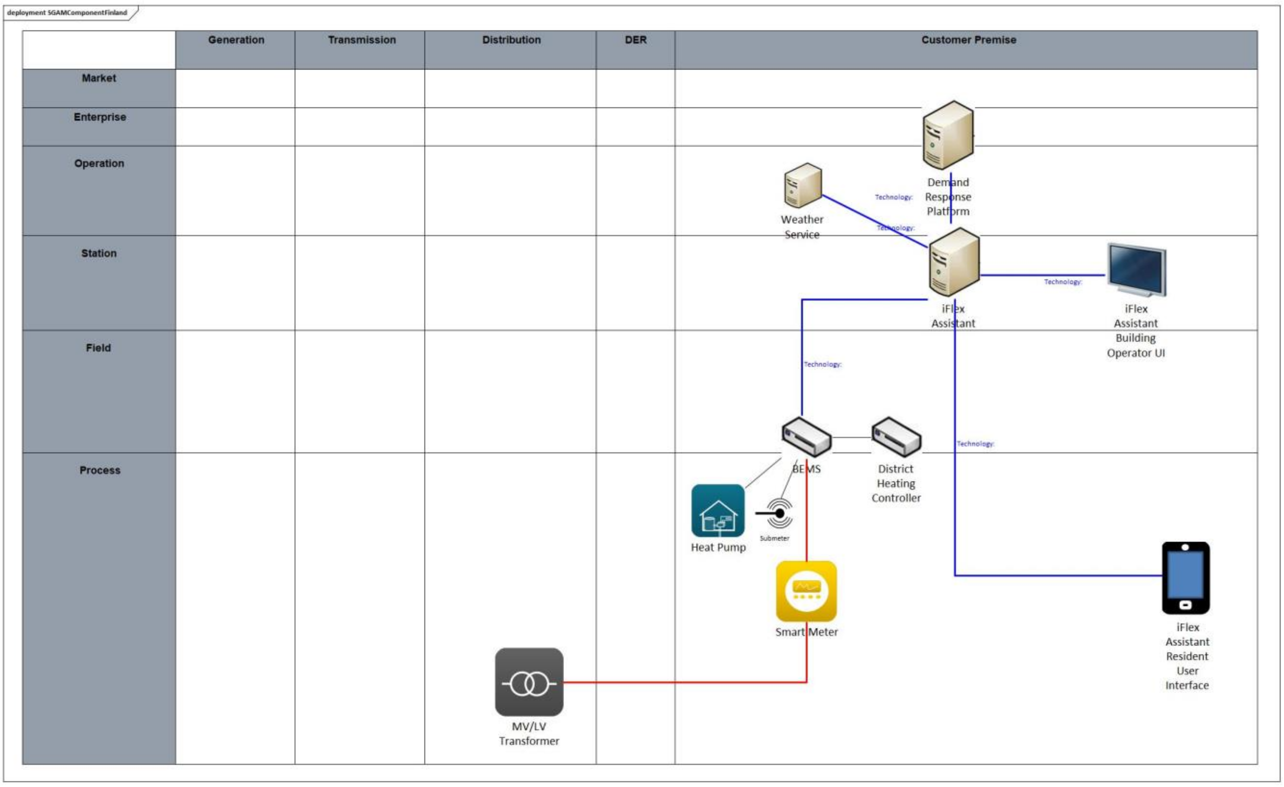

Figure 17: Representation of Component layer for the Finnish pilot

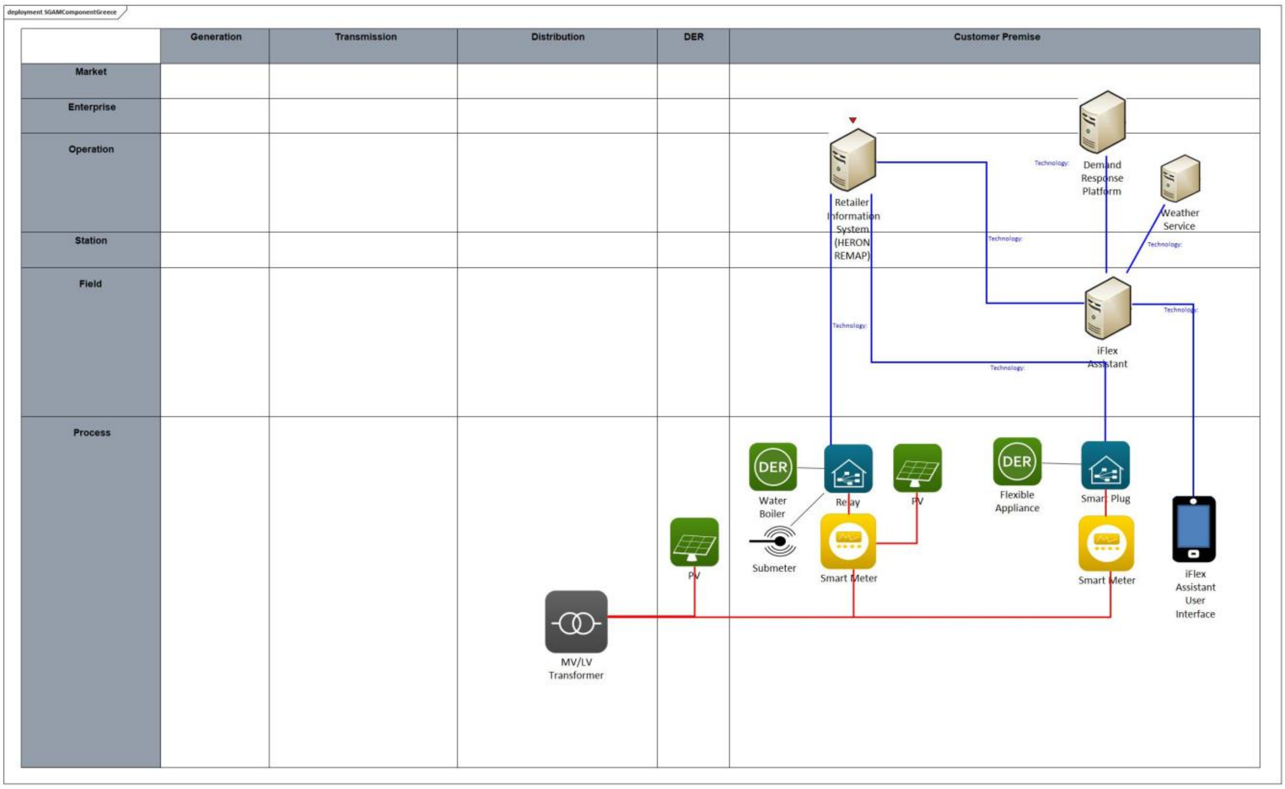

Figure 18: Representation of Component layer for the Greek pilot

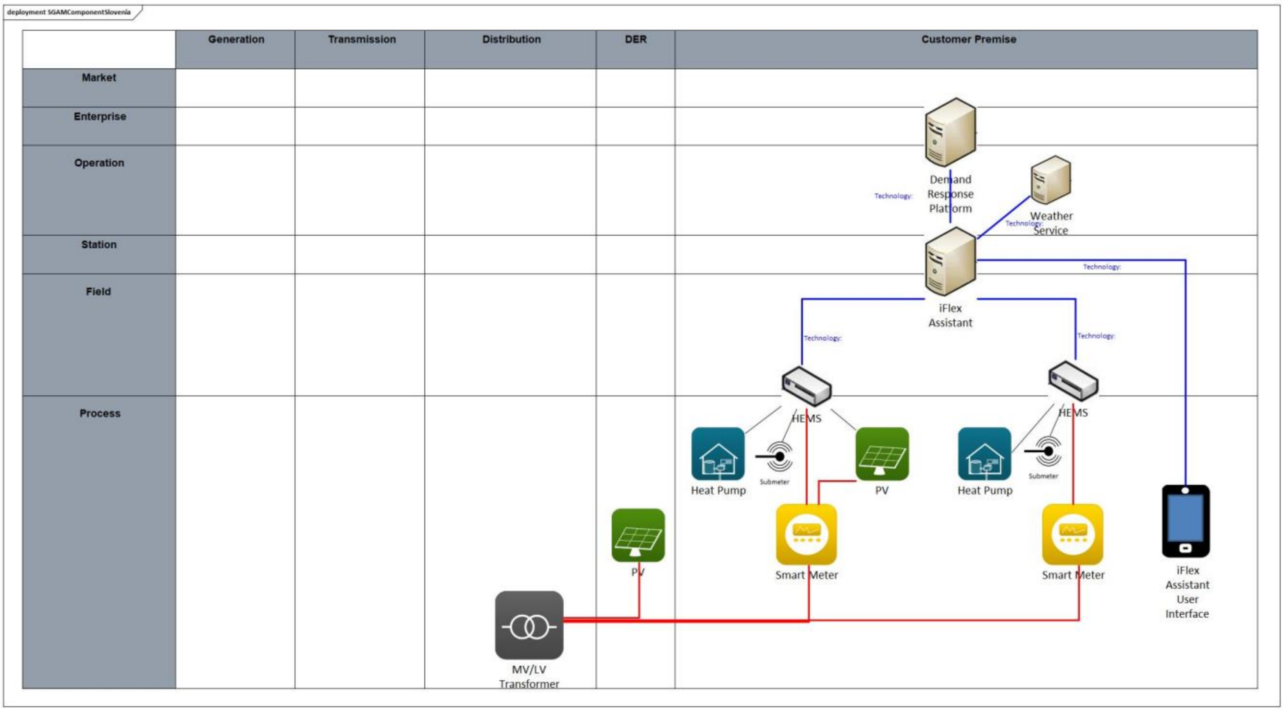

Figure 19: Representation of Component layer for the Slovenian pilot

The SRA for the component layer is analysed as follows:

- Availability of smart metering infrastructure: Apparently, the availability (or lack) of suitable smart metering infrastructure is the most important technical facilitator (or barrier, respectively) for the successful large-scale implementation of DR schemes, that is to conclude retail electricity contracts with some kind of time-differentiation, including dynamic electricity price contracts.

  While Member States are not required to roll out smart meters to 80% of consumers until 2024, the lack of these devices limits consumers' ability to react to and, therefore, potentially benefit from market price signals.

  Figure 20 illustrates the roll-out rate of smart meters in all EU Member States in 2022. Only thirteen Member States reached a significant level of smart metering deployment in 2022 (i.e., a roll-out rate of at least 80%) (ACER, 2023). Ten still have a roll-out rate below 20%, with some being practically at 0%. In addition, some Member States have experienced delays in their plans to develop smart meters, such as Austria, Romania, Poland and Slovakia.

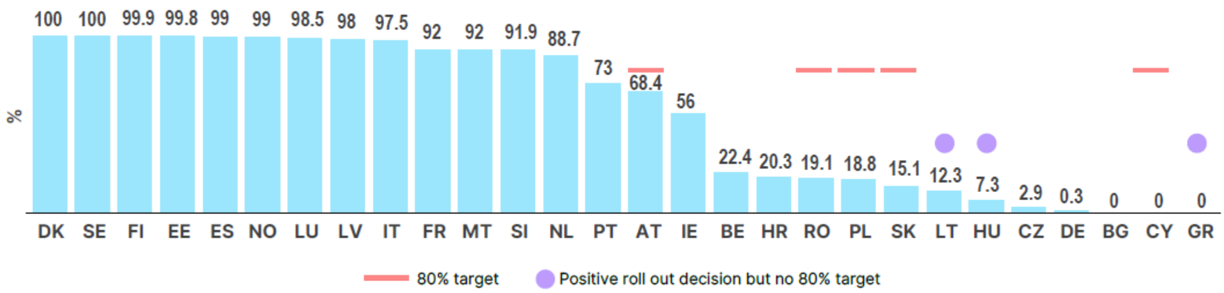

Figure 20: Roll-out rate of smart meters in EU 2022

In Finland and Slovenia, smart meters have been already implemented on a large-scale (almost 100%) and electricity consumption is regularly telemetered, thus enabling for the large-scale implementation of the iFLEX solutions.

On the contrary, in Greece the current percentage of smart metering deployment is almost zero. In fact, only the ~40 HV and ~11,000 MV consumers are currently tele-metered, while around 7,5 million LV customers are still equipped with conventional metering infrastructure allowing only for aggregated consumption data reading (monthly or four-monthly time intervals are usually used by the electricity suppliers to invoice their customers for their aggregated real consumption)[2]. Therefore, currently no IT infrastructure that would allow for unidirectional or bidirectional communication between Greek DSO/Suppliers and the end-consumers and, in turn, for the massive deployment of DR programs is available. However, an installation campaign for the roll-out of smart-metering infrastructure to all LV end-consumers in Greece has already been scheduled to take place in the short-/mid-term future.

However, equipping consumers with smart meters does not assure that these devices are interoperable and have the necessary functionalities that would allow consumers to benefit from all their potential. To that extent, Member States must define some minimum requirements for smart meters in their national legislation in line with the Electricity Directive (EU) 2019/944. Some minimum requirements of smart meters that have already been included in the respective national rules include (but are not restricted to) the following:

i. They must be interoperable with both the consumer energy management systems and the smart grids,

ii. They must accurately measure actual electricity consumption,

iii. They must provide validated historical consumption and non-validated near-real time consumption to final customers at no additional cost,

iv. They must account for electricity fed into the grid by active customers and make this data available to them or to a third party at no additional cost, and

v. They must enable final customers to be metered and settled at the same time resolution as the imbalance settlement period set at the national level.

- <u>Availability and mix of end-user devices:</u> The end-user device mix that can technically be involved in the implementation of DR schemes is one of the most important drivers for the successful scalability and replicability of the iFLEX solutions. The capability of iFLEX to accommodate different categories/types of devices can affect the level of iFLEX replicability. For instance, households comprising purely electric loads can easily participate in DR and provide heftier amounts of flexibility. Indicative examples comprise mainly flexible loads, such as electric boilers and/or heat pumps, whose power output can easily be lowered or stopped as well as EVs whose charging/discharging operation can be easily optimized i.e. they can be instructed when to begin charging or even when to discharge to provide energy back to the distribution network (Vehicle-to-Grid – V2G- operation mode). As the end-user devices that were actually available in the three iFLEX pilot sites, such as heat pumps, HVACs and electric boilers, were prioritized by the development team, exploitation of other assets has not been validated in the framework of iFLEX project. Hence, future consideration of additional flexible assets, such as EVs, which were not present in the pilot sites, is vital for a wide market adoption of the iFLEX Framework.

[2] A small number of large LV end-consumers with rated capacity > 85 kVA are currently equipped with smart metering infrastructure.

- Availability of DSL connection-enabled smart meters: Smart meters are usually equipped with SIM cards and modems and, therefore, communicate via mobile networks. Therefore, they do not have the capability of connecting and communicating via the home DSL connection, if present. Signal is often inadequate in customer premises and, therefore, enhancement of cell coverage is required.

  In Greece, it is common that DSL connection-enabled smart meters are not employed and this could be a major barrier to large-scale implementation of iFLEX solutions.

  In Finland, there is no need for DSL connection-enabled smart meters. The focus is on smart meters operating via wireless network and more specific on devices that support low-power wide-area network (LPWAN). Such technologies are for example SigFox and LoRa. Currently, SigFox network covers 85% of Finnish population and major urban areas in Europe. However, the technology is not yet widely used especially among consumers.

  As Slovenia is almost entirely covered by smart meters in the distribution newtork, the associated electricity distribution company (ELE) provides access to data via the so-called I1 port[3] on Iskraemeco and Landys+Gyr meters. The I1 port is in most cases the RS-485 communication protocol[4] or M-bus (Meter bus protocol)[5] and allows only one-way communication (this prevents unauthorized configuration of the distribution meter) between the smart meter and the device that intercepts data (in the Slovenian case, this is HEMS).

- Availability of communication, data storage and data processing infrastructure: Scalability issues may arise regarding the communication, storage and processing infrastructure of the acquired energy data. Transfer, storage and analytics of real-time data for millions of customers under fine time resolution (e.g. 5-min to 30-sec) might not be a trivial case and it will normally require notable investments in hardware and software infrastructure.

- Hardware compatibility and interoperability: Replicability and scalability may be hindered in case that available hardware in household premises (e.g. end-user devices, smart metering infrastructure, network infrastructure, etc.) presents compatibility and interoperability issues with the platforms and systems developed within the project.

  In Finnish pilot buildings, central heating is produced using both district heating and exhaust air heat pump systems. These types of apartment buildings are typically relatively new, while in older buildings the heating source is often limited to a single option, such as district heating alone. This limits the replicability of the iFLEX solution.

  In the Greek pilot, there were issues relevant to the recruitment – for DR-related activities – of end users that owned boilers. More specifically, solar boilers, which typically use an electric heater as a back-up, were not identified as suitable for validating DR use cases of the iFLEX solution. The reason behind this is the really high sunshine duration in Greece throughout the year, which results in the end users rarely activating the back-up heater. Instead, purely electric boilers can be considered as a good candidate asset for DR applications in Greece.

  In the Slovenian pilot the limits of the hardware compatibility were set by the abilities of HEMS platform utilized by the project. More devices supported by the HEMS, more are supported by the iFA solution. The solution for communication with the HEMSes is very general and standardised (MQTT)

[3] Instructions for reading I1 port: https://www.sodo.si/sl/za-odjemalce/specifikacije-vmesnika-i1
[4] https://en.wikipedia.org/wiki/RS-485
[5] https://en.wikipedia.org/wiki/Meter-Bus

and, therefore, the compatibility and interoperability is not limited to only one type of HEMS. A broader scope could easily be reached, and new HEMS systems could therefore be supported.

- Network congestion issues: The large-scale replication of iFLEX solutions may cause network congestion issues, either when requesting a concurrent large increase in demand or an increase in production provided by prosumers. In case that the iFLEX Assistant is operated simultaneously by a massive number of users, it is highly probable that the associated DR requests lead to a coordinated increase of electricity consumption (or coordinated increase of electricity production by the engaged prosumers) which, however, deviates from the traditional network utilization patterns and, therefore, may provoke network congestion and failures. Moreover, if during the large-scale replicability of the iFLEX Assistant EVs charging or V2G operation is introduced, then the said issue will become significantly more critical, since EV onboard chargers exchange much more power than the typical average household consumption does. These issues are expected to be critical, particularly in networks that were designed and still operate taking into account the traditional electricity consumption patterns and electricity flows.

  For instance, in Greece the electricity grid was structured taking into account synchronization factors. In other words, it is not designed and built to serve the rated power of all electricity supplies, because that would be too costly, but rather a percentage of their rated power, since it is assumed that not all electric loads shall be active simultaneously. To make things worse, in Greece there is currently no visibility of the real-time loading of the MV/LV transformers via telemetering infrastructure in the MV/LV substations.

  In recent years, the use of renewable energy sources from solar cells has been growing rapidly in Slovenia. Under good weather conditions (e.g. high sunshine), a certain excess of electricity occurs at certain transformer stations. This electricity surplus is reflected in increased voltage and change in frequency. In order to avoid excessive surpluses of electricity in the network and consequently to disrupt the electrical conditions in the network, solar power plants on the basis of pre-defined parameters defined by the DSO (parameters related to voltage fluctuations and frequencies in the network) are switched off or limit their electricity injection into the grid. When the operation of solar power plants is restricted, low-cost and eco-friendly electricity generation is not effectively utilized, which could otherwise be used e.g. for space heating / cooling, domestic water heating, etc. The above problem will be addressed in such a way that the HEMS system can increase the consumption by means of flexible loads (e.g. heat pumps) from own production sources, such as solar power plants.

- Joint operation of utilities' metering infrastructure: There are discussions for the cooperation of other utilities' (water, natural gas) metering infrastructure with the electricity metering infrastructure. Under this scheme, metering data from other utilities will be transferred, stored and transmitted in the DSO's telemetering system. Such parallel advances may pose delays in the development and real-time operation of the necessary DR telemetering system.

5 Lessons Learned from Pilot Implementation

In this Chapter, the lessons learned from the actual implementation of the iFLEX solutions to the Finnish, Greek and Slovenian pilot sites during all three phases are analytically presented.

5.1 Finnish pilot

The lessons learned from the Finish pilot of the iFLEX project are presented in this section, considering technical aspects, user engagement and acceptance, as well as applied incentive schemes.

5.1.1 Technical aspects

The Finnish pilot consists of two large buildings. The first is an apartment building that houses over 140 residents. The second is a supermarket, which was incorporated into the project through collaboration with the MakingCity project. Please refer to iFLEX D8.5 – "Final validation of federated pilots" (iFLEX D8.5, 2024) for more details about the co-operation of iFLEX project with the MakingCity project.

In both buildings the main flexible asset is the heating, ventilation, and air-conditioning (HVAC) system. However, the heating systems in the two aforementioned buildings are quite different: The apartment building has a hybrid heating system in which the heating (includes space heating and domestic hot water) is supplied by district heating and an exhaust air heat pump. On the other hand, in the supermarket the heating is provided by the heat pump (or refrigeration system) that also supplies cooling for the freezers and coolers. Heat wells (ground heating) are connected to the refrigeration system, and used as a source for extra energy when the waste heat from freezers and coolers is not enough.

In addition to the heat supply, also the heat distribution systems are different in the buildings. In the apartment building radiators with hot water circulation are used for heating the apartments. In the supermarket the hot water is used for heating the air supplied by ventilation. Additionally, floor heating covers part of the supermarket.

The main technical lessons learned from the deployment of the iFLEX Assistants to the Finnish pilot buildings are the following:

- Heating systems provide a lot of flexibility both in terms of power and energy. This is because most of the energy demand in buildings comes from heating, and building thermal mass can be used for storing heat (energy) for several hours. The thermal mass was identified to be 390 kWh/K and 120 kWh/K in the apartment building and supermarket, respectively.
- The buildings use different Building Automation Systems (BAS) and separate adapters needed to be implemented to the Resource Abstraction Interface module. Heterogeneity of BAS interfaces is a challenge that will be hopefully solved with standards such as the Smart Appliances REFerence ontology (SAREF) in the future.
- The model-based approach provided by the Digital Twin repository and the Automated Flexibility Management module works well for optimal control and makes it possible to estimate the baseline load (power forecast) and flexibility, as described in the S2 interface standard (EN 50491-12-2:2022, 2022).
- Hybrid modelling is a good solution for the HVAC systems as it makes it possible to create accurate and robust models without a need to physically model all the details of the HVAC system. This makes replication of the solutions easier for different types of buildings and heating systems. Work is still needed to develop a model that provides robustness (i.e, not a pure machine learning model), but that

can be replicated to different types of buildings without any manual modifications needed (i.e., all the differences are learned from data).

5.1.2 User engagement and acceptance

Both buildings were recruited by Caverion, who is the operator of the said buildings. Contracts were formed with the building owners that both are interested in the benefits that demand-side flexibility management can provide for them.

In addition to recruiting the buildings and building owners, a recruitment/communication campaign was also organized for the residents of the apartment building. The resident recruitment/communication in all phases was conducted via email. All residents of the pilot building were provided with possibility to engage with the iFLEX Assistant without any need to register to the pilot. The common iFA user interface enables residents to monitor the building level data, including electricity and district heating consumption, and cost and CO2 reductions that have been obtained with automated flexibility management. Additionally, we offered the possibility to obtain apartment-specific thermal comfort sensors for a selected number of residents. This required the residents that were interested in having the sensors installed to their apartments to register to the pilot and provide their consent for data collection, since thermal comfort data was classified as personal data by the project. In all three phases the residents of the pilot site were sent an email to advertise the pilot and inquire their interest in the thermal comfort sensors. A total of 10 households requested for thermal comfort sensors in their apartments. One Connected AirWits CO2 sensor was installed in each apartment, which measures temperature, CO2 and relative humidity. The sensors are resident/household-specific and, therefore, when a new resident moves into an apartment, a new personal data collection agreement must be approved/signed or data collection should be stopped. Residents were informed about the piloting with the help of the building owner and the residents' committee, which operates as an intermediary between the residents and the owner of the building.

Participation in the pilot was made as easy as possible for residents. An interface has been designed for residents and property managers, which can be used to monitor total energy consumption, environmental impact and residents' apartment-specific data. The interface also allows to provide feedback immediately if the living conditions become worse due to controls in the pilot.

5.1.3 Evaluation of applied incentive schemes

The incentives in the Finnish pilot were divided into two categories. First, the incentives for building owners to invest and participate in demand response. In both buildings the main incentive for building owners are energy costs reductions. In Finland, spot prices are nowadays typical. For the apartment building there is also the optimization and energy cost reductions that can be achieved by optimizing the district heating and the heat pump optimally in different situations. The supermarket is owned by a large chain that owns/operates thousand supermarkets, for which they purchase the required electricity volumes directly from the Nord Pool spot-market[6].

The main lessons learned from these incentives are as follows:

- Monetary incentives are naturally in the interest of the building owners.
    - Apartment building: There is no spot price contract for the electricity (in other words, no variable (hourly) tariffs are implemented). Therefore, any cost reductions can be obtained only through

[6] https://data.nordpoolgroup.com/auction/day-ahead/prices

energy efficiency and by optimally selecting the most efficient heating source (heat pump or district heating).

  - Supermarket: The building owner purchases the total volume of electricity needed from the Nord Pool day-ahead market. Therefore, it is naturally interested in reducing the associated electricity procurement cost by utilizing demand-side flexibility to shift the consumption to hours where lower market prices apply. In their case, how the flexibility will be used has to be forecasted on a day-ahead basis, as the total volume of electricity needed is purchased from the day-ahead market.

- Heating systems are a great asset for demand-side flexibility and provide significant monetary benefits. The monetary benefits are naturally higher in case of spot price-based contracts.

The second category of incentives were targeted for the residents of the apartment building. The role of these incentives was to engage residents to provide feedback and participate in the surveys in order to collect valuable feedback during piloting. The incentives were provided during the Phase 2 and Phase 3 of the project. The most important incentive for the residents is the increase of the energy awareness, in general, as well as the awareness of the effects of each resident's own energy consumption behavior. Through the pilot, the residents were familiarized with the concept of energy flexibility, and were informed regarding the ways in which a household consumer can provide flexibility, which may promote their participation in energy flexibility in the future. The residents achieved practical experiences in the pilot through monitoring the data about energy consumption and environmental impacts, and visualization of concrete benefits achieved with the demand flexibility of the building.

Only those residents that were genuinely interested in energy awareness and energy flexibility finally participated actively into the pilot, since even a high-value prize (i.e. a new mobile phone) had no impact to the residents' activity to participate. A feedback survey took place and valuable data were collected about the user interface, the impact of the provided data and the impact of the control commands to the residents' living conditions. A few suggestions to improve the user interface were received, as well as requests for the provision of additional data. The feedback survey was also found to be a good means to collect user experiences about the project and to detect changes in their awareness and consumption behavior.

5.2 Greek pilot

The lessons learned from the Greek pilot of the iFLEX project are presented in this section, considering technical aspects, user engagement and acceptance, as well as applied incentive schemes.

5.2.1 Technical aspects

From the technical viewpoint, the main lessons learned from the deployment of the iFLEX Assistants to the Greek pilot are summarized as follows:

- The wide rollout of smart meters is crucial, as it will enable collecting higher quality data (e.g. eliminating downtime), which will also be validated by the Distribution System Operator (DSO), from a large number of end users. This can serve as a base for the development of improved accuracy models for tools such as Digital Twins. Furthermore, it could result in estimating in an efficient way the flexibility potential of various types of end users, including residential ones. In the case of the smart meters, which were deployed in the Greek pilot by Heron (as the Retailer), downtime was reported. The reason behind this is the fact that the smart meters sent data via the users' WiFi. Thus, if there was an internet outage or the users turned off their router (e.g., when they leave for holidays or even at night), data for the relevant time period were missing. As opposed to that, a more reliable solution, namely smart meters installed by the DSO itself, would be needed for wide exploitation of residential Demand Response (DR).

- The aggregated flexibility potential of the pilot end users is not as high as desired. There were difficulties in recruiting a large number of residential end users with promising flexibility potential, e.g., owning assets such as (purely) electric boilers and HVACs. Furthermore, currently in Greece there is only a particularly limited number of EVs or heat pump installations, as the building stock is rather aging. This has a significant impact, since EVs and heat pumps are considered as prime candidate assets for DR due to their high flexibility potential. To conclude with, flexibility aggregation from residential end users would benefit from a larger and more diverse portfolio of flexible assets.
- The aspect of automation of the flexible assets is deemed as vital for the provision of flexibility, also from residential end users. The alternative of manual DR activation stipulates that the end users are at home and able to see the relevant DR notification in time, so that they can proceed to the required action effectively. This essentially results in extensive timeslots that are not appropriate for DR actions due to the absence of the end users from their houses or their inability to respond in time. In contrast to that, automated operation, which is based on the end-users' preferences, greatly facilitates the provision of flexibility, as it does not require its presence at the premises to activate or deactivate manually a device. On top of that, automated operation enables avoiding end-users' fatigue, which is caused by multiple interactions with energy and flexibility management applications, such as iFA.
- The agile approach that was followed for the design and implementation of the iFLEX app, which aimed at developing a user-friendly interface, was found to be efficient. Based on the project's requirements, first mockups of the User Interface (UI) were designed, which were validated with a group of potential users within iFLEX consortium. Subsequently, three releases of the iFLEX app were implemented throughout the project's lifetime, considering the feedback received from usability tests on the mockups and the previous versions of the application (iFLEX project, 2023). Furthermore, additional features were implemented based on the prioritization of requirements and test users' feedback. Moreover, the app is available also in the native language – besides English – to increase the users' comfort. Finally, it is noted that due to changes in the billing procedure – because of legislation modifications during the project's lifetime – it was not possible to expose to the end users their electricity tariffs in real or close-to-real time, as these are often determined afterwards – depending on the end users' type of contract.

5.2.2 User engagement and acceptance

In the first-phase, HERON employees were presented with iFLEX project objectives and the technical equipment (smart meters, smart relays) that would be needed to be installed, so that these objectives are achieved. Potential participants were provided with a web link and were asked to register in the associated HERON's platform. At this point, several legal complexities were identified. Most notably, HERON's legal team realised that some of the prospective iFLEX users were not the legal owners of the electricity supply, that is, they were not the electricity bill payers. This relates to a common issue in many Greek families in which the parent or one partner pays the electricity bill for their child or for the couple, respectively. The legal challenge here was that in the first phase, it was implicitly assumed that the user was the legal owner, without anything else being specified in the consent process. An additional issue was that there were not clauses regarding fair usage of the smart metering equipment, prohibiting unauthorised users from tampering with the installed equipment. The procedure to address these issues proved challenging and led to an overhaul of both HERON's Energy Control app and iFLEX specific consent forms after consultations with HERON's Data Protection Officer (DPO) and the organisation's legal team.

In addition, surveys of prospective iFLEX participants indicated that very few dwellings were equipped with electric water boilers for hot water use, which, in principle reduced considerably the potential impact of the Greek pilot. This is partially attributed to a recent surge of individual natural gas boiler installations, which replaced traditional indoor electric boilers for water heating. The installation of individual natural gas boilers had been subsidised through national and EU funded schemes until 2023, according to which 65% of the total equipment and installation costs were reimbursed for households with income lower than the national average. As a result, the majority of the available electric boilers was withdrawn, since their functionality can now be easily and fully covered by the operation of individual natural gas boilers with dual functionality (space heating and hot water for use). In addition, Greece due to its geographical position and climate has spearheaded the installation and use of solar water boilers, which also limited considerably the number of eligible pilot users in the Greek pilot.

Nevertheless, the survey identified a strong interest, which allowed installations to proceed offering to the pilot participants access to their real-time consumption data, while eligible pilot participants with an electric water boiler also were sought out. An initial pool of around twenty (20) candidates was identified, although on-site visits from HERON's certified electricians made it possible to install the relay for the electric water boiler remote control to only five (5) of them, due to the age and condition of the electrical installations and boards, in most of which there was not enough space for the installation of the necessary equipment (smart meter and relay) as shown in Figure 21 below.

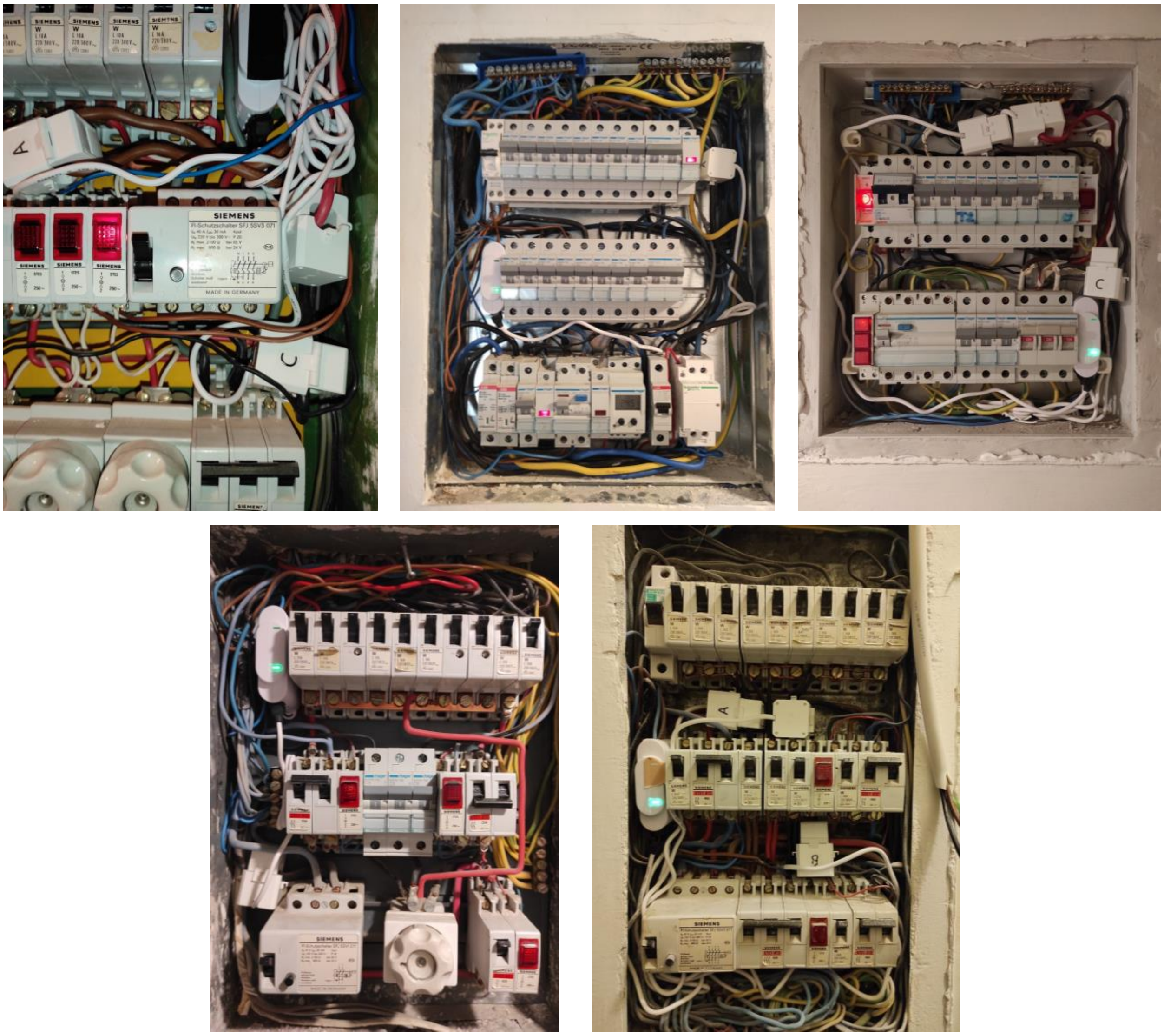

Figure 21: Indicative challenges in electrical boards of households in the Greek pilot

It is noted that there were more than five users whose electrical installation could support the installation of the necessary hardware and their involvement in the iFLEX solution, however the electrical boards were situated in locations with a poor WiFi signal (e.g. basements), which would hinder the unobstructed testing and validation. Extenders were installed to boost signal from routers (typically installed in living rooms in Greece) where it was applicable, but ultimately some prospective pilot installations had to be rejected due to performance reliability issues. That is, iFLEX control uses internet and local WiFi to communicate the necessary signal to the smart meter that sends the pulse to the relay, which, in turn, triggers the electric water boiler. If that signal is communicated but not actually received by the relay, the relay is left in a non-responsive state, which renders the requested DR actions unsuccessful.

To address these issues, we proposed modification of PUCs 9 and 10 (see iFLEX D2.1, 2021) to include implicit DR options focusing on providing requests in order to schedule the consumption of other energy-intensive household appliances, which were monitored through an installed smart plug along with a smart meter without remote control capabilities. This decision significantly increased the number of iFLEX users, with remote controllable boiler users being a small subset of Greek pilot participants, and consequently the impact of iFA and the developed DR services.

5.2.3 Evaluation of applied incentive schemes

In the Greek pilot, we have dealt with the optimal management of the flexibility offered by residential users under uncertainty. We developed a probabilistic user model to account for the uncertainty in the actual provision of the flexibility by a user in conjunction with incentives offered thereto, which we subsequently introduced in the Demand Response (DR) targeting process. We considered a suitable optimization framework to enable flexibility maximization and budget minimization as separate single-objective expressions with the appropriate constraints. We defined representative problems and solved them numerically for a wide range of user parameters, in order to illustrate the applicability and accuracy of our method, and to extract valuable insights. We developed techniques to resolve practical issues and to enable real-world implementation of the proposed scheme in pilot sites; namely, a mathematical expression to estimate the confidence intervals of the attained flexibility and a learning algorithm for extracting the individual user parameters according to their participation patterns. Finally, taking into consideration that the RES Aggregator faces penalties for his positive or negative imbalances when he participates independently in the wholesale market according to the "dual pricing" scheme, we also developed an optimization framework to achieve the required flexibility, while addressing the trade-off among maximizing the profit of RES and DR Aggregators and appropriately incentivizing the end-users. We conducted the respective analysis that highlighted the inter-dependencies of the demand-production energy imbalances to the user characteristics and the RES and DR Aggregator profits.

During the aforementioned investigations regarding the user incentivization and its impact on the provider/aggregator, several lessons were learned:

- It is beneficial for the flexibility procurer to select end-users that are more responsive to incentives, because the offered DR incentives will be smaller.
- The total flexibility earned will be maximized when selecting more responsive users that also require a small amount of minimum incentives to participate.
- When employing a budget constraint that includes the probability of user participation in DR, higher values of total flexibility are achieved on a wider span of user types, compared to the opposite case.
- However, the inclusion of the participation probability enables the discovery of optimal incentives that are less than the minimum acceptable ones of the users for most of the cases. In other words, this constraint leads to the counter-intuitive and "risky" policy to offering low incentives to many users. This may also lead to significant budget overshoots in case more users than those expected actually participate in DR.
- The formulation of the budget constraint without the probability leads to optimal incentives that are higher than the minimum acceptable ones, and thus to a "robust" incentive's policy, which is considered as more realistic, even though it falls behind on the forecasted total flexibility.
- Adequate knowledge to discriminate users in groups (according to their responsiveness to incentives), transfers part of the profit from the users to the provider without necessarily affecting the flexibility target. The provider should employ clustering techniques to split the user base in groups of similar characteristics. This will magnify his revenue and subsequently profit without increasing his budget.
- Reselling by the provider of the harnessed flexibility in the market gives rise to a different value chain that offers new opportunities and indirectly associates the grid benefit to stronger user and provider incentives. With careful selection of parameters, i.e. incentives budget and flexibility unit resale price (if negotiable) can lead to "all-win" situations, i.e. beneficial for all players involved in the corresponding value chain.
- The provider should try to engage users that can be compensated (at least partly) by means of non-monetary incentives. He should determine the age groups, social status etc. of such users and begin DR targeting from them.
- As regards the implementation of the bilateral trading scheme between a RES and DR Aggregator for mitigating imbalances in RES generation within an augmented common portfolio of RES units and end-user demand-side flexibility resources, using DR resources has proven to be beneficial for all the three types of stakeholders involved (i.e. RES Aggregator, DR Aggregator, end-consumers).
- Dividing profits among the three stakeholders can be a complex exercise: everyone will want to maximize his profit; if this is not done carefully, taking into consideration the proper incentivization of the other two entities, the program's effectiveness might be jeopardized.
- The magnitude of the RES deviation that can be offset in the energy market is closely dependent to the user base size and parameters. If the available users are few or unresponsive to incentives, neutralizing a large deviation might be very costly or onerous. On the other hand, a high deviation can be easily addressed, if there are many users willing to contribute. As a result, the RES Aggregator can follow a "riskier" policy in the DAM if he is aware that the DR resources are ample and vice versa. It is a strategic

advantage of the RES Aggregator to be able to identify this point in advance and act accordingly in the DAM.

- Similarly for the DR Aggregator: He should consider the availability of users because his profit might drop in case many users are needed, especially when they are unresponsive. When there is a high deviation, and the user base is not large or adequately responsive, it is critical for the DR Aggregator to negotiate high prices in order to realize the DR program and ensure his profit. Low prices of bilateral trading are often risky and not for the benefit of the DR Aggregator. However, even if hefty values of DR revenue are available, this is not necessarily beneficial for the DR Aggregator for the same reason.
- Prudent definition of the bilateral contract price between RES and DR Aggregators is an important part of the bilateral trading process. Very low contract price values do not provide any profit for the DR Aggregator and a fair starting point would be any value that is close to the DAM price.
- Both Aggregators and end-users have more room for profit in the case of a large deviation.

5.3 Slovenian pilot

The lessons learned from the Slovenian pilot of the iFLEX project are presented in this section, considering technical aspects, user engagement and acceptance, as well as applied incentive schemes.

5.3.1 Technical aspects

In the first pilot phase of the iFLEX project, the Slovenian pilot area focused mainly on the optimal selection of users who meet the pre-defined criteria. The selection of users was also carried out based on technical requirements, as in the first pilot phase the user profile was defined, which was upgraded in the second and third phase from the point of view of controlling user devices (support for different electric consumers and generators for example heat pump, solar power plant and distribution power meters). Furthermore, in the first pilot phase, two different HEMS (Home Energy Management System) from two different manufacturers were installed and tested for the first two friendly end-users (users with technical knowledge and a great deal of understanding required in experimentation period). Based on experimental testing, useful information was obtained from the first pre-pilot users, based on which the embedded devices were later software updated and hardware upgraded.

Numerous tests of various HEMS devices were carried out within the Slovenian pilot in order to obtain a solution that will be as functional, easy to use and efficient as possible. The selection of HEMS devices took into account the aspects of the end-user, which requires that the installation of such a system is simple and fast (without interference with concealed electrical installations and recommended connection via wireless communication protocols, etc.). The HEMS solution, which was implemented in the iFLEX framework in the second and then in the third pilot phase of the iFLEX project, is based on the connection of consumer (heat pumps), metering (distribution meters) and electricity generation equipment (solar cell inverters). In this way, a smart HEMS system, which was able to connect to already installed devices at the end-user via existing communication protocols, was installed at the end-user. In the second and third phase a number of HEMS installations have been done: 40 in total, 5 of them industrial in nature. All of the HEMSes have been integrated in the RAI module, running in the JSI cloud environment. Of the supported devices, 5 types of heat pumps have been supported (Kronoterm, Bosch, Nibe, Shelly plug operated), 4 types of PVs (SolarEdge, Deye, Austa, smart meter monitored), 2 types of EV charging stations (Etrel and OCPP controlled) and 7 types of smart meters (producers Iskra, LandisGyr and Deye). The entire ecosystem setup allowed experimentation with other system components, the Digital Twin (DT) and the Automated Flexibility Management (AFM). The experimentation was oriented towards three use cases: building physical parameters determination and nighttime flexibility estimation, increasing self-consumption and novel network tariffs adaptation.

The main technical lessons learned from the deployment of the iFLEX Assistants to the Slovenian pilot are the following:

- HEMS systems are relatively easy to install and can support a large number of diverse devices. Access to the devices can be made uniform through proper REST and MQTT interfaces which have been wrapped into a programming library, thus providing a flexible and convenient way to program the iFA. Despite the ease of programmable access an overall smart grid application development would benefit from improved semantic unification of devices configurations cross diverse set of devices. For example, all HVACs, even with diverse capabilities, should be accessible through the same set of variables and controls which would allow for greater portability of the developed applications.
- Security and privacy can be provided with a very light overhead and access to the iFA resources can be provided in a fine grain manner based on widely used security standards. Privacy requirements can be fulfilled even if the RAI backend systems are provided in the cloud.
- One of the challenges to build a digital twin of a household is an access to the data collected for building a household twin or a possibility to assess basic household building physics parameters. The work done in the project indicates that it is feasible to determine basic household building parameters with advanced Neural ODE and to use these parameters to implement quite accurate household heat demand prediction.
- The households with HVAC systems and PVs exhibit a lot of flexibility potential which can be utilized for a number of applications, like improving self-consumption, adapt to novel multi-band tariff systems or offer flexibility to aggregators without major comfort loss to the end user. Besides the possibility to harvest flexibility, the costs of heating can be reduced as well. The key to these results is iFA programmability as well as advanced machine learning for implementation of the Digital Twin and the Automated Flexibility Management for optimization of the household consumption according to the user needs.
- iFLEX Assistant End User Interface (EUI) App can provide a lot of utility to the end users and it is easy to use. The App interface has been provided in Slovenian which has lowered the adoption barriers. The deployment should be done through relevant App stores instead directly through a download link. Installations of a such App triggers a lot of security checks and has scared some users off using the App.

5.3.2 User engagement and acceptance

The Slovenian pilot focused mainly on so-called friendly users, as well as on users who are also technology enthusiasts. The selected end-users accepted the stated conditions in the associated informed consent form and at the same time they were informed that major interventions in their personal lives may be possible from multiple (sometimes daily) access to their equipment (heating source, room thermostats, solar power plant inverters and distribution power meters) inside or outside of the end-user living area (house with surroundings area). The end-user recruitment is presented in the flowchart below (see Figure 22).

During the second pilot phase, the Slovenian segment of the pilot consortium focused on reaching out to as many potential pilot users as possible to engage them in the iFLEX project. The pilot partner ECE provided a pool of users receiving electricity supply through a package known as a heat pump. Based on the measurement data of potential users, an analysis of thermal dependence was conducted, identifying individuals whose electricity consumption varies according to external temperatures. All potential pilot users demonstrating thermal dependence were contacted via regular mail. Along with a description of the iFLEX project, potential pilot users received a questionnaire aimed at gathering all necessary technical and non-technical information about the potential user. Anticipating a low return rate of completed questionnaires in the Slovenian part of the project, we incentivized each participant who returned a completed questionnaire with a €20 coupon, redeemable under specific conditions, for online purchases on the ECE Shop website. We thoroughly analyzed all returned questionnaires and re-addressed potential users who met the criteria of the Slovenian pilot segment with a detailed project description, outlining all benefits they would receive, and requiring an explicit statement as a condition to join the iFLEX project. Based on the received questionnaires, it was evident that the addressed households use heat pumps from various manufacturers and different types, which are entirely incompatible with each other in terms of supported communication interfaces for control purposes and data collection via an external control device. Some of the heat pumps do not even offer additional communication interfaces, which became apparent during the installation of control equipment at pilot users' premises.

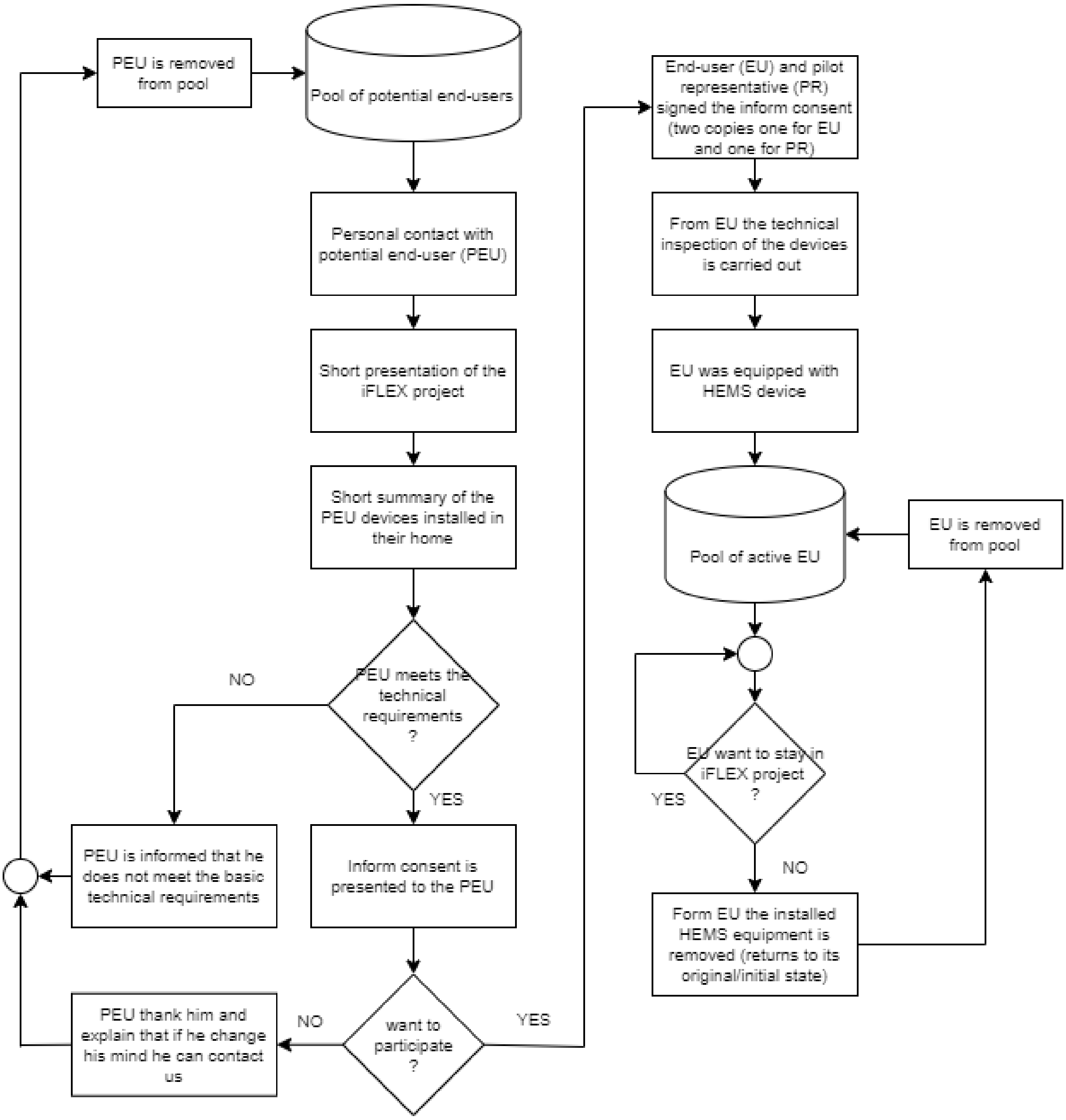

Figure 22: End-user recruitment flowchart procedure (Slovenian pilot site)

Towards the end of the second and the beginning of the third pilot phase, activities were carried out to address potential pilot users from both small and large industrial complexes. This opportunity arose through customers who ordered the service of supply and installation of larger solar power plants with a capacity of over 500 kW from the company ECE. All these customers received an invitation to participate in the project, enabling them to install equipment and monitor electricity consumption and production almost in real-time. Based on the installed equipment and measurement data, some industrial users developed their own production adjustment systems. However, in the iFLEX project, we decided against adjusting production processes, as it posed such a high risk for all project partners as well as end-users.

Specifically, for the user engagement and co-creation activities we defined a consumer or pilot user journey (see Figure 23 below), which we followed during the project phases.

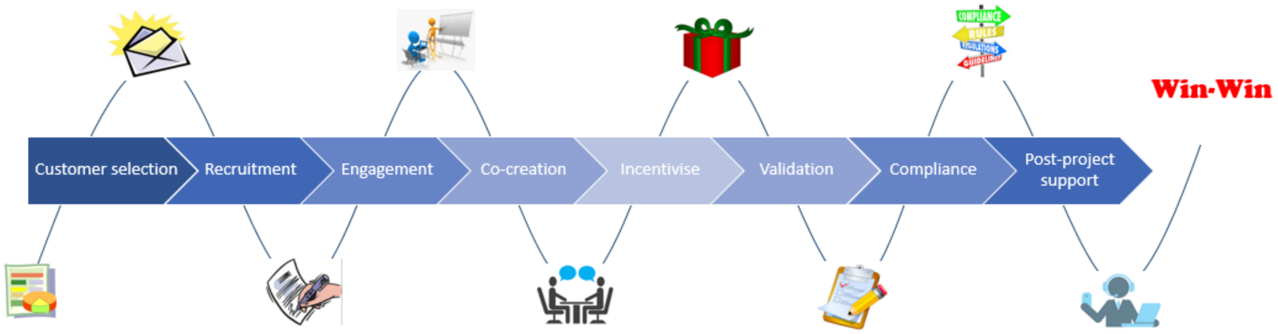

Figure 23: Consumer/pilot user journey in the Slovenian pilot site

Major benefits of having clear pilot user journey and early pilot user involvement can be identified, which are listed as follows:

- User Satisfaction
- Early Feedback
- Adaptability
- User Engagement - a sense of ownership
- Reduced Risk of Misalignment

This or similar approach to engage pilot users is something we learned as beneficial for the project and would recommend this as best practice for large-scale implementation.

The second lesson learned is clear and prompt communication to pilot users, since they were faced with too many unknown new things related to the iFLEX project, indicatively listed as follows:

- New Technology
  - New technology installed in their premises
  - New mobile application
- New business model and uses cases
  - Adjusting energy consumption according to the network signals
  - Adjusting energy consumption according to the price signals
  - Providing instant feedback
  - Accept/Reject energy advice
  - Incentive mechanism
- New companies
  - Several stakeholders

  - Several project partners
  - Vendors and subcontractors
- New data to be shared
  - Personal data to be shared
  - Energy consumption data
  - Personal preferences, habits

5.3.3 Evaluation of applied incentive schemes

As already described above, potential pilot users from the very beginning received a questionnaire for the collection of all necessary technical and non-technical information about the potential user. However, since a low return rate of completed questionnaires in the Slovenian part of the project was expected, each participant who returned a completed questionnaire was rewarded with a €20 coupon, redeemable under specific conditions, for online purchases on the ECE Shop website. This assisted considerably towards increasing the number of potential users as well as their vivid and continuing interest to the iFLEX activities.

Therefore, rewards and/or incentives for persuading an end-user to participate in an innovation project like iFLEX should be defined upfront as well as they should be clear and communicated upfront.

5.4 Key Lessons Learned from pilot implementation

The implementation of the iFLEX solutions to the three pilot sites (Finland, Greece, Slovenia) in all three phases of the project led to a set of key lessons learned from the technical, user engagement and acceptance and economic incentives point of view, which are summarized in the following:

Regarding the technical dimension, the following key lessons learned have been identified:

➢ *Implementation*

- The wide rollout of smart meters is crucial, as it will enable collecting higher quality data (e.g. eliminating downtime), which will also be validated by the Distribution System Operator (DSO), from a large number of end users. This can serve as a base for the development of improved accuracy models for tools such as Digital Twins. Furthermore, it could result in estimating in an efficient way the flexibility potential of various types of end users, including residential ones.
- The installation of smart HEMS systems that are able to connect to already installed devices at the end-user premises via wireless network and without interference with concealed electrical installations is extremely simple, fast and efficient procedure, as a number of measuring and control parameters can be obtained from the devices via already existing communication protocols.
- Heterogeneity of Building Automation System interfaces is a challenge as regards their interoperability with the Resource Abstraction Interface module of the iFLEX framework, which is expected to be addressed in the future with the implementation of standards like SAREF4ENER and EEBUS.
- Hybrid modelling is a good solution for the HVAC systems, since accurate and robust models can be created without a need to physically model all the details of the HVAC system. This will allow for the replication of the solutions more easily for different types of buildings and heating systems. Further work is needed to develop a more robust model (i.e, not a pure machine learning model), which however can be replicated to different types of buildings without any manual modifications needed (i.e., all the differences are learned from data).

- Following the domain standards, the interactions with the Demand Response Management System (DRMS) were modelled on the basis of OpenADR2.0 profile (also available as IEC 62746-10-1 ED1). However, the use of this protocol could prove a bottleneck in the design, since it was designed for field device communication, rather than cloud-based communications as it is in the cases of many iFLEX Assistant components relevant in the DR communication lifecycle. A recommendation on this end would be to extend OpenADR for cloud-based communications or DR clients (also known as VENs) managing multiple customers.
- Security and privacy can be provided with a very light overhead and access to the iFA resources can be provided in a fine grain manner. Privacy requirements can be fulfilled even if the RAI backend systems are provided in the cloud.

➢ *Flexibility*

- Heating systems constitute a fair source of flexibility both in terms of power and energy. This is because most of the energy demand in buildings comes from heating, and building thermal mass can be used for storing heat (energy) for several hours.
- Automation of the flexible assets, based on the end-users' preferences, greatly facilitates the provision of flexibility, as it does not require the physical presence of the end user at the premises to activate or deactivate manually a device. On top of that, automated operation enables avoiding end-users' fatigue, which is caused by multiple interactions with energy and flexibility management applications, such as iFA.
- In some pilot sites, such as Greece, the flexibility aggregation from residential end users would benefit from a larger and more diverse portfolio of flexible assets (e.g. EVs and heat pumps).
- The model-based approach provided by the Digital Twin repository and the Automated Flexibility Management module works well for optimal control and makes it possible to estimate the baseline load (power forecast) and flexibility, as described in the S2 interface standard.

➢ *User Interfaces*

- The agile approach that was followed for the design and implementation of the iFLEX app, which aimed at developing a user-friendly interface, was found to be efficient and produced high-quality end results.

Regarding the user engagement and acceptance dimension, the following key lessons learned have been identified:

➢ *Recruitment*

- Easiness in recruiting potential end-users (e.g. clear, concise and informative project presentation and goals, effortless signing of associated informed consent forms, clear presentation of potential benefits for end-users) is very important to simplify recruitment procedure.
- A clear pilot user journey and early pilot user involvement provides a lot of benefits, including user satisfaction, early feedback, adaptability, user engagement - a sense of ownership, and reduced risk of misalignment.
- Although potential pilot participants show very strong interest in the beginning in participating in such a research and innovation project, various technical and other restrictions may reduce significantly the number of eligible pilot users and/or their enthusiasm. Among others, the unavailability of flexible electrical loads (e.g. electric water heater) in their premises, the unavailability or poor quality of

telecommunication infrastructure for the unobstructed communication of the installed equipment or the fact that some electrical boards do not fulfil minimum requirements for the installation of the necessary technical equipment (e.g. aged boards in poor condition, not enough space for additional devices) may hinder the flawless installation, testing and validation procedures.

- In general, it is beneficial for the flexibility procurer to select end-users that are more responsive to incentives, because the offered DR incentives will be smaller. In this context, the total flexibility earned will be maximized when selecting more responsive users that also require a small amount of minimum incentives to participate. Adequate knowledge to discriminate users in groups (according to their responsiveness to incentives), transfers part of the profit from the users to the provider without necessarily affecting the flexibility target. The provider should employ clustering techniques to split the user base in groups of similar characteristics. This will maximize his revenue and, in turn, his profit without increasing his budget.

➢ *Installation*

- Since end-consumers may be generally reluctant to allow for even minor interventions in their premises (e.g. installation of new hardware in the electrical boards, need to maintain reliable operation of internet connection to allow for uninterrupted communication of all devices and software platforms, personal data protection concerns, etc.), a clear and prompt communication to pilot users is of utmost importance, since the latter are faced with too many unknown aspects, including new technologies (i.e. technical equipment installed in their own premises, new web/mobile applications), new business models and use cases (i.e. adjusting energy consumption according to price or network signals, need to provide instant feedback, accept/reject energy advices, operation of incentive mechanisms), new companies and institutions (i.e. project stakeholders, market authorities, institutions and operators, project partners, equipment vendors and subcontractors), new data streams to be shared (i.e. personal data to be shared, energy consumption data, personal preferences, habits).
- Compliance with GDPR is paramount. In particular, residents that are interested in having equipment installed to their apartments should register to the pilot and provide their consent for data collection. Depending on the local legislative and regulatory framework, several legal complexities and implications may arise as regards the person(s) that should sign the associated consent form(s) (i.e. legal owner of the property or pilot end-user(s)). In the same context, clauses regarding fair usage of the smart metering equipment, prohibiting unauthorized users from tampering with the installed equipment should be clearly included in the consent form. Finally, the equipment (and particularly any sensors that collect personal data) are resident/household-specific and, therefore, when a new resident moves into an apartment, a new personal data collection agreement must be approved/signed or data collection should be stopped.

➢ *Operation*

- Web/mobile interfaces designed for residents and property managers, which can be used to: a) monitor total energy consumption, environmental impact and residents' apartment-specific data, b) provide energy advices, d) facilitate the involvement of the end-consumers in DR actions through push notifications or other mechanisms, and d) visualize concrete benefits from their active participation in the project, are fundamental tools for the fulfilment of the project objectives. Innovative functionalities, such as the possibility to the end-user to provide feedback immediately if the living conditions become worse due to controls in the pilot, assist towards maximizing user acceptance and engagement.
- Feedback surveys was also found to be a good means to collect user experiences about the project and to detect changes in the end-consumers' awareness and consumption behavior. Suggestions to improve

the user interface as well as requests for the provision of additional data need to be addressed to keep the end users' interest unabated.

Regarding the evaluation of the applied incentive schemes, the following key lessons learned have been identified:

- *Incentives*

- Monetary incentives are naturally in the interest of the building owners/end-consumers and they usually depend on the type of the end-consumer:
  - ✓ For small electricity consumers (e.g. households) where no spot price-based contracts are usually available yet, any cost reductions can mainly be obtained through energy efficiency (i.e. reduction of total electricity consumption) and by optimally selecting the most efficient heating source (e.g. heat pump or district heating).
  - ✓ In the case of large commercial buildings, where spot-price based contracts can be more easily adopted, demand-side flexibility can be used for load-shifting of flexible loads (i.e. shift the electricity consumption from high market price hours to time intervals where lower market prices apply). In this case, how the flexibility will be used has to be forecasted on a day-ahead basis, as the total volume of electricity needed is mostly purchased from the day-ahead market.
- It may be almost impossible to alter the billing systems of the electricity supply companies involved in the project to apply customized discounts or any special tariffs related to the incentive policies on end-consumers. Unfortunately, in some pilot sites such suggestions are currently not feasible from a regulatory point of view, without a clear estimate on when it would be possible to facilitate this type of transactions.
- Exogenous rewards based on an agreed reward mechanism that is not linked to electricity usage or billing but is still designed to motivate users' enthusiastic participation in such innovative DR projects could be a viable alternative. However, piloting showed that high-value prizes (i.e. a new mobile phone) may have no impact to the residents' activity to participate and only those residents that are genuinely interested in energy awareness and energy flexibility finally participate actively into the pilot. On the contrary, in other cases, it has been proved that direct monetary rewards in the form of redeemable coupons are able to boost the participation of end-users in relevant DR actions.
- Non-monetary incentives to end-consumers can also be successful: Energy awareness and particularly the increase of awareness regarding the effects of each resident's own energy consumption behavior, the familiarization of residents with the concept of energy flexibility and the ways in which a household consumer can provide flexibility are decisive factors towards promoting their participation in energy flexibility actions in the future.

- *Business opportunities*

- Heating systems are a great asset for demand-side flexibility and provide significant monetary benefits. The monetary benefits are naturally higher in case of spot price-based contracts for electricity consumption.
- Reselling by the provider of the harnessed flexibility in the market gives rise to a different value chain that offers new opportunities and indirectly associates the grid benefit to stronger user and provider incentives. With careful selection of parameters, i.e. incentives budget and flexibility unit resale price (if

negotiable) can lead to "all-win" situations, i.e. beneficial for all players involved in the corresponding value chain.

- As regards the implementation of the novel bilateral trading scheme between a RES and DR Aggregator for mitigating imbalances in RES generation within an augmented common portfolio of RES units and end-user demand-side flexibility resources, using DR resources has proven to be beneficial for all the three types of stakeholders involved (i.e. RES Aggregator, DR Aggregator, end-consumers). However, dividing profits among the three stakeholders can be a complex exercise: everyone will want to maximize his profit; if this is not done carefully, taking into consideration the proper incentivization of the other two entities, the program's effectiveness might be jeopardized. The prudent definition of the bilateral contract price between RES and DR Aggregators is an important part of the bilateral trading process. Very low contract price values do not provide any profit for the DR Aggregator and a fair starting point would be any value that is close to the day-ahead market clearing price. Finally, both Aggregators and end-users have more room for profit in the case of a large RES generation imbalance.

6 Final Best Practices and Replication Roadmap

In this Chapter, a roadmap for iFLEX market replication is presented and discussed. The roadmap is based on a list of best practices, recommendations and guidelines that would enable the scalability and replicability of the iFLEX solutions. It is noted that some of these best practices, recommendations and guidelines may not refer to actions or improvements that need to be taken by private entities or independent research and development consortia like iFLEX, but they refer to fundamental legal, regulatory or institutional reforms that need to be addressed centrally by the EU Member States.

In any case, the implementation of such best practices is deemed indispensable towards mitigating the barriers that hinder the large-scale deployment of demand response in versatile market environments. For the sake of clarity, the derived set of best practices that follows is separated in different groups:

- *Legal, regulatory and institutional measures*
- *Economic measures*
- *End-consumer recruitment and engagement actions*
- *Technical aspects*

6.1 Legal, regulatory and institutional measures

The legal, regulatory and institutional measures that would allow for the large-scale replication of iFLEX solutions comprise the following:

- *Definition of proper national legal framework for all new entrants in line with European legislation in all EU countries*: The main roles and responsibilities of active end-consumers, aggregators and energy communities should be fully defined in all EU countries. A secondary legislation defining more detailed duties, rules, and procedures is also needed to ensure that these new actors can perform their activities in an efficient, non-discriminatory, and transparent manner.
- *Eligibility of all energy resources to participate equally in all electricity market segments and system operation services:* National rules should legally allow all electricity market segments (i.e. day-ahead market, intra-day market, balancing market) and system operation services (i.e., balancing and congestion management services) to be fully and equally opened to all types of distributed energy resources, including demand response actors. The aim is to ensure non-discriminatory access to distributed energy resources, individually or through aggregation, as required by the European legislation.
- *Definition of demand response baseline methodology and remuneration rules:* A specific baseline methodology regarding the participation of demand response in all wholesale electricity market segments should be transparent and balance integrity and accuracy. On top of this, clear and sustainable remuneration rules will further unlock consumer participation and engagement.
- *Definition of legal and regulatory framework for the integration of energy storage systems and electric vehicles:* A clear, transparent and detailed legal and regulatory framework for the rapid integration of energy storage entities and electric vehicles in the power system, which can act complementarily with demand response resources, is of utmost importance towards maximizing the efficient and economic operation of the grid. In this new power system operation paradigm, TSOs and DSOs should act as neutral market facilitators, unless no other market participant, including demand response, can ensure

the provision of the required market and system operation services that can be provided by these innovative resources.

- *Establishment of local flexibility mechanisms:* DSOs should procure flexibility services from providers of distributed generation, demand response or energy storage and shall promote the uptake of energy efficiency measures, where such services cost-effectively alleviate the need to upgrade or replace electricity capacity and support the efficient and secure operation of the distribution system. Moreover, flexibility procurement ought to happen, whenever possible, under market-based mechanisms and based on standard products. This demands DSOs and National Regulatory Authorities (NRAs) to address the use of flexibility in the short-term. Hence, the network development plans made by DSOs shall include the use of demand response, energy efficiency, energy storage, or other resources that may be used as an alternative to system expansion. The implementation of flexibility mechanisms needs an innovative way of planning and operating the network that leads also to new organizational models and cost structure for the DSOs.
- *Removal of restrictive requirements for participation in wholesale market segments and other mechanisms:* Less restrictive requirements regarding the everyday participation of demand response in all wholesale market segments, such as smaller minimum product size and higher time granularity will enable the effective participation of demand response in these markets. To ensure capacity mechanisms and interruptibility schemes are effectively available to all resources with non-discriminatory design features and processes, restrictive eligibility requirements that directly exclude smaller units, units connected to lower voltage levels should be removed and capacity contracts should be set with the same provisions for all types of capacity providers to ensure a level-playing field.
- *Access to final customer data:* National rules should allow new actors offering innovative solutions to get access to data of non-customers in a level playing field compared to suppliers while ensuring data protection and security. To ensure they all have access to data in a non-discriminatory manner and simultaneously, access to the same type and amount of data and through the same data platform or tool should be provided.

6.2 Economic measures

The economic measures that would allow for the large-scale replication of iFLEX solutions comprise the following:

- *Target competitive retail markets*: Highly concentrated retail electricity markets limit new entrants' ability to compete on a level playing field and to offer innovative and flexibility products allowing end-consumers' benefit from potential costs savings. In addition, markets where low correlation between the energy component of retail prices and the associated wholesale market prices is observed discourages and limits the possibility of new actors to gain acceptance and market shares. Therefore, iFLEX should target primarily market jurisdictions that are characterized by intense competition and low retail market concentration to effectively promote and replicate its proposed solutions in a large-scale.
- *Removal of price interventions:* Retail price interventions, including regulated prices, are not a barrier when targeted and aimed at those most in need. However, in some markets retail price intervention essentially kills the business case for new actors, such as aggregators and suppliers, aiming at unlocking flexibility from innovative distributed energy resources, including demand response. Therefore, it is recommended that any retail price interventions should not target the entire customer base, but they

should be targeted and aimed solely at those most in need (e.g. low-income households, vulnerable end-consumers, etc.)

- *Formulation of clear, transparent and precise electricity bill:* The electricity bill should be clear, transparent, precise and easily replicable by the end-consumers. A higher share of the electricity supply cost component as well as a higher correlation between the energy consumption and the network charges would provide end-consumers with clear price signals to enhance their flexibility potential. Additionally, other charges/levies that are fully irrelevant to the electricity consumption (e.g. municipal tax, property tax, etc.) should be removed from the electricity bill.
- *Availability of retail contracts with time-differentiation:* Time-differentiated retail electricity contracts can provide adequate price signals to end-consumers as regards the cost of electricity production, transmission and distribution depending on the time of consumption.
  - *Electricity supply cost:* The availability of dynamic pricing regarding electricity supply cost will be key enabler towards maximizing end-consumers engagement in demand response schemes.
  - *Network charges:* Variable network tariffs will allow end-consumers to actively participate in the energy management of their premises and benefit themselves by exploiting reduced (or even zero) network charges when their energy behaviour contributes towards alleviating network burden. The formulation of a specific methodology that would allow the DSO to incentivize end-users to shift their electricity consumption in order to minimize peak load consumption that requires higher network utilization in terms of electricity transfer, and, in turn, higher energy losses would further facilitate the deployment of demand response programs.

  However, the effectiveness of the associated price signals depends on the share of the respective cost components (supply cost, transmission cost, distribution cost) in the electricity bill (see also point above) and/or the price differences between the applied time intervals.
- *Application of customized discounts or special retail tariffs to end-consumers participating in pilot projects:* The billing systems of the electricity supply companies involved in such projects should be able to apply customized discounts or any special tariffs related to the incentive policies on end-consumers.
- *Promotion of exogenous rewards based on agreed reward mechanisms that are not linked to electricity usage or billing:* Exogenous rewards (prizes or redeemable incentives) should be carefully designed to motivate users' enthusiastic participation in such innovative DR projects. Such awards can be introduced prior to the application of customized discounts or special retail tariffs to end-consumers participating in pilot projects or in parallel with them.
- *Non-monetary/redeemable incentives to end-consumers can also be successful:* Energy awareness and particularly the increase of awareness regarding the effects of each resident's own energy consumption behavior, the familiarization of residents with the concept of energy flexibility and the ways in which a household consumer can provide flexibility are decisive factors towards promoting their participation in energy flexibility actions in the future.
- *Implementation of innovative trading schemes between market stakeholders:* The implementation of innovative trading schemes such as the bilateral trading scheme between a RES and DR Aggregator for mitigating imbalances in RES generation within an augmented common portfolio of RES units and end-user demand-side flexibility resources that was tested in the iFLEX Greek pilot would add value and facilitate the large-scale replication of iFLEX, since it has proven to be beneficial for all the three types of stakeholders involved (i.e. RES Aggregator, DR Aggregator, end-consumers). However, certain

modifications of the existing legal and regulatory frameworks may be necessary to allow for the real-life implementation of the proposed scheme.

6.3 End-consumer recruitment and engagement actions

The end-consumer recruitment and engagement actions that would allow for the large-scale replication of iFLEX solutions comprise the following:

- *Broad communication campaigns through versatile channels (social media, websites, press):* This will encourage overall implicit demand response, where the potential benefits for end-users as well as appropriate key messages on "green transition" should be clearly and concisely presented.
- *Clear and prompt communication to potential end-users:* Transparent and concise information (in lay language) of various aspects related to demand response, including new technologies, new business models and use cases, new companies and institutions, new data streams to be collected and shared what consumers/prosumers can expect in terms of impact on their daily lives (energy consumption), potential economic/non-economic benefits, existing and new service agreements, etc., be provided from the very beginning of their involvement to eliminate any concerns raised by end-consumers regarding their participation in such projects and boost end-user interest and active participation.
- *Easiness in recruiting potential end-users*. The clear, concise and informative project presentation and goals, the effortless signing of associated informed consent forms, the clear presentation of potential benefits for end-users are very important to simplify recruitment procedure.
- *Extensive surveys to identify technical and/or other restrictions in potential end users' premises:* Potential unavailability of flexible electrical loads, unavailability or poor quality of telecommunication infrastructure for the unobstructed communication of the installed equipment as well as premises that do not fulfil minimum requirements for the installation of the necessary technical equipment should be identified from the very beginning of the projects.
- *Targeted communication campaigns through messages, emails and reminders to specific groups of consumers:* Demographic and societal criteria, personal preferences and habits, level of energy education, lifestyle and household/commercial/industrial information of the end-consumers should be taken into account to formulate and spread insights and tips about ways to shift their energy consumption away from peak times or engage in energy efficiency actions.
- *Select and cluster end-users based on their responsiveness to incentives:* In general, it is for the benefit of the provider to select end-users that are more responsive to incentives, because the offered DR incentives will be smaller. In this context, the total flexibility earned will be maximized when selecting more responsive users that also require a small amount of minimum incentives to participate. Adequate knowledge to discriminate users in groups (according to their responsiveness to incentives), would transfer part of the profit from the users to the provider without necessarily affecting the flexibility target. The provider should employ clustering techniques to split the user base in groups of similar characteristics. This would magnify his revenue and subsequently profit without increasing his budget.
- *Provide fully functional web/mobile interfaces designed for residents and property managers:* These can be used to: a) monitor total energy consumption, environmental impact and residents' apartment-specific data, b) provide energy advices, d) facilitate the involvement of the end-consumers in DR actions through push notifications or other mechanisms, and d) visualize concrete benefits from their active participation in the project. Innovative functionalities, such as the possibility to the end-user to provide

feedback immediately if the living conditions become worse due to controls in the pilot, will assist towards maximizing user acceptance and engagement.

- *Provide consumers with practical information about the power intensity of different devices supplemented by additional information on lower power substitutes and more energy efficient means of using devices*.
- *Targeted free (or more accessible) energy audits*: The goal is to determine what can be done to optimise energy use and provide an estimate of the level of savings possible for some consumers.
- *Compliance with GDPR:* Residents that are interested in having equipment installed to their apartments should provide their signed consent for data collection. Legal complexities and implications should appropriately be considered in the formulation of the consent forms, while clauses regarding fair usage of the smart metering equipment, prohibiting unauthorized users from tampering with the installed equipment should be clearly included in the consent form. Finally, the equipment (and particularly any sensors that collect personal data) are resident/household-specific and, therefore, when a new resident moves into an apartment, a new personal data collection agreement must be approved/signed, or data collection should be stopped.
- *Collaborative partnerships with stakeholders:* Fostering of collaborative partnerships with utilities, grid operators, technology vendors, energy service providers, and other stakeholders will leverage collective expertise, resources, and networks. This will allow for knowledge sharing, innovation, and cross-sector collaboration towards continuous improvement, innovation and large-scale replication of the developed demand response solutions*.*

6.4 Technical aspects

From the technical point of view, the best practices and recommendations that would allow for the large-scale replication of iFLEX solutions comprise the following:

- *Documentation of the system architecture:* The iFLEX system architecture has been thoroughly documented in the relevant deliverables, thus allowing for an unobstructed large-scale replication of the proposed solutions.
- *Compliance with common standards for system architecture:* Compliance with standard system architectures for smart grid premises, and the standard protocols at the information and communication layers have been guaranteed to allow for the integration of the iFLEX Assistants with demand-side flexibility management solutions developed outside the project.
- *Compliance with trust, security and privacy standards:* iFLEX Assistant trust, security and privacy procedures, mechanisms and services are fully compliant with common standards and relevant regulation and legislation. In general, compliance with the General Data Protection Regulation (GDPR) is addressed and fulfilled. Planned use cases have been carefully studied and assessed from privacy and information security point of view. The said compliance assures that the iFLEX Assistant and framework can be replicated in diverse environments and ecosystems and the compliance with regulation and legislation is not a barrier for replication in target countries. However, the iFLEX Assistant enables control of household or building devices which needs to be carefully checked and allowed only to authorized persons.
- *Wide rollout of smart meters:* This will enable collecting higher quality data (e.g. eliminating downtime), which will also be validated by the Distribution System Operator (DSO), from a large number of end users. This can serve as a base for the development of improved accuracy models for tools such as Digital

Twins. Furthermore, it could result in estimating in an efficient way the flexibility potential of various types of end users, including residential ones.

- *Use of smart HEMS systems that are able to connect directly to already installed devices at the end-user premises*: The installation of such HEMS systems that are able to directly connect to already installed devices via wireless network and without interference with concealed electrical installations is an extremely simple, fast and efficient procedure, as a number of measuring and control parameters can be obtained from the devices via already existing communication protocols.
- *Ability to wrap diverse home and building energy management systems:* Replication requires an ability to wrap diverse energy management systems (EMS) with an intent to collect data from the EMSs and to control the devices through EMS. On the one hand, since the iFLEX Assistant needs to support broad integration, compliance with common standards is a good indicator of wrapping ability. On the other hand, iFLEX has little control on what is available from the EMSs that the project would like to wrap. Often there is little or no information how EMS systems could be accessed or controlled.
- *Interoperability of the heterogeneous Building Automation System interfaces with the Resource Abstraction Interface module*: This is a key challenge, which if addressed in the future with the implementation of domain standards like SAREF4ENER and EEBUS will allow for the large-scale replication of iFLEX solutions.
- *Target heating systems:* Heating systems constitute a fair source of flexibility both in terms of power and energy. This is because most of the energy demand in buildings comes from heating and building thermal mass can be used for storing heat (energy) for several hours.
- *Automation of flexible assets*: This is based on the end users' preferences and greatly facilitates the provision of flexibility, as it does not require the physical presence of the residential end user at the premises to activate or deactivate manually a device. On top of that, automated operation enables avoiding end users' fatigue, which is caused by multiple interactions with energy and flexibility management applications, such as iFA.
- *Use of HTTP Rest and MQTT protocols:* Regarding the communication layer, the iFLEX system architecture is based on highly scalable HTTP REST and MQTT protocols. The scalability of HTTP is evident in the WWW. Depending on the quality of service, a single MQTT broker can serve up to 40.000 messages/second when run on a typical computer. A single broker is therefore enough to serve more than 100.000 customers in typical iFLEX use cases. The system can be easily scaled to larger group of iFAs by adding new MQTT brokers and configuring the routing between iFAs and aggregation platforms accordingly.
- *Extend OpenADR for cloud-based communications or DR clients (VENs) managing multiple customers:* Following the domain standards, the interactions with the Demand Response Management System (DRMS) were modelled on the basis of OpenADR2.0 profile (also available as IEC 62746-10-1 ED1). However, the use of this protocol could prove a bottleneck in the design, since it was designed for field device communication, rather than cloud-based communications as it is in the cases of many iFLEX Assistant components relevant in the DR communication lifecycle. A recommendation on this end would be to extend OpenADR for cloud-based communications or DR clients (also known as VENs) managing multiple customers.
- *Use of the agile approach*: The agile approach for the development of a user-friendly interface for a web or mobile application can be very efficient and deliver high-quality end results.

7 List of figures

7.1 Figures

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